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MODELLING FINANCIAL SUSTAINABILITY OF CLUSTERS: THE CASE OF HUNGARY

Abstract. In Hungary, like in other post-socialist countries, clustering started only around the turn of the millennium. However, the mostly top-down organised clusters seemed not to be viable because the basic requirements of long-term operation, such as financial support and sufficient number of members, were not fulfilled. Thus, the main aim of this paper is to establish such a cluster-model which is applicable for the examination of clusters' opportunity to be self-supporting under different circumstances. By determining the criteria of the long-term financial sustainability of clusters, the model and its simulations can considerably support the work of cluster managers and the competitiveness of clusters.

Key words: clusters, financial sustainability, model, simulation, Hungary.

1. INTRODUCTION

In developed countries, clustering has had a relatively long history (Marshall, 1920). However, clusters came into the focus of researchers only in the last decades of the 20th century, since the efforts of distinct economic actors for co-operation became stronger parallel to the progress of globalisation and to the intensi-

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fication of competition (Brenner, 2004; Breschi and Malerba, 2006; Porter, 1998; Steiner, 1998). Clusters as special spatial formations of these collaborations, and as systems of interconnected companies and other institutions play an outstanding role in the spread of knowledge and enhancement of competitiveness (Fontagné *et al.*, 2013; Porter, 2000).

Although in developed countries many clusters already operated at the end of the last century (Breschi and Malerba, 2006; Cruz and Teixeira, 2010), in post-socialist countries it was only then that they started to appear. In Western countries they emerged in a bottom-up manner as an integral part of a lengthy evolution process (Commission…, 2008; Grosz, 2006), while in post-socialist countries they were organised in a top-down approach. There are also significant differences in the efficiency and durability of clusters' operation depending on their location. In developed countries, major parts of clusters operate effectively because their financial situation is mostly adequate, and they are in the mature stage of their development (Isaksen, 1997; Isaksen and Hauge, 2002).

In contrast with this, in post-socialist countries clustering is not so advanced even today, and most clusters are at earlier stages (initial phase) of development because the collaborations among enterprises of different sizes, ownership structures and activities were hindered by several factors (distrust, poor management skills, the lack of a sufficient number of enterprises and skilled labour force, poor infrastructure, the lack of entrepreneurship traditions, etc.), particularly in the beginning (Buzás, 2000; Kiss, 2010; Kowalski and Marcinkowski, 2014; Rosenfeld, 2002). Usually the serious financial difficulties have caused the largest problems for the development and lasting operation of these clusters because either the number and composition of members participating in a collaboration are not appropriate or the necessary income for their operation is not available.

In Hungary the concept of clusters emerged in the 1990s and the first clusters were created at the turn of the millennium as the country was a leader in the post-socialist transformation. Since then, their number has continued to increase, but only a small proportion of them operates durably, because the funding available to clusters from various sources is insufficient for sustaining an effective operation. The main aim of this paper is to determine the necessary income and membership ('critical mass') for the financial sustainability of clusters by creating a model. The idea of this cluster-model was inspired by biology, more precisely the example of a community of lions. Haque, Egerstedt and Martin (2010) strove to elaborate a generally applicable model seeking the optimal membership composition of African lion prides. Using the lessons from that model as the basis, a cluster-model has been developed which suggests the size of funding and membership composition necessary for the long-lasting, sustainable operation of clusters.

This study provides an original contribution to the cluster literature because previous studies on clusters have not dealt with the relationship between the financial situation of and membership in clusters. The model can be considered the first attempt to fill this gap. The other novelty is the research approach, as the idea of the model came from natural sciences, and the intention to adopt it in social (e.g. regional) sciences is not common at all. Moreover, the methods applied are also new. The use of simulation is not a 'customary' tool of analysis in the cluster literature, it rather is an 'innovative' one. Its greatest advantage is the ability to demonstrate the results of the changes in conditions without their experiences in reality, and this was the main reason for its application.

This paper consists of five sections. After the introduction, section two discusses the concepts of clusters primarily in terms of membership and clustering in Hungary, including the main features of the financial support for clusters. The third section describes the model together with methodological issues. Section four presents the simulations of the model based on the data and experiences of empirical research (primarily interviews) conducted among the managers of some clusters located in western Hungary. Finally, a short discussion and conclusions complete the article.

2. THEORETICAL BACKGROUND

2.1. The cluster concept

The quantity (number) and quality (composition) of cluster members are important elements of the model for clusters to become self-sustainable, which is why this approach focusses on the analysis of cluster concepts. In recent decades the concept of a cluster was defined in many ways demonstrating its evolution well (Bresnahan *et al*., 2001; Dahl and Pedersen, 2003; Hertog and Maltha, 2004; Maskell, 2001; Menzel and Fornhal, 2009; Steiner, 1998). By now, relevant shifts have occurred in the cluster literature from more descriptive accounts to more dynamic and systemic approaches (Cruz and Teixeira, 2010), and many cluster concepts exist. For example, Martin and Sunley (2003) identified 10 while Cruz and Teixeira (2010) 15 different cluster concepts, in which different levels of significance were assigned to the composition of cluster members.

The most often used cluster definition is that by Porter, who has defined a cluster as follows: "Clusters are geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (for example, universities, standard agencies, and trade associations) in particular fields that compete but also co-operate." (Porter, 1998, p. 197). Ten years after Porter's definition, the European Union – in response to new challenges – defined the cluster concept in the following way: "…group of firms, related economic actors, and institutions that are located near each other and have reached a sufficient scale to develop specialized expertise, services resources, suppliers and skills." (Commission..., 2008, p. 5).

According to both definitions cluster membership can be divided into two homogeneous groups – just like in a lion pride. The so-called "productive" group includes competing but also collaborating economic actors who represent a specific industry and pursue activities closely related to that sector's profile, plus their suppliers. The other "non-productive" group consists of non-profit institutions, educational and research units, support and background institutions (agencies, foundations, and consulting firms) that are assigned to help and support the operations of productive cluster members along with their research, development, and marketing efforts. They participate in continual market monitoring, data collection, tender drafting, specialised consulting, and workforce training and development to meet corporate needs, as well as in obtaining external funding vital for cluster operation, and in establishing an adequate business environment. The two homogeneous groups forming a cluster have clear and well-separated responsibilities. When compared to a lion pride, the productive members have the role of lionesses: hunting or feeding the group. Non-productive members, however, have the male lions' role: protecting the group (Haque *et al.*, 2010). Thus they help the cluster's productive members and participate, to some extent, in 'feeding' the cluster, too, by obtaining external funding and paying membership fees, yet this contribution is usually modest from a financing standpoint.

Although cluster theory does not refer to how many cluster members have to operate effectively in a cluster, it is obvious that the successful operation of a cluster requires a certain minimum number of members, a 'critical mass' to enable the exploitation of the benefits arising from collaboration and geographical concentration, and to attract other companies and supporting organisations into the region or the network (Grosz, 2006; Isaksen and Hauqe, 2002). As cluster membership renders exclusive benefits (access to additional information from markets and trend monitoring, joint action options in research, development and marketing, the elaboration of benchmarking systems, the adoption of best practices, the reduction of transaction and transportation costs, etc.) to member organisations which are not accessible to outsiders, outside organisations strive to become cluster members. The increasing number of cluster members, however, raises the issue of the long-term sustainability and viability of the cluster.

In the model, the option of increasing cooperation is left open, noting that the growth of membership is not a single-sided process. Any increase in the number of productive members is also accompanied by an increase of non-productive members, as both have their specific functions in the cluster and supposedly there exists an optimum ratio between the two. Within certain limits, this ratio may change, constituting an important factor during the simulation.

2.2. Cluster support and clustering in Hungary

Since the 1980s, the EU has developed several cluster development programs which vary considerably across EU Member States (Commission…, 2008). The history of these programs clearly reflects a shift from a quantitative to a qualitative approach, also impacting cluster support practices. A growing number of analyses (Engel *et al*., 2011; Junichi and Okamuro, 2011) shows that, first, cluster development intensified in the past decade and Hungary's cluster policy matched pace with international trends. Second, it also became apparent that indirect support has been gaining significance instead of direct support (Roelandt and den Hertog, 1999). According to the European Cluster Observatory, national budgets were the primary sources of financing for national cluster programs in Europe, while EU cohesion policy was a secondary source. The contribution of national budgets for funding cluster programs was estimated at 63% while the support of EU at 19% (Commission…, 2008). Probably this relatively good financing was the main reason why Cruz and Teixeira (2010) have found little research on cluster financial problems among 3,000 articles published in developed countries between 1962 and 2007. However, such articles may have not been published either because other 'features' of clusters (e.g. the role in networks, competitiveness, regional development or in the spread of innovation, and knowledge) in line with EU economic and regional policies were more important in the last decade (European Commission, 2010; Ketels, 2015).

In Hungary, support for clusters has been in focus since 2000, when the first cluster was established in the automotive industry, though its intensity often fluctuated. It depended considerably on the approach of consecutive governments to clusters and on the changes in the national and regional cluster policy. According to different studies, the Hungarian government provides far more money to cluster formation than to cluster operation. The related ratios are 60 percent versus 40 percent, respectively. At the same time, it also became obvious that at least HUF 20–25 million (EUR 66–82,500 at current prices) was necessary for each cluster, or even HUF 100 million in the case of a major one would be necessary to maintain their efficient operation (Grosz, 2006; Hegedűs, 2008).

Support for clusters can be provided from various (internal and external) financial resources. Internal funding refers to membership fees while external funding comes from sources outside a cluster, for example from tenders. Initially, clusters could mostly obtain funding from domestic sources. Their rapid growth after 2000 was enabled by the availability of significant funding in 2001 and 2002. Back then HUF 266 million was granted to 13 cluster initiatives. After the change of the government, support for cluster formation and maintenance temporarily received less attention. In 2005, 19 bids complied with the requirements defined in the call for tenders. Those bids received HUF 122 million in total, which was about HUF 13.6 million on average (Rödönyi, 2009).

Cluster support reached a new high after 2006 when EU funds became accessible, as the EU assigned great significance to developing clusters and strengthening their innovation relations. Funding was provided from the Structural Funds that were only opened to former communist countries after their accession to the EU. Also, between 2007 and 2013, cluster development had a priority in Hungary. Clusters could apply for various forms of funding depending on the depth of their collaboration: they were categorised as initial, developing, or accredited innovation clusters. In 2008, out of 181 applicants, 79 were rated as initial and 21 as developing clusters, receiving an average amount of HUF 25 and 62 million, respectively. At the same time accredited clusters (25 in 2011) were not granted direct support, they only gained eligibility for participating in certain tenders. Since 2014 the support from different EU sources for the development of already existing clusters has gained greater attention. For example, since 2016 clusters have been able to apply for HUF 5–50 million to improve the quality of their services for their members to become more competitive. Nowadays Hungary is developing a new development strategy and support system of the next financial period for operating clusters.

In 2019, there were 183 clusters in Hungary, many of which (55%) were still cluster-initiatives where the smooth operation or financial sustainability was least ensured. The number of accredited clusters was 27 (15%). Many clusters represented ICT, environmental, energy, and health industries, but the majority (41%) operated in different branches of the manufacturing industry (Fig. 1).

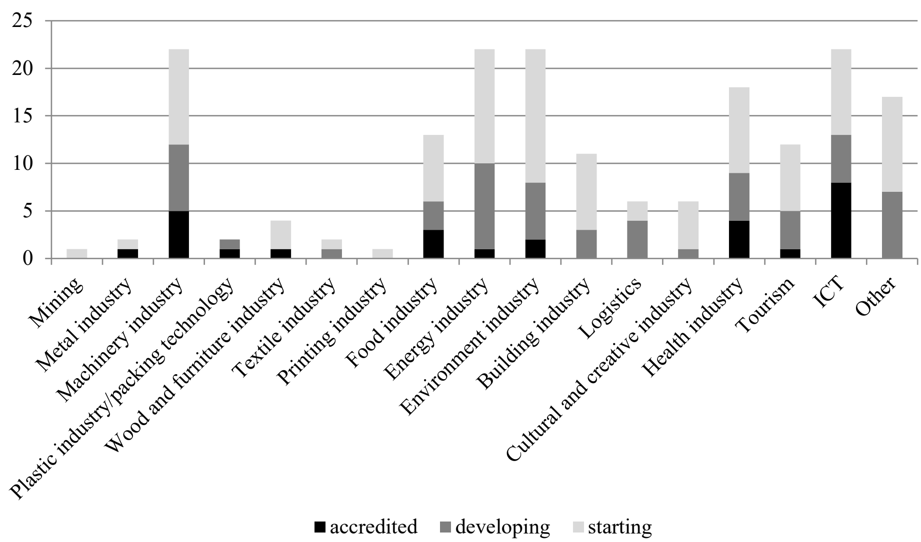


Fig. 1. Economic sectors and the level of development, 2019

Source: own work based on www.klaszterfejlesztes.hu.

In Hungary, clusters are usually local, which means their members are found in the same settlements. Particularly in the beginning, the geographical distribution of clusters was closely connected to the new spatial pattern of Hungarian industry where the preconditions of clustering emerged soon after 1989 due to considerable foreign direct investments (Kiss, 2007, 2010). This was the reason why the first and more developed clusters could be found in the manufacturing industry, the primary location of which has been the north-western part of the country. Today, however, the majority of clusters are located in central Hungary, especially in and around Budapest and in some county seats because during the last decade clustering started to accelerate in other economic sectors and in other regions of the country (Fig. 2).

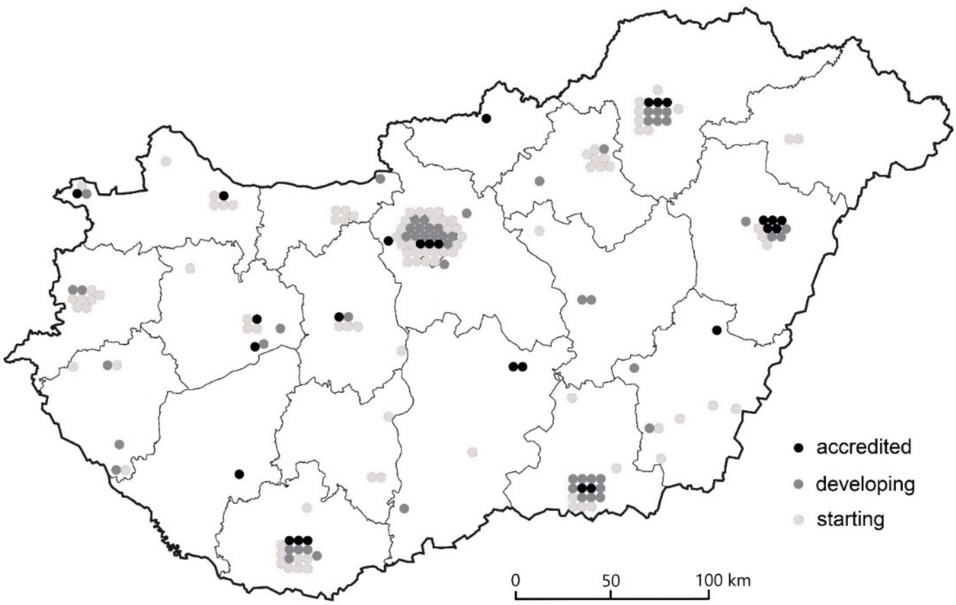


Fig. 2. Clusters in Hungary by the settlement of their headquarters and by the level of development, 2019

Source: own work based on www.klaszterfejlesztes.hu.

Even today many clusters operate on an on-and-off basis and are highly dependent upon external resources, have many passive members, or lack a critical mass of economic actors. The last fact is especially important because if there is not an adequate number of members, it is practically no longer justifiable to maintain the cluster and obtain government support for its further evolution. That is why the development of the model can promote the qualitative development and smooth operation of clusters in Hungary over the longer term.

3. METHODOLOGY AND THE CLUSTER-MODEL

3.1. Conditions related to financing

Regarding the income acquisition opportunities and financing systems of Hungarian clusters, the following conditions have been specified, which are, in fact, the building blocks of the model:

1. If a membership fee is payable, all cluster members are required to pay a set amount. However, this amount may vary depending on whether a member is a productive or a non-productive one. Usually a higher number of productive members participate in network cooperation and each of them pursues profit-oriented activities that generate income, thus they take a larger share in financing joint expenditures within the cluster. In most cases, non-productive members pay a lower membership fee. The more members a cluster has, the more significant this income source is. (It must be noted that zero is written if membership fee is not collected in the cluster.)
2. Service fees are linked to external service contracts and derive from work performed by productive cluster members. Therefore, it is in a cluster's interest to have as many productive members as possible in collaboration. (The presumably optimum ratio between productive and non-productive cluster members has been already determined and actual values are usually spread around this rate.) If non-productive members also perform services for external economic players, this problem can be managed easily with a single additional parameter.
3. Productive and non-productive members participate equally in obtaining external funds from tendering as the chance of winning grows proportionally to the number of cooperating members, although capped by an upper limit. In bid evaluation and the awarding of tenders (again up to a certain limit) additional points are given to bids submitted by an ad-hoc association of large groups. Further, the chance of winning is also higher if there are non-productive members among bidders. This finding called for assumption number 4.
4. Each bid drafting team formed within a cluster must include both productive and non-productive members. To keep things simple, their ratio should be the same in each group.
5. Not every cluster member is required to participate in an ad-hoc bid drafting team established to pursue funding for the cluster. However, each member is allowed to participate in one group only: thus the overall number of cluster members is greater or equal to that of cluster members 'going to battle' for tender funds. The network may also include passive members – at least in the short term. In the long run, a cluster must spot and exclude 'stowaway' members, otherwise the organisation becomes unstable and will break up sooner or later.

6. The sum of all funds obtained by an entire cluster in a year equals the sum of money successfully won in tenders by ad-hoc bidding associations of cluster members in the same year. However, these funds are spent and used jointly at the cluster level, i.e. every cluster member receives the same share from the profits from the services granted regardless of whether the member participated in drafting the winner bid or not.

7. The higher the number of ad-hoc bid drafting groups in a cluster, the higher the funding they are expected to obtain. If there are too many teams, however, they mutually reduce each other's chances of winning along with the likelihood of successful bidding.

8. Incomes rise proportionally to the increase in cluster members, but a higher number of network participants entail more difficulties in harmonising diverse and often conflicting interests, and in coordination and maintaining contact across the group. Further, administrative and operating expenses also grow proportionally, for example, owing to the need for printing a larger quantity of promotional materials, and staging larger events and meetings.

If the government's cluster and financing policy change, the conditions must be altered accordingly to avoid any compromises in the applicability of the model.

Like every model, this one needed simplified assumptions. One pivotal item is the model's monetary nature. Once critical mass is achieved, certain additional benefits and positive external impacts emerge that are difficult (if not impossible) to capture in financial figures, although they may justify cluster operations in themselves. At the same time, in the model all benefits associated with cluster membership that collaborator participants can fulfil through services or merely through geographical proximity or capacity harmonisation were 'monetised'. This is necessary because continual and regular communication, relationship network extension, joint marketing efforts, and localisation benefits will sooner or later lead to increased revenues, i.e. financial gains that each member would like to share in.

3.2. Abbreviations and notations

Abbreviations and notations used for describing the above-mentioned criteria by mathematical tools are the following:

C = number of members in a given cluster,
J = number of productive members,
I = number of non-productive members,
m_J = source demand of productive members for a year,
m_I = source demand of non-productive members for a year,
M = total income of the cluster in a year,
t = annual membership fee that has to be paid by the members of the cluster,
t_J = membership fee of productive members,

t_I = membership fee of non-productive members,
S = total income from external services for external firms,
s_J = income from external services generated by productive members,
Pr = bivariate function describes the probability of the chances of a bid for winning. These applications were submitted by the groups formed in an ad-hoc manner within the cluster to apply for money from the EU and the Hungarian government.
g = project teams established within the cluster,
j_g = productive cluster members in project or cluster teams,
i_g = non-productive cluster members in project or cluster teams,
k_{opt} = optimal ratio of productive – non-productive members in the cluster. The best for the cluster is when the J/I ratio agrees with the value of k_{opt}. The aim of clusters is to reach this optimal value.

3.3. The assumptions of the cluster model

The number of cluster members is aligned with the total number of productive and non-productive members in a cluster. This condition can be described by the equation

$$C = I + J \tag{1}$$

The long-term operation and the sustainability of the cluster require a minimum level of annual income sources necessary to cover the operating expenses and to facilitate the provision of services for the cluster's members (e.g. to maintain a common webpage, to organise different trainings, to represent the cluster's members at conferences). This can be expressed by the formula

$$M \min\left(I, J\right) = m_I \cdot I + m_J \cdot J \tag{2}$$

The money flowing into the cluster within a year is jointly utilised by the members to fulfil their common goals. Therefore, when the model is simulated it is assumed that the share from the network's money is the same for productive and non-productive members. That was the reason why the same amount was introduced in m_I and m_J, but it can be modified. If the contribution of the productive members to a cluster's maintenance is more considerable than that of the non-productive ones, it is justifiable to allocate a larger amount to them, which means: $m_J > m_I$.

The annual income of a cluster also has to be increased. It can be derived from membership fees, from external services, and from successful applications. Thus

$$M(I,J) = t_I \cdot I + t_J \cdot J + s_J \cdot J + g \cdot \bar{M} \cdot \Pr(j_g, i_g) \tag{3}$$

where M indicates the amount of the average annual money acquired by the applying groups formed ad hoc within the cluster, while $\Pr(j_g, i_g)$ shows the probability of the applications' chance for winning.

Hence $\Pr(j_g, i_g) \in |0, 1|$ gives a probability, the value of which can move between 0 and 1. The probability can be received by inserting these values ($x = j_g$, $y = i_g$) in the following equation[1]:

$$\Pr(x,y) = \frac{1}{(x-ky_0)^2 + k^2 \cdot (y-y_0)^2 + e^{(x-ky)^2}} \tag{4}$$

and at the same time the condition $x_0 = k_{opt} y_0$ is also valid. As a consequence the chance for winning is the largest along the $x = ky$ line, and the function $\Pr(x, y)$ takes up its absolute maximum in the point (x_0, y_0) (Fig. 3).

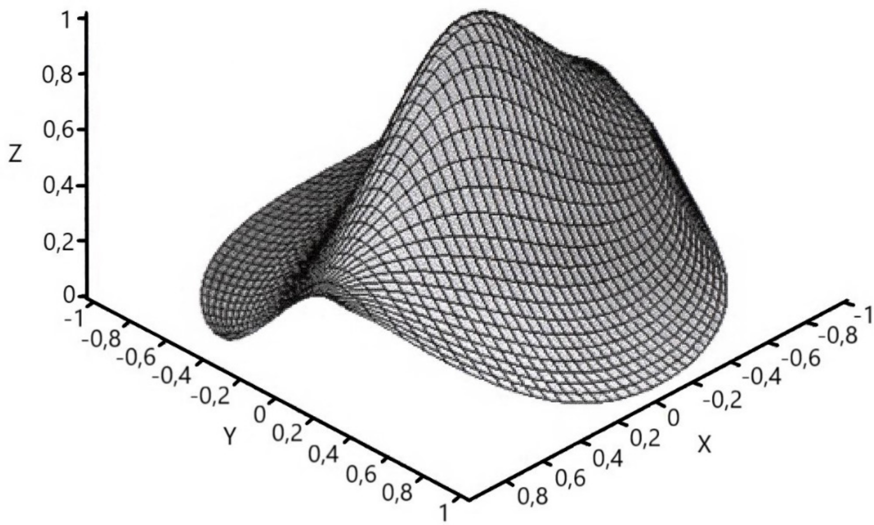


Fig. 3. Distribution of the normal probability function

Source: own work.

The applications' chances of winning are higher if the members form more teams to write and submit proposals and if a group consists of more members,

[1] The equation (4) was created to best match the expectations and the conditions prevailing in the model. Many bivariate probability functions are possible, but for our purpose this proved to be the most suitable.

though to a certain limit. However, after reaching the upper limit, which is usually 15 members per group (because until this point the applicants of clusters can get some advantages, i.e. extra points, in the course of the evaluation of their applications), the coordination and harmonisation of the members' interests become more difficult and efficiency decreases.

In each group of a cluster which applies for governmental support there are productive and non-productive members, their ratio marked by k is supposed to be the same in all groups in order to agree with the whole productive and non-productive ratio of the cluster, thus

$$k = J / I = j_g / i_g \tag{5}$$

Provided that every member of the cluster participates only in one application at the maximum and not every member of the cluster has to participate in an application:

$$g \cdot j_g \leq J \tag{6}$$

$$g \cdot i_g \leq I \tag{7}$$

This makes it possible for groups within a cluster to have passive members, too. A cluster can be maintained from the financial viewpoint in the long-term if the condition:

$$J \cdot \left(m_J - t_J - s_J\right) + I \cdot \left(m_I - t_I\right) \leq g \cdot \bar{M} \cdot \Pr\left(j_g, i_g\right) \tag{8}$$

is fulfilled.

4. TESTING THE MODEL: SIMULATIONS

After the creation of the model which provided the theoretical basis for simulations, it was made operational. First, based on the data and information collected from the managers of three developed clusters (Pannon Mechatronikai Klaszter, Pannon Fa- és Bútoripari Klaszter, and Pannon Textil Klaszter) in western Hungary, an 'average' cluster was created for testing, and it was described using mathematical equations. Then, those were fed into a computer and different possible solutions were generated by changing input parameters (*M, t*). The computer simulation[2] has proven to be an appropriate analytical tool for testing the model

[2] The calculations, simulations, and illustrations of the cluster-model were made with the "Maple" software.

because it enabled us to observe different results in accordance with the changes of conditions on a computer instead of in real life.

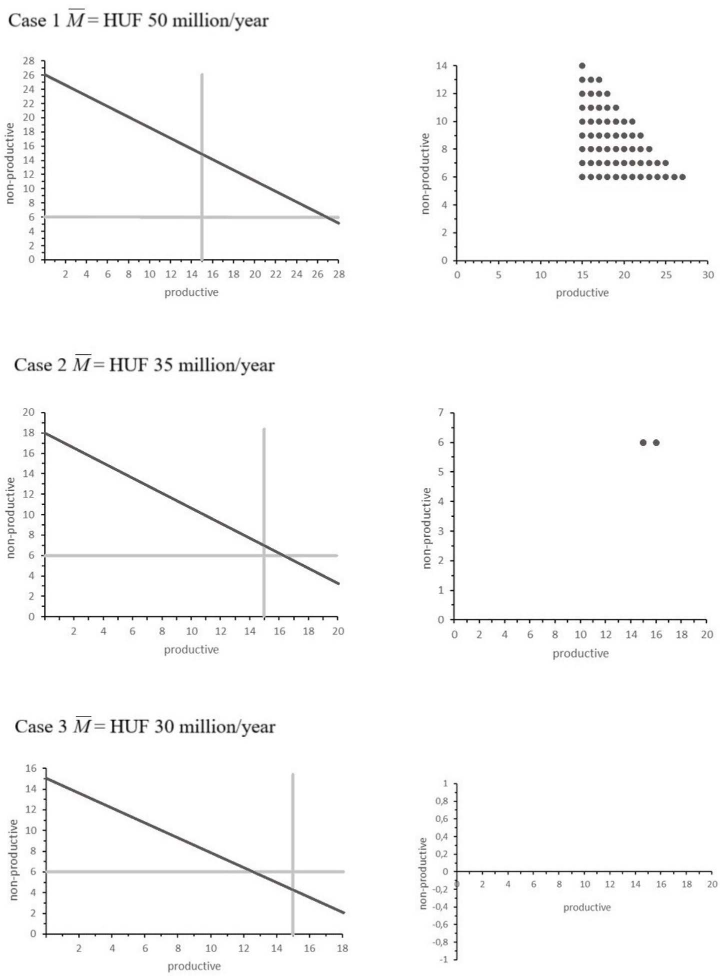
Although, several tests were conducted by changing each parameter, only the results of two examinations will be demonstrated. In the first simulation, the following criteria were valid in the cluster. The amount of the annual membership fee was t_J = HUF 100,000 for productive members and t_I = HUF 50,000 for non-productive ones. The optimal productive–non-productive ratio in the cluster and in all groups formed within the cluster was assumed to be two, i.e. $k = 2$.

The cluster had also other sources of income, which arose from external services conducted by productive members for external firms. The amount of the annual service charge was estimated by the data collected from the three managers. Its value was s_J = HUF 67,000. It was also assumed that three groups (g = 3) were organised within the cluster to submit applications and to apply for financial support in order to be able to fulfil their common projects and ideas. Regarding the composition of proposal writing groups, it was assumed that each group consisted of five productive and two non-productive members: $j_g = 5$ and $i_g = 2$.

The cluster members shared the sources gained in a year equally because they utilised the money jointly. Based on the assumption, the average annual resource demand of non-productive and productive members was the same. This amounted to $m_J = m_I$ = HUF 500,000. Then the question arose: which clusters were sustainable in the long-term under these conditions? The answer was illustrated by the results of the first simulation (Fig. 4).

The three cases differed from each other only in that the amount of money acquired by winning tenders was decreased gradually while every other parameter remained the same. In the first case, HUF 50 million acquired from external sources made the long-term operation possible, as well as the maintenance of a cluster which had 60 members of different sizes and compositions. This solution could be represented by a triangle bound by three lines arising from the equations in points 5, 6 and 7. When the amount of external sources was reduced, the number of members of the sustainable cluster also decreased. When the support was HUF 35 million, due to changes in the financial criteria, the steepness and position of the line also changed. The area of the triangle (solution of the mathematical equation) became smaller and led to less viable clusters in the long-term. Only a cluster with 2 members could operate under these circumstances. In the third case when the assumed external contribution to the cluster's budget was HUF 30 million, there was no such network cooperation which could be maintained in the long-term.

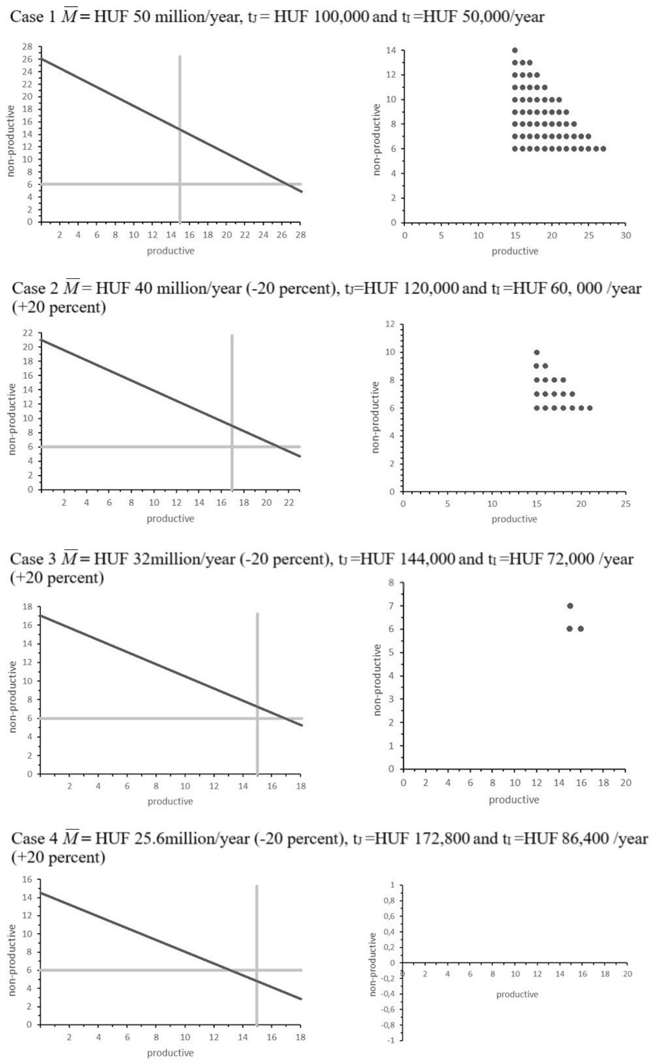
The second simulation examined what would happen if the amount of external sources of a cluster was decreased while the annual membership fees of productive and non-productive members were increased. This idea was considered a good one by the experts dealing with the financial maintenance of clusters because they emphasised the importance of organisations' self-maintenance, which is essential in long-term operation. The same measurement (20 percent) was assumed in the reduction of the governmental support and in the increase of the amount of annual fees. This meant that three parameters changed simultaneously in the model: M which indicated the amount of the average annual money acquired by the winning applications decreased by 20 percent year-to-year while t_J and t_I (the annual membership fees of productive and non-productive members) increased by 20 percent each year. All other data remained unchanged compared to the initial state (Fig. 5).



Note: HUF 50 million about EUR 165,000

Fig. 4. The results of the first simulation

Source: own work.



Note: HUF 50 million about EUR 165,000

Fig. 5. The results of the second simulation

Source: own work.

In the first case when the data was the same as in the initial state of the first simulation, the result was the same because the cluster consisting of 60 members of different sizes and compositions was viable. One year later there was a 20 percent decrease and because the external sources represented a larger proportion in the financial structure of the cluster than the amount of annual membership fees, their reduction could not be compensated by an increase of annual membership fees. (This remained roughly aligned with present-day Hungarian reality.) As a consequence, the size of the sustainable cluster decreased year by year. In the second case only a cluster with 19 members remained viable, while in the third case (after a newer modification) only a cluster with three members, and then their number reached zero.

The conclusion of the second simulation has been that without a balanced financial structure – where the external sources do not represent an extremely big proportion in a cluster's budget – it is not possible for decreasing external sources to be substituted by an increase of participant contributions; in other words: by increasing membership fees.

Although the cluster model describes the situation in a single year, one might presume that if the conditions in the model were fulfilled durably, the model would be dynamic and sustainable for a long time.

5. DISCUSSION AND CONCLUSION

In recent years in the course of the theoretical and empirical research on clusters it has become obvious that in order for clusters in Hungary, functioning with a distorted financing structure and dependant mostly on external sources, to advance to a higher stage of development and become self-sustaining, analytical tools that can help them reach the critical mass and establish appropriately sized clusters are required. Borrowing from an idea in biology, we designed our cluster model to serve this purpose. It represents an examination method that can define the limits of cluster operability in the long-term by defining and adjusting some of their operational parameters. It ensures clusters to operate more smoothly and not to have financial problems in the long run, thus these organisations can shift into a more developed phase.

In testing the model, simulations have proved on the one hand the operability of the model under certain circumstances, while, on the other, it has also been revealed that clusters will not be self-sustainable if the decrease of external sources exceeds a certain amount. But if membership fees increase at the same rate as external sources decrease, the increasing membership fee cannot compensate the decreasing external sources because the latter usually form a larger proportion in the budgets of clusters, particularly in the initial phases of their development.

In general, the financial status of clusters depends on in which development phase they are. Usually greater support is necessary in the first phase of their life cycles. After they are established, in the growth stage the most important task is to increase the number of members and reach a critical mass while forming the organisational and operational conditions for clusters. At this time external sources are extremely important for the survival of clusters. In the mature stage the effective cooperation of members is already realised, their financial situation is stable, and they cover their operational costs primarily from membership fees.

Usually the most viable clusters are those with firms of different sizes and owners. It is quite often that clustering is more advanced among enterprises with foreign interests and better financial statuses. The development and appropriate internal structure of clusters depending on the geographical location and the specialities of economic sectors can be also different. One might presume that branch party affiliation can also have an indirect impact on the measure of clustering and on the number of cluster members because in certain economic sectors the intention or compulsion for cooperation can be more intense.

The sustainability of clusters also depends on the quality of the political, economic and social environment because it can affect the operation and the size of obtainable support. Depending on governmental politics, the latter can often change. After the turn of the millennium, when clusters were ‘new’ in Hungary and several factors hindered their establishment and operation, they received considerable state support. But later, when the number of clusters increased and the volume of state support decreased, other sources, membership fees in particular, became increasingly important in the budgets of clusters. That is why the model or the number and composition of cluster members are relevant, just like in a pride of African lions, where there is also a special internal structure and finding an optimal member structure can be essential for its survival.

The results of this research can be of great help to authorities and economic policy makers interested in cluster development and to decision-making managers of clusters alike because they determine those factors (number and composition of cluster members, income) which are necessary for the sustainable operation of clusters. The different results of simulations can provide ideas to cluster managers, for example how to organise cluster members or to what to pay attention in connection with finance and membership when establishing and/or managing clusters. In fact, they present a basis for different calculations in different circumstances, namely what payments, membership fees or what kind of membership composition it requires. Knowing this, those who are interested in cluster development will be able to choose cluster members – to a certain degree – more consciously to ensure a cluster’s sustainable financial operation.

In terms of future research, one option would be to examine how the model works in other post-socialist countries. Moreover, it would be also interesting to study some other limitations of the model (e.g. the relations inside and outside a cluster, the relevance of EU funds in promoting innovation, especially in the recent accessors to the EU). Perhaps further analysis will reveal such new connections which could contribute to a different or a more complex interpretation of the model. A better understanding of the operation of clusters could also increase their competitiveness, which is extremely important in the economic crisis caused by the current global pandemic in the age of the fourth industrial revolution.

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