Oligopsonistic resource markets – modelling firm decisions in Maple

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Economic reality offers us several situations in which the buyers of a certain production resource appear only in a limited number on the market, thereby being able to exercise significant market power against the producers. Our article proposes to study these oligopsonistic markets, modelling the behaviour of the buyers using the *Maple* software. Considering the limits of graphical representation we mainly focus on the case of oligopsony with two and three buyers, illustrating their decisions in two- and three-dimensional coordinate systems. During the modelling process we first concentrate on the case of market equilibrium. Since the state of equilibrium is not Pareto efficient, oligopsonistic firms tend to move away from the equilibrium to cooperate with each other in a cartel. Consequently, the last two parts of the article deal with the modelling of the cartel and the breakup of the cartel on an oligopsonistic market.

Keywords: oligopsony, resource market, Cournot-equilibrium, cartel, cartel breakup.

JEL codes: D21, D43

Introduction

Increasing market concentration can be observable in many industries. By market concentration companies on the demand or supply side may gain important market powers, which will result in different steps and decisions on company-level compared to perfectly competitive markets. Our article focuses on the case where the market of a particular production resource is concentrated, and the producers of the given resource face only a limited number of buyers. In economic reality we can find many such oligopsonistic markets, examples include several sec-

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tors of agriculture and the food-processing industry, where agricultural producers face only a limited number of players from the food processing industry (Just and Chern 1980, Sexton 2000, Vukina and Leegomonchai 2006). The same oligopsonistic power applies to the relationship between the logging and wood processing industry in several countries (Kallio 2001, Mohammadi Limaei and Lohmander 2008), but the market power of employers against employees on labour markets can also be considered as a form of oligopsonistic situation (Bhaskar et al. 2002).

The main purpose of our article is to present the oligopsonistic power on factor markets, and to model the behaviour of oligopsonistic firms on such markets using the *Maple* software. Due to the limitations of graphical representation our paper focuses mainly on the case of oligopsonistic markets with two and three buyers (duopsony and triopsony), illustrating them in two- and three dimensional coordinate systems. Numerical data corresponding to our figures can be found in the *Appendix* of our article. The first part of the paper deals with the equilibrium of the oligopsonistic market, while the last two parts focus on the modelling of the cartel and the break-up of the cartel on an oligopsonistic market.

1. Equilibrium on the oligopsonistic factor market

Let us assume that *N* different companies, using the same resource as input, produce one or more products, which are then sold on perfectly competitive markets. The resource in question is produced by many different producers, thus they do not have a dominant market position. The companies that buy the resource are limited in number so they have an oligopsonistic dominant position on the resource market. These companies are naturally using in their production other inputs besides the examined resource as well (e.g. other material resources, human resources, capital goods etc.). Thus, their production technology can be described as a multivariate function. Let j mark the number of each oligopsonistic company (j=1..N), y_j the j^{th} company's output, and i the number assigned to the examined resource. Hence, the production function of the companies can be written as follows:

$$y_j = f_j(x_1,x_2,\ldots,x_i,\ldots) \qquad j=1..N \tag{1}$$

Since we focus in our article exclusively on the market of the i^{th} resource, the quantity of other production resources will be considered constant. Thereby we are able to simplify our model by reducing each company's production function to a single-variable function. Since there is no need to further differentiate between types of resources, let the lower index of x denote the number of that oligopsonistic company, that is buying the resource in question from the market.

Thus, the partial production function of the j^{th} company can be written as follows:

$$y_j=f_j(x_j) \tag{2}$$

where y_j marks the output of the j^{th} company, x_j denotes the quantity of the i^{th} resource purchased by the j^{th} company, and $f_j(x_j)$ marks the production technology of the j^{th} company.

Let P denote the market price of the products produced by the companies (which can obviously vary from company to company, but – taking into consideration the focus of our article on the resource market – we are not entering into detailed examination of the product market), and p_i the price function of the i^{th} resource, namely the inverse supply function of the resource market, which is dependent on the sum of the resource quantities purchased by oligopsonistic companies, namely $p_i(x_1+x_2+\ldots+x_N)$.

Then, the profit functions of the companies are the following:

$$\pi_j=P\cdot f_j(x_j) - p_i(x_1+x_2+\ldots+x_N)\cdot x_j - FCj \qquad j=1..N \tag{3}$$

where FCj marks the cost of all other inputs of the j^{th} company, which is considered to be constant. Equation (3) shows that the profit of the j^{th} company is not only a function of the resources bought by itself, but it also depends on the resource quantities purchased by the other companies.

Since we assumed perfect competition on product markets (meaning that the companies cannot influence the price of the product), and a resource market with limited number of buyers (that are able to influence the price of the resource in question), the following relationships hold:

$$\frac{\partial P}{\partial x_j} = 0 \text{ and } \frac{\partial p_i}{\partial x_1} = \frac{\partial p_i}{\partial x_2} = \ldots = \frac{\partial p_i}{\partial x_N} > 0 \qquad (4)$$

All buyer companies seek to maximize their profits, so the derivatives of their profit functions (3) yield the following conditions:

$$\frac{\partial \pi_j}{\partial x_j} = P \cdot MPj - \frac{\partial p_i}{\partial x_j} \cdot x_j - p_i(x_1+x_2+\ldots+x_N)=0 \qquad j=1..N \quad (5)$$

where MP_j marks the marginal product function ($MP_j = \frac{\partial f_j(x_j)}{\partial x_j}$) of the j^{th} company. The $P \cdot MP_j$ product represents the value marginal product function and is marked with VMP_j. The negative elements of equation (5) represent the derivative of the resource's cost function ($p_i(x_1+x_2+\ldots+x_N) \cdot x_j$), which is termed as the marginal factor cost function of the j^{th} company, and is marked with MFC_j from now on.

Based on these, the first order condition of profit maximization for all companies is the following:

$$VMP_j(x_j)=MFC_j(x_1,x_2,\ldots,x_N) \qquad j=1..N \qquad (6)$$

Equations (5) and (6) show that the j^{th} company would be able to decide on the optimum quantity of the resource to be purchased, only if it knew the resource quantities to be bought by the other companies. Substituting these values with anticipated quantities the j^{th} company is able to determine x_j optimal resource quantity which leads to profit maximization.

This relationship – similar to the case of the oligopolistic market – is called the company's *response function* or *reaction function* (Kopányi 2007, Feuer and Szidarovszky 2009). Thus, there exists a gj response function for each oligopsonistic company:

$$x_j=g_j\left(\sum_{\substack{i=1\\ i\neq j}}^{N} x_i^E\right) \qquad j=1..N \qquad (7)$$

where the x_j quantities of equation (7) fulfil the optimum criteria from equation (6). Let us now assume that the inverse supply function of the investigated resource, described by equation (3), is linear, namely $p_i = A \cdot (x_1 + x_2 + \ldots + x_N) + B$. Then equation (5) can be reformulated as follows:

$$\frac{\partial \pi_j}{\partial x_j} = P \cdot MP_j - A \cdot x_j - A(x_1 + x_2 + \ldots + x_N) - B = 0 \qquad j = 1..N \tag{8}$$

Expressing x_j from equation (7) leads to the following response function:

$$x_j = -\frac{1}{2} \cdot \sum_{\substack{i=1 \\ i \neq j}}^{N} x_i^E + \frac{P \cdot MP_j - B}{2A} \qquad j = 1..N \tag{9}$$

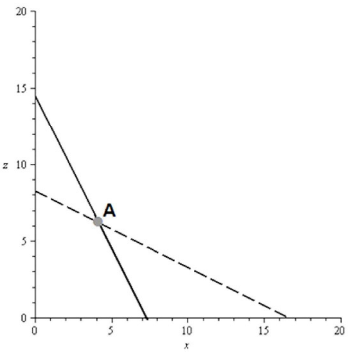
Thus, companies are forced to form expectations of the quantities to be purchased by the competitor(s) present on the same resource market. These quantities are called anticipated volumes. Equation (9) shows that response functions have negative slope. This means that if the anticipated purchase volume(s) is(are) increasing (which also increases the market price of the resource in question, see equation (4)), the company responds by decreasing its own purchase volume, and vice versa.

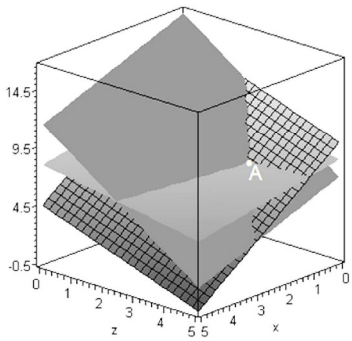
We have modelled the oligopsonistic market with two and three players (duopsony and triopsony) by implementing equations (1)-(9) in *Maple*. In order to simplify graphical representations and their understanding, we assumed that production functions (see equation (2)) are constant yield functions, however implementing the more frequent decreasing yield functions would have lead to similar results. The parameters of the production functions and the numerical data connected to the figures can be found in the *Appendix*.

We have graphically illustrated both cases (two and three players) in a Cartesian coordinate system, where the axes represent the quantities of resource purchased by the oligopsonistic companies. In case of duopsony the response functions are represented by two curves with negative slope, while in case of triopsony the response functions are represented by response surfaces.

Figure 1 illustrates the case of duopsony (*N=2*). It contains the response function of the two duopsonistic companies, where the continuous line denotes the *first* (x axis), while the dashed line denotes the *second* (z vertical axis) company's response function. Point *A* marks the intersection of the two response functions.

Figure 2 illustrates the case of triopsony ($N=3$). It shows the response surfaces of the three triopsonistic companies, where the gridded surface denotes the *first* (x axis), the dark gray coloured surface the *second* (z axis), the light gray coloured surface the *third* (t axis) company's response surface. Similarly to Figure 1, point *A* marks the intersection of the three response surfaces.





Source: own calculation, *Maple*

Figure 1. Response functions of duopsonistic companies and the Cournot-equilibrium

Figure 2. Response functions of triopsonistic companies and the Cournot-equilibrium

The equilibrium of the oligopsonistic market, also termed as the point of Cournot-equilibrium (marked with point A on the figures), is located at the intersection of the response functions. Early researches were primarily focusing on the existence and uniqueness of the equilibrium, based on the seminal work of Cournot (1838), and demonstrated it for several different market situations (e.g. Szidarovszky and Yakowitz 1977, Okuguchi 1998). Similarly, numerous articles examined the stability of this equilibrium point (e.g. Shone, 2002).

Response functions indicate how an oligopsonistic company determines the resource quantity to be purchased on the market, based on the anticipated purchase quantities of the other companies. Therefore, the point of intersection of the response functions, namely the point of Cournot-equilibrium, is a point where all expectations of the oligopsonistic companies are fulfilled, and ultimately they purchase exactly the equilibrium quantities (x_j*) from the factor market (numerical values of purchased resource quantities corresponding to the point of equilibrium can be found in the *Appendix)*. Thus, purchased resource quantities are the following:

$$x_j = x_j^E = x_j^* \ , \ j=1..N \tag{10}$$

and

$$x_j = g_j\left(\sum_{\substack{i=1\\ i\neq j}}^{N} x_i^E\right) = g_j\left(\sum_{\substack{i=1\\ i\neq j}}^{N} x_i^*\right) \quad , \ j=1..N \tag{11}$$

However, several articles analyzing oligopolistic and oligopsonistic markets show that the point of Cournot-equilibrium is not necessarily Pareto-efficient, and that companies may shift away from this point (Okuguchi 1976, Dixit 1986). This means that in the point of equilibrium at least one of the companies is able to change its purchased quantity in a way that will increase its own profit, while in the same time the profit of the other companies will not drop. The Cournot-equilibrium assumes that oligopsonistic companies are not cooperating. Thus, their decisions are made at the same time, and are based exclusively on anticipated purchase quantities, namely decisions are made along the response functions. In this way, each and every company tries to maximize its profit separately. The oligopsonistic situation, however, often motivates companies to collude in order to further increase their total profit.

Based on equation (3), profits of individual companies are determined as a function of purchased resource quantities. Let now *isoprofit d*enote those resource-quantity combinations at which the profit of one given company is constant. This is actually a hyper-surface in the N dimensional space. The isoprofits of the individual companies can be written as follows:

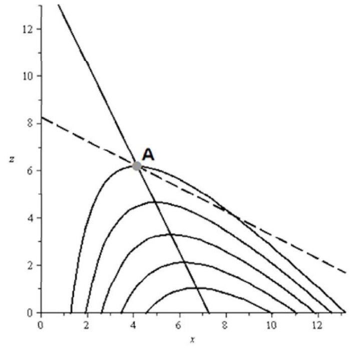
$$\text{isoprofit}_j=\{(x_1,x_2,\ldots,x_n) : \pi_j(x_1,x_2,\ldots,x_N)=\text{const}\} \qquad (12)$$

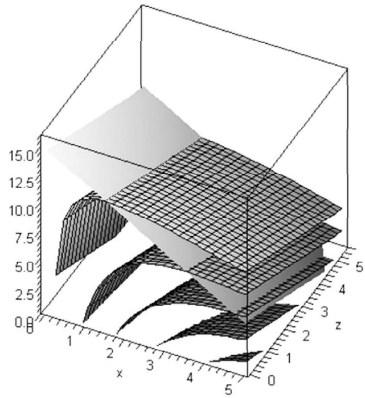
Implementing isoprofits in *Maple* we get concave isoprofit curves in case of duopsony, and isoprofit surfaces in case of triopsony.

Figure 3 illustrates the response functions of the two duopsonistic companies and a few of the isoprofit curves for the *first* company. The figure also contains the equilibrium isoprofit curve of the *first c*ompany, which has its most distant point from the horizontal axis exactly in the point of Cournot-equilibrium. In fact, in the coordinate system there exist an infinite number of isoprofit curves. The most distant points from the horizontal axis of these curves form the response function of the company. Besides this, the lower an isoprofit curve is positioned in the coordinate system, the higher the profit level represented by it. This is also shown by the fact that the *first* company would earn the highest possible profit if the s*econd* company purchased zero quantity of the i^{th} resource, namely at that point, where the response function of the *first* company intersects the horizontal axis. In fact, in this case the *second* company would not even be present on the resource market, making it possible for the *first* company to take advantage of its dominant market position as a monopsonistic player.

Similarly to the case of duopsony, Figure 4 illustrates the response surface of the triopsonistic *first* company, and a few of its isoprofit surfaces (in order to simplify the understanding of the illustration the figure now does not show the response surfaces of the other two companies). Similarly to the duopsonistic situation, the isoprofit surfaces situated lower represent higher profit levels, and the most distant points of the these surfaces relative to the horizontal axis form the response surface of the company.

A closer examination of algebraic relationships behind the graphical representation of isoprofits may contribute to a better understanding of the figures. First of all, let us simplify the general oligopsonistic situation to an equation with two variables, by summing up resource quantities purchased by all the other companies (except the j^{th} company) in a single variable (X_j), where:





Source: own calculation, *Maple*

Figure 3. Response functions of the two duopsonistic companies and the isoprofit map of the *first* company

Figure 4. Triopsonistic response surface and corresponding isoprofit surfaces of the *first* company

$$X_j = \sum_{\substack{i=1 \\ i \neq j}}^{N} x_i \tag{13}$$

In this case, the slope of the isoprofit curves shows how the purchased resource quantity of the j^{th} company changes as other companies marginally change their purchased quantities, while the profit of the j^{th} company remains constant. In order to determine the slope of the isoprofit curves we are going to use the implicit function theorem. First of all we fix the profit of the j^{th} company at a given π_j level and formulate the following equation, equal to zero:

$$\pi_j^0 = \pi_j - P \cdot f(x_j) + p_i(x_j + X_j) \cdot x_j + FC = 0 \tag{14}$$

Based on equation (14), the implicit function theorem states that the slope of the tangent line to the isoprofit curve is:

$$\frac{\partial X_j}{\partial x_j} = -\frac{\dfrac{\partial \pi_j^0}{\partial x_j}}{\dfrac{\partial \pi_j^0}{\partial X_j}} \tag{15}$$

Calculating the differentials in equation (15), and using the variables introduced in equation (6):

$$\frac{\partial X_j}{\partial x_j} = -\frac{-P \cdot MP_j + \frac{\partial p_i}{\partial x_j} \cdot x_j + p_i}{\frac{\partial p_i}{\partial X_j} \cdot x_j + p_i} = -\frac{-VMP_j(x_j) + MFC_j(x_j, X_j)}{MFC_j(x_j, X_j)} = \frac{VMP_j - MFC_j}{MFC_j} \tag{16}$$

Based on relationship (16), while $VMP_j > MFC_j$, the isoprofit curve has a positive slope, and after reaching its maximum point, it decreases (here $VMP_j < MFC_j$). Hence, the maximum point of the isoprofit curve (where $VMP_j = MFC_j$) satisfies the first order condition of profit maximization, presented in relationship (6). Consequently, the response function, which is deduced from the profit-maximizing condition, connects the maximum points of the isoprofit curves. This corresponds to the interpretation of response functions, since – given the quantities purchased by all the other companies – our company will strive to purchase exactly the quantity which will assure him maximum profit, placing the company on the lowest isoprofit curve possible. Another conclusion of relationship (16) is the concavity of isoprofit curves.

Let us now investigate profit conditions in the Cournot-equilibrium of the oligopsonistic market, using the isoprofit curves. On the figures below we first plotted the isoprofit curves, which correspond to the profits reached in case equilibrium quantities are purchased by each company.

Figure 5 contains not only the isoprofit curves of the *first* company, but also those of the *second* company, marked with dashed lines. These have a similar shape to the isoprofit curves of the *first* company. The figure illustrates those two isoprofit curves as well, that pass through the point of Cournot-equilibrium (point *A*).

For better perspicuity, in case of the three triopsonistic companies we plotted on Figure 6 only those isoprofit surfaces that correspond to the Cournot-equilibrium.

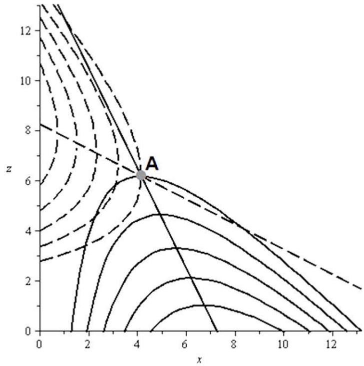
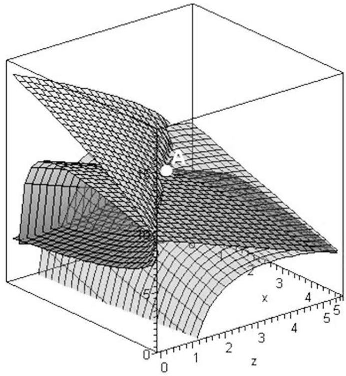


Figure 5. Response functions and isoprofit curves of duopsonistic firms



Source: own calculation, *Maple*

Figure 6. Isoprofit surfaces of triopsonistic firms in the Cournot-equilibrium

On the two-dimensional figure (in case of duopsony) we can identify an area, whose points exclusively assure a higher profit for both companies relative to the Cournot-equilibrium (point A*)*. Let us now concentrate on the two areas delimited by the two isoprofit curves passing through point A and the corresponding axes. Each point of the common segment of these two areas (a lens-shaped area) refers to such combinations of purchased resource quantities that assure higher profit for both companies, placing them on lower isoprofit curves.

Similarly, in case of three buyers we can identify a portion of space again whose points would exclusively assure a higher profit for all three companies compared to the Cournot-equilibrium (point *A*). On Figure 6 there is a common portion of the three spaces delimited by the three isoprofit surfaces passing through point *A* (the three spaces are delimited from "above" by the three isoprofit surfaces towards the direction of their corresponding axis). Each internal point of the common portion of space refers to such combinations of purchased resource quantities that assure a higher profit for all three players, placing them on lower isoprofit surfaces.

The set of points that assure higher profits for the oligopsonistic companies presumes, however, a shift away from the equilibrium (point *A*). The Cournot-equilibrium, marked with point A on the figures, is unstable, since it is not Pareto efficient. However, companies are able to shift away from this point only if they cooperate. One possible way of such cooperation is the cartel agreement which will be discussed in the next section.

The fact, that it is worth for companies to shift away from the Cournot-equilibrium, can be formulated as a conditional extremum problem, as presented below. Let us take a look on the j^{th} company which strives to earn a higher profit than in the Cournot-equilibrium, while the profit of the other players should not change. Let π_i^* denote the equilibrium profit of the i^{th} company. In this case the optimization problem of the company can be formulated as follows:

$$\frac{\pi_i^* = P\cdot f_i(x_i) - p_i(x_1+x_2+\ldots+x_N)\cdot x_i - FC \qquad i=1..N,\ i\neq j}{\pi_j = P\cdot f_j(x_j) - p_i(x_1+x_2+\ldots+x_N)\cdot x_j - FC \rightarrow \max} \qquad (17)$$

It can be seen, that the point of equilibrium satisfies the constraints. Besides that, the j^{th} company is able to increase its own profit while not influencing the profit of other oligopsonistic players. A conditional extremum problem similar to problem (17) can be formulated for all oligopsonistic companies. Consequently, there exists a set of combinations of purchased resource quantities, for which the profit of each company is greater than or equal to the profit of the Cournot-equilibrium. This set corresponds to the common section of the areas/spaces delimited by the isoprofit curves/surfaces, as we have discussed it above.

2. Cartel agreement between oligopsonistic firms

The conditions of oligopsony encourage companies to collude, since by that they are able to obtain a Pareto-improvement in comparison with the Cournot-equilibrium. A cartel agreement does not concentrate on maximizing the profit of each oligopsonistic company, but it strives to maximize the sum of all company profits:

$$\pi = \sum_{j=1}^{N} \pi_j \rightarrow \max \tag{18}$$

In this case the sum of profits of the companies participating in the cartel is:

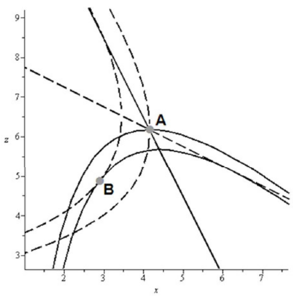
$$\pi(x_1,x_2,\ldots,x_N)=P\cdot\sum_{j=1}^{N} f_j(x_j) - p_i(x_1,x_2,\ldots,x_N)\cdot\sum_{j=1}^{N} x_j - \sum_{j=1}^{N} FC_j \tag{19}$$

Differentiating expression (19) with respect to each variable we get the profit-maximizing conditions of the cartel:

$$\frac{\partial\pi}{\partial x_j} = VMP_j(x_j) - MFC_j(x_1,x_2,\ldots,x_N) = 0, \quad j=1..N \tag{20}$$

Under the fulfilment of the conditions presented in point (20), the total profit of the cartel will be higher than the sum of equilibrium profits of each company (see also the conditional extremum problem (17) and the corresponding explanations). The figures below illustrate one such case each.

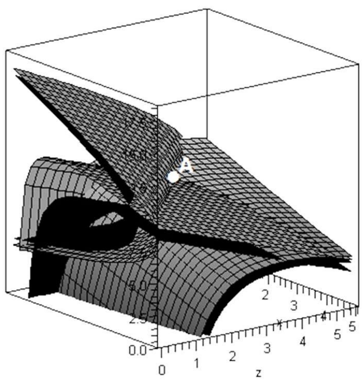
Figure 7 illustrates a cartel agreement for two companies. As a result of collusion the companies shift away from point *A* to point *B*. This shift means basically that – as a condition in the agreement – both companies will lower the resource quantity purchased from the market, both reaching thereby higher profit levels. On the figure it can be seen that isoprofit curves corresponding to point *B* are positioned lower than those corresponding to point *A*. The concrete numerical data is presented in the *Appendix*.

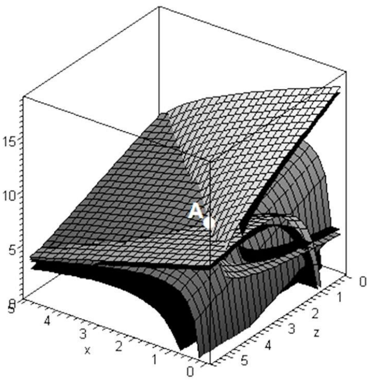


Source: own calculation, *Maple*

Figure 7. Duopsonistic cartel agreement

Figure 8 and 9 are similar to Figure 6 (for an easier understanding Figure 8 is shown from a different angle too, this is Figure 9). They illustrate – in a similar manner as on Figure 6 – isoprofit surfaces corresponding to the equilibrium and to the cartel agreement of triopsonistic companies. For a better overview, isoprofit surfaces corresponding to the cartel received a black color, while those passing through point A received a grey color and a gridded texture. It is easily observable that to each grey, grid-textured isoprofit surface a black surface can be associated, which lies closer ("lower") to the corresponding axis, therefore it represents a higher profit level compared to the values of the Cournot-equilibrium (point *A*). In case of three companies the intersection of the three black colored isoprofit surfaces corresponding to the cartel agreement, namely point *B,* is not visible, since it is positioned inside the common portion of space delimited by the three equilibrium isoprofit surfaces. Numerical data corresponding to this point is included in the *Appendix,* hence it can be compared to the situation in point *A.*





Source: own calculation, *Maple*

Figure 8. Cartel agreement in case of triopsony

Figure 9. Cartel agreement in case of triopsony (different angle)

The collusion in a cartel refers practically to the fixation of quotas (restrictions on resource quantities to be purchased), namely those resource quantities that assure a higher profit for each company participating in the cartel. Let x_j denote the restricted quota quantity for the j^{th} company, while x_j^* the quantity corresponding to the Cournot-equilibrium. In this case following relationships stand:

$$\pi(\overline{x}_1,\overline{x}_2,\ldots,\overline{x}_N) > \sum_{j=1}^{N} \pi_j(x_1^*,x_2^*,\ldots,x_N^*) \tag{21}$$

$$\overline{x}_j < x_j^* \ , \ j=1..N \tag{22}$$

$$p_i(\overline{x}_1,\overline{x}_2,\ldots,\overline{x}_N) < p_i(x_1^*,x_2^*,\ldots,x_N^*) \tag{23}$$

namely oligopsonistic companies collude in a cartel for higher total profit (21) by setting restrictions on purchased quantities on the resource market (22), which drives resource prices down (23).

3. Cheating in a cartel agreement

Inside a cartel two different interests are constantly in conflict with each other. The collective interest refers to the maximization of the cartel's total profit, when the companies try to push purchase prices down. The individual interest strives to only maximize the company's own profit, even at the expense of pushing down the profit of the other players. Based on Stigler's (1964) seminal work many researchers argued that the individual interest inside a cartel will inevitably lead to cartel breakup. In a more recent study Levenstein and Suslow (2006), after investigating twenty different industries, concluded that the average survival period of a cartel is only five years. One of the most fundamental reasons behind this is that one member company of the cartel may significantly increase its profit by breaking the cartel agreement, while others keep to it. In case the other players stick to the quotas set by the cartel agreement, the company in question may obtain higher profits by purchasing larger quantities than the quota on a lower price level. Cheating in a cartel can, thus, be formulated as a conditional extremum problem, where the constraints represent the fact that all other players besides the j^{th} company stick to the quota limitations set by the cartel agreement, namely:

$$x_i = \overline{x}_i\,,\ \ i = 1..N,\ \ i \neq j \tag{24}$$

Let $\overline{X}_j$ denote all the resource quantities purchased by companies other than the j^{th} company, quantities that correspond to the quota restrictions ($\overline{X}_j = \sum_{\substack{j=1 \\ i \neq j}}^{N} \overline{x}_i$). Besides the constraints formulated in point (24), the objective function is the profit maximization of the j^{th} company that cheats in the cartel:

$$\pi_j = P \cdot f(x_j) - p_i(x_j + \overline{X}_j) \cdot x_j - FC \rightarrow \max \tag{25}$$

Differentiating the profit function of the j^{th} company we can get the x_j resource quantity that needs to be purchased from the market in order to cheat in the cartel, and, hence, to maximize its own profit on the expense of the other players that stick to the quotas set by the cartel agreement. Thus, differentiating the profit function described by expression (25):

$$\begin{gathered} \frac{\partial \pi_j}{\partial x_j} = P \cdot MP_j - \frac{\partial p_i}{\partial x_j} \cdot x_j - p_i(x_j + \overline{X}_j) = 0 \\ VMP_j(x_j) = MFC_j(x_j, \overline{X}_j) \end{gathered} \tag{26}$$

As a result, we get a similar profit-maximizing condition, than in the base case scenario where oligopsonistic firms do not collude (see condition (6)). Hence, cheating in a cartel is somewhat similar to the procedure described in the base case scenario. However, in this case the j^{th} company is not obliged to anticipate resource quantities to be purchased by other players, since quota restrictions are known. Thus, the company follows its own reaction function, and maximizes its profit.

Figure 10 illustrates the duopsonistic situation, where the *first* company cheats in the cartel on the expense of the *second* company. The *second c*ompany holds on to the quota set by the cartel agreement (point B*)* – this is represented by the horizontal dotted line. Knowing this, the *first* company decides to increase its purchased resource quantity, thereby maximizing its own profit. The situation after the cheating is represented by point *C,* which lies at the intersection of the horizontal dotted line, corresponding to the quota limitation of the *second* company, and the reaction function of the *first* company. Point C represents the profit-maximizing situation of the *first* company, given the quota of the *second* company. The consequences of cheating are illustrated by the isoprofit curves passing through point C. It is observable that the *second* company moved to an isoprofit curve placed even higher than that corresponding to the Cournot-equilibrium (point A), thereby earning a lower profit compared to both the base-case and the cartel situation. On the other hand, the *first* company relocated itself to an isoprofit curve placed even lower than that corresponding to the Cournot-equilibrium, which resulted naturally in a higher profit level.

Figure 11 deals with the triopsonistic situation where the *first* company cheats in the cartel on the expense of the other two players. For a better overview, in this case we only illustrate the shift between points B and C (as defined in the duopsonistic situation) by plotting isoprofit surfaces corresponding to the cartel, and to the cheating in the cartel, respectively. Due to the position of the isoprofit surfaces the two points are not observable. Isoprofit surfaces corresponding to the cartel agreement got a dark grey colour, while those corresponding to the cheating in the cartel got a light grey colour. For a better understanding the ar-

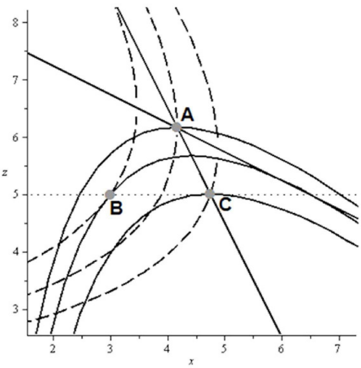
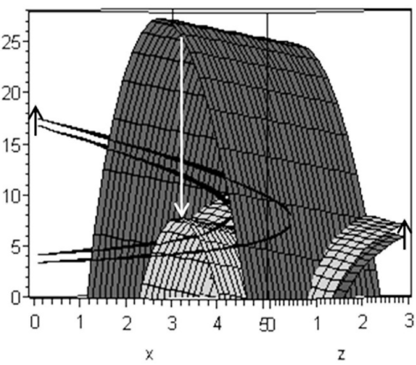


Figure 10. Cheating in a duopsonistic cartel



Source: own calculation, Maple

Figure 11. Cheating in a triopsonistic cartel

rows on the figure show the direction of the shift of each company from the isoprofit surface of the cartel towards the isoprofit surface corresponding to the cheating in the cartel. It is obvious that the *first* company repositioned itself on a much lower isoprofit surface (shift marked by the white arrow on the figure), thereby increasing significantly its profit on the expense of the other two players, who thereby got on higher isoprofit surfaces (shift marked by the black arrows on the figure).

Numerical values corresponding to points *A*, *B*, and *C*, both in the duopsonistic and in the triopsonistic situation are indicated in the *Appendix* of this paper.

Hence, in both situations the company that cheats the cartel agreement gets into a more favourable situation (and, accordingly, on lower positioned isoprofit curves/surfaces), while the companies who stick to the cartel agreement have their profits decreased (and, accordingly, relocate themselves on higher positioned isoprofit curves/surfaces). The players that stick to the cartel agreement may only sense cheating by observing that the price of the resource in question has increased on the market, and, thus, they are able to earn only a lower profit. Naturally they can suspect that cheating could be the reason of decreased profits, however, based on market information they can not unequivocally prove it.

Conclusion

Our paper discussed the behaviour of oligopsonistic firms on resource markets. Algebraic relationships behind oligopsonistic decisions were implemented using the *Maple* software, thereby aiming to illustrate the case of oligopsonistic markets with two and three players, respectively (duopsonistic and triopsonistic markets). The first part of our article concentrated on the situation of market equilibrium, by determining and plotting response functions and isoprofit curves/surfaces. Since the Cournot-equilibrium is not Pareto efficient, the second part of the article dealt with the case when oligopsonistic companies are able to collude, thereby aiming at a Pareto-improvement on market level. Consequently, in the second part we modelled the situation of cartel agreements, while the last section illustrated the unilateral cheating in the cartel in both duopsonistic and triopsonistic situations.

Appendix

The appendix contains the initial parameters of the production technologies assumed, and it also indicates the corresponding purchased resource quantity, output, and profit values, both for the duopsonistic and the triopsonistic situations. For a simpler graphical representation, initial technological parameters refer to a constant yield production functions. Purchased and produced quantities are expressed in natural units, while company profits are measured in monetary terms. In the tables below it is easy to compare how these quantities change as oligopsonistic companies move away from the Cournot-equilibrium (point *A* on the figures of this paper) and collude by creating a cartel agreement (point *B* in the article), and also when one company (in both cases the *first* company) cheats in the cartel (point *C* in the article). Quantitative changes are also marked by the arrows in the table.

Table 1. Values of purchased resource quantity, production output, and profit in duopsonistic scenarios

		First company ($y_1=5\cdot x_1$)		*Second* company ($y_2=3\cdot x_2$)	
	i=1..2	Value	Change	Value	Change
Cournot-equilibrium (point *A*)	Purchased qty (x_i)	4,167		6,167	
	Output (y_i)	20,833		18,500	
	Profit (π_i)	34,722		76,056	
Possible cartel agreement (point *B*)	Purchased qty (x_i)	3	↓	5	↓
	Output (y_i)	15	↓	15	↓
	Profit (π_i)	39	↑	85	↑
Cheating in the cartel (point *C*)	Purchased qty (x_i)	4,75	↑	5	-
	Output (y_i)	23,75	↑	15	-
	Profit (π_i)	45,125	↑	67,5	↓

Source: own calculations, *Maple*

Table 2. Values of purchased resource quantity, production output, and profit in triopsonistic scenarios

		First company ($y_1=5 \cdot x_1$)		*Second* company ($y_2=3 \cdot x_2$)		*Third* company ($y_3=6 \cdot x_3$)	
	i=1..3	Value	Change	Value	Change	Value	Change
Cournot-equilibrium (point *A*)	Purchased qty (x_i)	1,5		3,5		8	
	Output (y_i)	7,5		10,5		48	
	Profit (π_i)	4,5		24,5		128	
Possible cartel agreement (point *B*)	Purchased qty (x_i)	1,3	↓	2	↓	6	↓
	Output (y_i)	6,5	↓	6	↓	36	↓
	Profit (π_i)	13,52	↑	28,8	↑	140,4	↑
Cheating in the cartel (point *C*)	Purchased qty (x_i)	3,25	↑	2	-	6	-
	Output (y_i)	16,25	↑	6	-	36	-
	Profit (π_i)	21,25	↑	21	↓	117	↓

Source: own calculations, *Maple*

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