Quadruple Helix and firms' performance: an empirical verification in Europe

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Quadruple Helix and firms' performance: an empirical verification in Europe

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Abstract The emerging relationships connecting organizations are the condition on which innovation is founded nowadays, so it is pivotal to achieve a vaster comprehension of the phenomenon through the exploitation of new dynamics and the exploration of new trajectories. In line with the Quadruple Helix (QE) approach, it seems reasonable to expect that the different environments in which firms operate would highlight the expectations of the various market governance systems, which firms must comply with in order to gain social legitimacy and improve their capacity for survival. To determine whether the Quadruple Helix model has an effect on the firms' profitability, the authors employed the classification analysis method (Classification And Regression Trees). The sample is composed by 4215 manufacturing firms located in science parks. In our empirical model, the variable "citizen" classifies businesses with high Return On Investment in the best way. This shows that in science parks "the fourth helix" (citizen) has an important role in classifying the firms with the highest performance. Moreover, the majority of firms that attribute high importance to the collaboration with private financial institutions in order to finance innovations have a high ROI. In addition, firms with high economic performance in the model of the quadruple helix generate product innovation.

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1 Introduction

At the basis of this work is the assumption that firms actively try to extract maximum benefit from exploiting the status quo so that they can sustain their position in their own special niche. Our contention is that they are unaware, or uninterested, in the aspects that would allow them to function in the longer-term, while negotiating the many possibilities open to them within the seemingly cut-throat environment of competition (Del Giudice and Maggioni 2014; Campanella et al. 2013a, b; Maggioni and Del Giudice 2011; Soto-Acosta et al. 2015; Palacios-Marqués et al. 2015a; 2015b; Soto-Acosta et al. 2010).

Competition is built on a business design where the (subjective) concept of value means more than merely satisfying the economic expectations of players and institutions within and without the firm. Competition also implies that firms have the power to act within a recognized institutional environment (Carayannis et al. 2015a, b; Carayannis and Campbell 2009; Carayannis and Rakhmatullin 2014; Carayannis et al. 2012; Park 2014; Arnkil et al. 2010).

Firms have, on the one side, the power to develop and control their operations and, on the other, to give social legitimacy to their actions. Firms need to re-elaborate the external environment in order to identify any possible limitations to their strategic thinking. This, in turn, opens a completely new research perspective onto the pressure exercised by the institutional environment for firms to conform. It addition, this perspective can also highlight the possible conflicts between the rules originating from the outside world and the firm's internal standards of efficiency, set according to its own needs. In reality, conceptually speaking, if we leave the abstractions of neoclassical models and enter the complexity of the organizational world, a firm's independence, which is expressed through the decisions taken by its managers and stakeholders, can be seen as an exception justified by the artificial concept of the perfect market, rather than being a rule that can be applied generally. The external environment is not a standard or uniform context (Etzkowitz and Leydesdorff 2000a, b; Etzkowitz 1998, 2003, 2008; Etzkowitz et al. 1998; Etzkowitz and Leydesdorff 1995; Leydesdorff and Etzkowitz 1998). Rather, it is composed of often very powerful organizations (firms, governments, political parties and movements) that express a great number of demands which are often in conflict with each other. Deciding which demands need to be satisfied is not arbitrary or cause-dependant, but it is conditioned by the firm's need to access the resources that are essential for its survival.

This vision of the relationship between firm and environment is loaded with conceptual consequences. The first is that, if a firm sets itself objectives, chooses allies and counterparts, exercises pressure and develops a strategy, then, although the environment in which it operates is neither predictable nor static, it is largely an environment selected and moulded by the firm itself. The second consequence is linked to the interdependence between the players in the system and the strategic game play among them. Interdependence is, however, ambivalent. On the one side, it can lead to coordinated action that increases group power over the environment. On the other, interdependence requires mediation and individual players are generally unable to achieve results that reflect their wishes entirely. In reality, this consideration leads us to the conclusion that it impossible to

remove the influence of external ties over the end goals of a firm totally. Through their influence, the various powers of the outside world negotiate their way into the decisions being made by a firm, so that its final objective is rarely unique or clearly defined.

The most interesting theoretical problem that comes out of this lies in the conviction that a firm in pursuit of profit—with its own internal efficiency standards and able to survive because it can manage its operational and relational networks autonomously—is restricted to making strategic choices that it sees as a legitimate means for gaining competitive advantage in the market place.

In the world of today, these alternative options must learn to co-exist. Often, by exploiting paradoxes and contractions, it is possible to find coherence between management applications at a deeper and broader level, in the very fabric of a complex environment, rather than in the isolated entrepreneurial events. All the changes and economic crises of recent years have had a deep effect on national and international frameworks, radically altering the way firms behave. While depending absolutely on the resources that their environment can provide (or refuse through a form of self-righteousness), firms are capable of implementing strategically differentiated responses and can manage their relationship with the environment in many different ways.

Coupled with this is a wide-spread system of knowledge and relationships concerning the running of firm processes, that is, the set of operations (decisions and actions), both internal and external to the firm, that cut across its specialized and functional areas. The technical balance and the organizational and cultural mechanisms whereby a firm can maximize its operational efficiency also include its relationships with other organizations and external players involved in its operational processes (Afuah 2002; Howells 2006; Del Giudice and Maggioni 2014; Campanella et al. 2013a, b; Maggioni and Del Giudice 2011; Del Giudice et al. 2012, 2013a, b; Del Giudice and Straub 2011).

In the light of this perspective, not only can a firm analyze and design processes that can lock into all the various operational combinations of other players belonging to its value system, but, in addition, the strategic thinking stimulated within the firm can redefine its scope of action.

In substance, firm processes are identified through objective elements, but that is not all. These processes are also identified implicitly by interpreting the methods used by the firm to make its own strategic arrangements, in other words, its own way of being on the market. This logic suggests that the reality of a firm is so complex that it becomes extremely difficult to classify the procedures that are put in place to reconcile a series of apparently incompatible performance objectives.

In the way that it is designed, the Quadruple Helix model allows us to move forward and improve our theoretical and empirical understanding of the processes that shape and determine economic performance (Kim and Mauborgne 2004; Colapinto and Porlezza 2012; Maldonado et al. 2009; Pfeffer, 2011; Altmann and Ebersberger 2012; Pisano 2006).

In line with the QE approach, it seems reasonable to expect that the different environments in which firms operate would highlight the expectations of the various market governance systems, which firms must comply with in order to gain social legitimacy and improve their capacity for survival (Gouvea et al. 2013; Lindberg et al. 2014; Carayannis et al. 2012; Cai 2013; Cho 2014; Yang et al. 2012; Yawson and Robert 2009).

In order to determine whether the Quadruple Helix model has an effect on a firm's profitability, the authors employed the classification analysis method to examine the fundamental levers and success factors used to explain the nature and the entity of successful results. Satisfactory economic performance is measured in the context of economic relationships with a number of players and institutions that do not simply pose restrictions

over the choices that the firm makes, but are clearly capable of influencing corporate objectives while they are in the process of being made. The success of a firm is an event where the theories and methods have not led to any general agreement and there is no foreseeable dominant paradigm. If, however, the objective for a firm is not simply the right to survive but, more precisely, to produce long-term value, then it is based on a "falsehood", forcing us to re-read the proposed strategies in a critical light and raise issues that are useful for the purposes of scientific research and management practice (Dubina et al. 2012; MacGregor and Carleton 2011; Colapinto and Porlezza 2012; Hafkesbrink and Schroll 2011; Etzkowitz and Leydesdorff 2000a, b; Etzkowitz et al. 2000a, b, c; Gouvea et al. 2013; Leydesdorff and Etzkowitz 1998; Leydesdorff and Park 2014).

2 Theoretical background and research hypotheses

New "emerging" relationships are now the condition on which innovation is based, and, by exploiting new dynamics and new trajectories, the Quadruple Helix model can be used to gain a greater understanding of these relationships. In fact, without the learning processes fuelled by the increasing power of science and industry (Carayannis et al. 2006, 2011) and enacted by firms, there would be no chance to control the structural complexity and uncertainty that characterize the entire economic and social context. Actually, as firms have to comply with the principle of competitive performance, it follows that they are compelled to understand the way to manage the relationships that channel the increasingly diverse and intense division of labour connoting knowledge production and utilization. Modern industrial capitalism is characterized by situations that are heavily diversified and evolve rapidly; thus, firms may overcome the limitations established by cognitive boundaries, if they are able to capture "what the public wants" when it comes to obtain the effects from an innovative process.

In fact, as stated by Arnkil et al. (2010, p. 14), "another candidate as fourth helix is the user that is very close to Yawson's candidate, the 'public'". It follows that a useful relationship between the user and the firm must be created, if the latter is willing to survive and be continually present within its operating context. Therefore, the issues satisfied by the firm through its productive capacity must be addressed more directly and promptly. However, this way, an indefinite and basically infinitive link between the user and the firm is established. This link forms the basis for its survival and development, while, in a different perspective, the link established through the narrow channel of "giving an asset or benefit that meets a given need" would only be valid for the length of time in which there is that precise need and at the moment in time when the precise asset or benefit can satisfy that need in the best possible way. Moreover, the issue the user aims at solving must not be under-estimated. It should also be clarified that the desired solution may not be encompassing, since an overall accurate description may not be always possible. As a consequence, firms have an important social and moral responsibility, and it is also in their own interest to suggest suitable solutions to real issues (Gouvea et al. 2013; Lindberg et al. 2014; Carayannis et al. 2012). Furthermore, interaction between firm and user is guaranteed, and the former becomes the best interlocutor to comprehend the actual needs of the latter. This knowledge, together with all its particular effects on the logics of economic production, may be exploited by firms in order to determine if they can provide solutions to the user's advanced issues the same way or even better than those present on the market (Carayannis and Campbell 2011; Lindberg et al. 2012; Colapinto and Porlezza 2012).

In any specific moment in time, interaction will take place between the firm and the potential users who are not willing to establish a long-term relationship, because they are not requiring a fixed problem-product; this is partly due to the endless changes to their psychological, sociological and economic state, and partly to technological evolution. This is the reason why, in order to meet the users' problems, always new solutions are provided. Consequently, in both international and inter-industry markets, the relationships between firms and users must be continually monitored and cared for, since they are very unstable and sensitive to change. Through awareness of these changes, firms can address strategies, find new solutions, and eventually follow all the evolutive process of the user's needs. Actually, the basis of such evolution is the capacity of the firm to respond immediately and take advantage of the potential provided by change. Nevertheless, at this time, it appears best to analyse in more detail both firms and users within their own particular contexts. Firstly, it should be stressed that the perspective of development is not a matter that concerns firms only.

So as to manage the development of science and technology, and ensure the competitiveness of the environment in which the firms operate, there must be compatibility between the users' needs and the environment itself; the needs in question are of cultural, political, bureaucratic and other nature (Betz 2010; Carayannis et al. 2014; Deakin and Leydesdorff 2014; Deakin 2010, 2011; Deakin and Leydesdorff 2011; Mieg and Töpfer 2013; Mieg 2012; Nicotra et al. 2014; Rieu 2014; Sassen 2003; Hall and Wagner, 2012; Hansen et al. 2009; Nidumolu et al. 2009; Hagedoorn 1993, 2002). By accepting this structure, it is obvious that a firm must be capable of create a system with the right strengths to achieve its development. Indeed, if a firm desires to ensure its economic performance, it must be capable of establishing and addressing an increasing number of complex relationships. These, in turn, must manage to intervene strategically over the firm's goals, without merely setting contractual boundaries to the decisions made by the firm. The actors that play their part in the innovative system are more and more entities with their own different interests, which have a set value and a recognized meaning, and with whom the firm establishes dedicated relationships, and are less and less unspecified quantities without any peculiar features. Specifically, the Quadruple Helix model is not limited to the introduction of new innovation vectors, the new innovation-enabler organizations or suggesting them as new barycentres, which are leaving the periphery of the system and are about to become its centre (Andersson et al. 2009).

The Quadruple Helix model may also intuitively acknowledge that, so as to reach less vulnerable competitive positions, a type of innovation is required, that implies the search for new ways to use the recipients of the innovation, and thus a more effective utilization of the new knowledge (Colapinto and Porlezza 2012; Maldonado et al. 2009; Pfeffer 2011; Altmann and Ebersberger 2012; Kaufmann and Toedtling 2001; Leydesdorff and Ahrweiler, 2013; Leydesdorff 2012; Leydesdorff and Etzkowitz 1996; Leydesdorff and Etzkowitz 1998; Leydesdorff and Park 2014; Leydesdorff et al. 2014; Lindberg et al. 2014; Lombardi et al. 2011; MacGregor et al. 2010).

This leads to the following research hypothesis being formulated:

H1 The majority of firms involved in science parks based on Quadruple Helix model have a higher ROI than those which are not involved in Quadruple Helix model.

H2 The majority of firms that operate in Quadruple Helix model and that attribute high importance to the collaboration with private financial institutions in order to finance innovation have a high ROI.

3 Sample, variables and empirical study method

The sample used for this empirical research contains 4215 firms that, in 2013, were located in 28 European countries, which are Austria, Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the UK. These firms are classified as manufacturing sector and located in science parks.

To determine whether the Quadruple Helix model has an effect on the firms' profitability, the authors employed the classification analysis method.

Classification trees were used for the following purposes (Lemon et al., 2003):

- to identify the determinants of the dependent variable. To achieve this, the analyst had to pinpoint the explanatory variables (X) that classify the dependent variable (Y) most precisely. Specifically, following the resulting segmentation, it is possible to identify the main explanatory variables within subsets of units that are increasingly accurate;
- to discard redundant data. Subordinately, the segmentation process was also used to discard variables reflecting information subsumed in other variables and variables with a limited bearing on Y;
- to search for interaction between the predictive variables. Interaction is the effect of a combination of procedures carried out on the dependent variable and can only be detected by analyzing the conditional distribution patterns (hierarchies of variables);
- to generate prediction or classification rules. Based on the sample, the analyst lays down a rule to predict the value of the dependent variable for a new unit, to which the explanatory variables apply;
- to search for non-linear or non-monotonic relationships.

The classification rule for a research sample has to be defined before building the classification tree (Andone and Sireteanu, 2009). The classification rule for this research is to make the distinction between "*High ROI*" and "*Low ROI*" firms. This classification rule is reflected in the Y variable for the classification tree. Variable Y has been structured as follows:

Y = an explanatory variable standing for the firm's performance. The dichotomous variable is set at 1 if the firm has a high ROI, otherwise, it is set at 0. High ROI occurs when the average ROI of the sector is less than the ROI of the firm. Using the Eurostat database, we calculate firms' overall ROI in European manufacturing sector. The ROI was 2.67 % in 2013.

At this point, a recursive partition technique was applied to assign each statistical unit to one of the classes defined a priori by Y. The sample units were repeatedly split into groups which were increasingly more homogeneous with respect to the dependent variable Y. The splitting procedure was conducted with reference to the explanatory variables $X = (X_1, X_2, \ldots, X_s, \ldots, X_p)$.

In line with the aim of their research, the authors had to define the variables (X) that have a bearing on the firms' ROI.

Accordingly, they defined the following nine independent variables:

1. Innovation = an explanatory variable standing for the type of innovation produced by the firm (product innovation or process innovation). The dichotomous variable is set at 1 if the firm produce product innovation and at 0 otherwise;

2. Other_firms = an explanatory variable standing for the importance of collaboration with other firms to create innovation. This dichotomous variable is set at 1 if the importance of the collaboration is high and at 0 otherwise;
3. Research_institutions = an explanatory variable standing for the importance of collaboration with research institutions to create innovation. This dichotomous variable is set at 1 if the importance of the collaboration is high and at 0 otherwise;
4. Innovation_promoters = an explanatory variable standing for the importance of collaboration with innovation promoter to create innovation. This dichotomous variable is set at 1 if the importance of the collaboration is high and at 0 otherwise;
5. Business_community = an explanatory variable standing for the importance of collaboration with business community to create innovation. This dichotomous variable is set at 1 if the importance of the collaboration is high and at 0 otherwise;
6. Pub_authorities = an explanatory variable standing for the importance of collaboration with public authorities to create innovation. This dichotomous variable is set at 1 if the importance of the collaboration is high and at 0 otherwise;
7. Citizens = an explanatory variable standing for the importance of collaboration with users, consumers and citizens to create innovation. This dichotomous variable is set at 1 if the importance of the collaboration is high and at 0 otherwise;
8. Financial_institutions = an explanatory variable standing for the importance of collaboration with private financial institution to finance innovation. This dichotomous variable is set at 1 if the importance of the collaboration is high and at 0 otherwise;
9. Public_funding = an explanatory variable standing for the importance of collaboration with public funding to finance innovation. This dichotomous variable is set at 1 if the importance of the collaboration is high and at 0 otherwise.

The value of variables was determined using a questionnaire for 4215 entrepreneurs. The questionnaire is carried out using the Computer-Assisted Telephone Interviewing (CATI) system. The questionnaire comprised of questions on how intensively different actors are involved in innovation activities of the firms. The value of ROI was determined using Datastream (Thomson Reuters) databases and annual reports.

Based on the predetermined category reflected in the dependent variable Y (basis) and the explanatory variables $X = (X_1, X_2,\ldots,X_s,\ldots,X_p)$, the set of 4215 firms constituting our sample was progressively split into smaller and smaller partitions with increasing internal homogeneity in terms of the dependent variable Y.

At this and at each subsequent step, the best separation was obtained by using an optimality rule, i.e. by maximizing the homogeneity of Y within the subsystems and the heterogeneity of Y between the subsystems. More precisely, the authors generated all possible segmentations for each explanatory variable (Y) and picked the variable that produced the most homogeneous subset.

The reason why the segmentation process was performed using the CART (Classification And Regression Tree) process was that this algorithm is widely held to be particularly suited to empirical studies (Olshen et al. 1984; Campanella 2014) for a number of reasons:

1. firstly, because it offers the possibility of using both qualitative and quantitative dependent variables;
2. secondly, because the data sets can be split using combinations of quantitative and qualitative variables as predictors; the splitting criterion itself is defined by minimizing the impurity level of a node;
3. the algorithm can be used to prune large-size trees down to optimal dimensions.

With reference to the first point, it was necessary to use the CART algorithm because of the presence of a quantitative dependent variable (Razi and Athappilly, 2005). Based on the CART procedure, the database was split into ever more Y-homogeneous subsets. A terminal node is described as "pure" when the value of the dependent variable is the same for 100 % of the cases in the node.

Concerning the second point, the splits, i.e. the partitions in each subset, were obtained using binary queries, one for each of the subsets envisaged.

The ultimate purpose of the splitting process is to obtain child nodes that are less impure than the corresponding parent nodes. Impurity levels can be measured in a variety of different ways (Brida et al. 2009, 2010):

(a) in terms of deviance: $D_i = -2\sum_k n_{ik} \log(p_{ik})$;
(b) in terms of entropy: $\sum_k p_{ik} \log(p_{ik})$;
(c) and with reference to the Gini heterogeneity index: $\sum_{j=k} p_{ij} p_{ik} = 1 - \sum_k p_{ik}^2$

Using the classification tree technique, each set was split into smaller and smaller partitions until further partitioning would have resulted in overstepping one of the following limits: (a) minimum number of node units below the pre-fixed threshold; (b) minimum child node impurity decrease rate below the pre-fixed threshold.

To minimize the number of terminal nodes, the tree was constructed in line with the following specifications:

- minimum number of cases in parent node: 100;
- minimum number of cases in child node: 50.

Impurity was measured with reference to the Gini index, i.e. by fixing the minimum rate of change at 0.0001. Lastly, to ensure the construction of a, possibly, reliable tree, the partition was validated through a training sample including 60 % of the firms in the aggregate sample. The remaining 40 % were used to validate the model (test sample).

At this stage, it was possible to analyze and comment on the sub-tree with the minimum classification error rate.

The overall efficiency of the proposed model was evaluated by the Receiver Operating Characteristic Curve (ROC Curve).

4 Results and discussion

The model specifications and the results of our analysis are given in Table 1. The section on 'Specifications' provides information on the criteria for building the tree model, including the analysis variables, whereas the values reported in the section on 'Results'gives the number of aggregate nodes, number of terminal nodes and tree depth.

The authors initially identified nine independent variables. All variables were included in the model. Figure 1 shows the tree diagram of the training sample at the end of the pruning process. The optimal sub-tree was found to include nine variables (Fig. 1).

On analyzing the CART classification sub-tree of the training sample (Fig. 1), it is worth noting that:

1. the 'Citizens' variable splits the data into two nodes, node 1 and node 2. The data in node 1 show that 70.4 % of firms that attribute high importance to the collaboration with users, consumers and citizens to create their innovation have a high ROI; node 2

Table 1 Model summary

Specifications	
Growing method	CRT
Dependent variable	ROI
Independent variables	Public_funding, Research_institutions, Business_community, Other_firms, Citizens, Innovation_promoters, Innovation, Pub_authorities, Financial_institutions
Validation	Split sample
Maximum tree depth	5
Minimum cases in parent node	100
Minimum cases in child node	50
Results	
Independent variables included	Citizens, Research_institutions, Other_firms, Pub_authorities, Financial_institutions, Innovation, Business_community, Innovation_promoters, Public_funding
Number of nodes	15
Number of terminal nodes	8
Depth	4

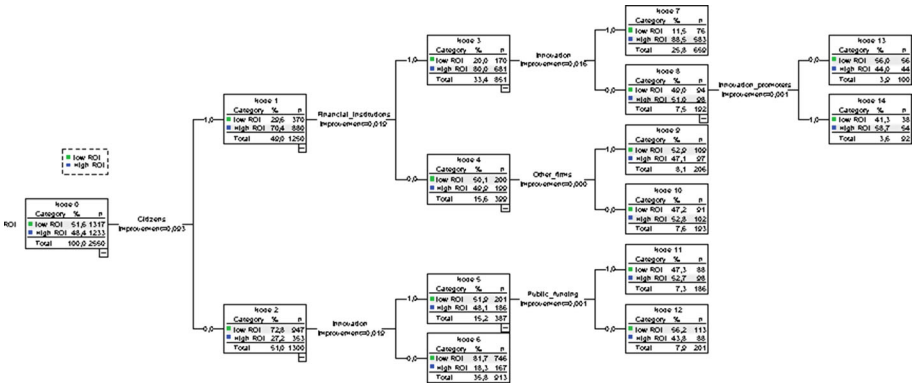

Fig. 1 Training sample

displays that 72.8 % of firms that attribute low importance to the collaboration with users, consumers and citizens to create their innovation have a low ROI;

2. the subsequent best classification variable for firms in node 1 is financial institutions (node 3). In node 3, 80.0 % of firms that attribute high importance to the collaboration with private financial institutions to finance innovation have a high ROI;
3. the subsequent best classification variable for firms offering in node 3 is innovation (node 7). In node 7, 88.5 % of firms offering product innovation have a high ROI;
4. firms with lower ROI than other firms are classified in node 2. These firms attribute low importance to the collaboration with users, consumers and citizens to create their

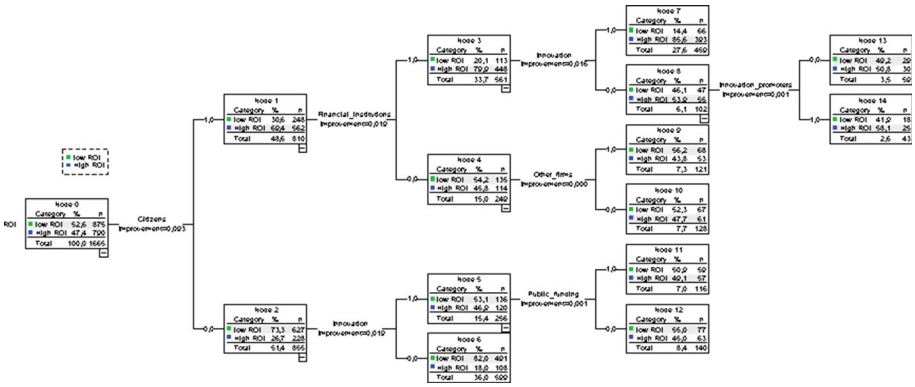

Fig. 2 Test sample

innovation. The subsequent improved classification for firms with a low ROI is node 6. Within node 6, 81.7 % of firms offering process innovation have a low ROI. Node 6 is a terminal node.

Parallels between the findings for the training sample (Fig. 1) and those of the test sample (Fig. 2) confirm the appropriateness of the model. The Risk and Classification Tables (Tabs 2 and 3) show that the classification error risk rate of the model is 27.0 % with a 0.009 standard error value and that the correct classification rate obtained for the training sample is 73.0 %.

Table 4 summarizes the gain for nodes and shows the number of nodes, the number of cases, the average profit and ROI (Return on Investment). Node 7 performs best, node 6 worst.

Table 5 refers to the target variable "High ROI" and it includes the gain in percentage, the response rate and the percentage index (lift) per node.

Figures 3 and 4 illustrate their relative node performance compared to the gain and the index. In Fig. 3, the gain chart increases rapidly towards 100 % then falls along the diagonal. This graph indicates that the model is quite reliable. It can be seen that a model that does not provide information follows the baseline of the diagonal.

In Fig. 4, the cumulative indexes plots tend to start above 100 % and gradually decrease until they reach 100 %. This graph shows that the model is reliable. Indeed, in a reliable model, the value of the index starts well above 100 %, and then rapidly drops to 100 %. For a model that does not provide information, the line will overlap the 100 % line for the whole chart.

The overall efficiency of the optimal tree was evaluated through the Receiver Operating Characteristic Curve using the predicted probability of the model (Table 6, Table 7; Fig. 5).

Table 2 Risk

Sample	Estimate	Std. error
Training	0.270	0.009
Test	0.279	0.011

Table 3 Classification

Sample	Observed	Predicted		
		Low ROI	High ROI	Percent correct (%)
Training	Low ROI	1024	293	77.8
	High ROI	396	837	67.9
	Overall percentage	55.7 %	44.3 %	73.0
Test	Low ROI	665	210	76.0
	High ROI	254	536	67.8
	Overall percentage	55.2 %	44.8 %	72.1

Growing method: CRT

Dependent variable: ROI

Table 4 Gain summary for nodes

Sample	Node	N	Percent	Profit	ROI (%)
Training	7	659	25.8	4.193	4.9
	14	92	3.6	2.109	3.5
	10	193	7.6	1.699	3.0
	11	186	7.3	1.688	3.0
	9	206	8.1	1.296	2.5
	13	100	3.9	1.080	2.2
	12	201	7.9	1.065	2.2
	6	913	35.8	−0.720	−2.6
Test	7	459	27.6	3.993	4.8
	14	43	2.6	2.070	3.4
	10	128	7.7	1.336	2.6
	11	116	7.0	1.440	2.7
	9	121	7.3	1.066	2.2
	13	59	3.5	1.559	2.9
	12	140	8.4	1.150	2.3
	6	599	36.0	−0.738	−2.7

The Area Under the Curve (AUC) in Fig. 5 is equal to 0.797. The best cut off is at 0.4989 (Youden's index = 0.449) (Table 7 and Table 8).

The empirical analysis highlighted that a high ROI for firms in scientific parks is expressed by the following features: (1) firms that attribute high importance to the collaboration with users, consumers and citizens to create their innovation; (2) firms that attribute high importance to the collaboration with private financial institutions to finance innovation; (3) firms offering product innovation.

In the model of the quadruple helix, citizens have a central role in addition to other factors (universities, other firms, public institutions). In our empirical model, the variable citizen classifies businesses with high ROI in the best way. This shows that in science parks

Table 5 Target category: High ROI—gain for nodes

Sample	Node	Node		Gain		Response (%)	Index (%)
		N	Percent	N	Percent		
Training	7	659	25.8	583	47.3	88.5	183.0
	14	92	3.6	54	4.4	58.7	121.4
	10	193	7.6	102	8.3	52.8	109.3
	11	186	7.3	98	7.9	52.7	109.0
	9	206	8.1	97	7.9	47.1	97.4
	13	100	3.9	44	3.6	44.0	91.0
	12	201	7.9	88	7.1	43.8	90.5
	6	913	35.8	167	13.5	18.3	37.8
Test	7	459	27.6	393	49.7	85.6	180.5
	14	43	2.6	25	3.2	58.1	122.5
	10	128	7.7	61	7.7	47.7	100.4
	11	116	7.0	57	7.2	49.1	103.6
	9	121	7.3	53	6.7	43.8	92.3
	13	59	3.5	30	3.8	50.8	107.2
	12	140	8.4	63	8.0	45.0	94.8
	6	599	36.0	108	13.7	18.0	38.0

Growing method: CRT

Dependent variable: ROI

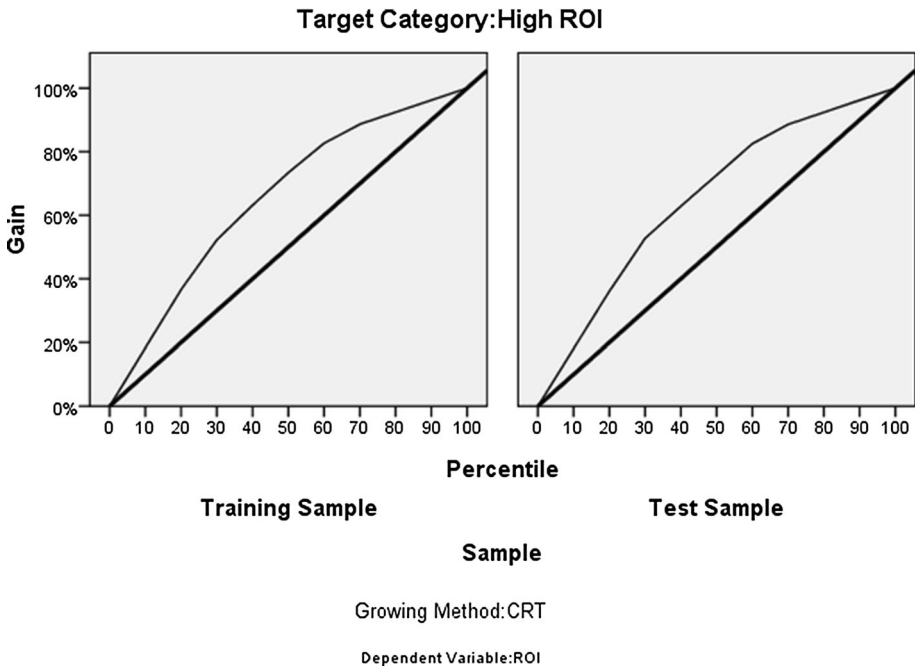

Fig. 3 Target category: High ROI—Node performance: gain

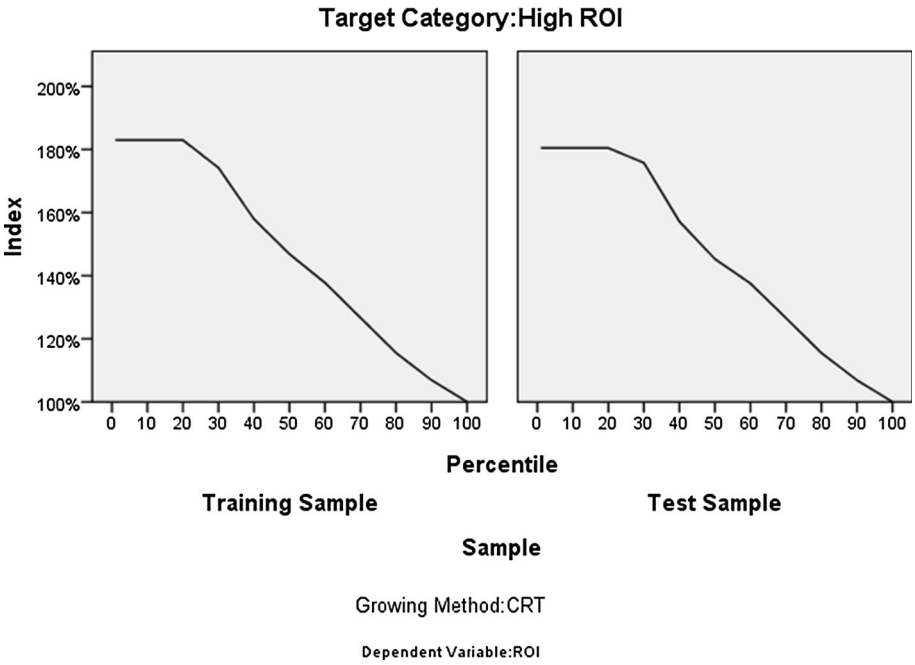

Fig. 4 Target category: High ROI—Node performance: index

Table 6 Case processing summary

ROI	Valid N (listwise)
Positive[a]	2023
Negative	2192

Larger values of the test result variable(s) indicate a stronger evidence for a positive actual state

[a] The positive actual state is High ROI

Table 7 Area under the curve (AUC)

Area	Std. error[a]	Asymptotic Sig.[b]	Asymptotic 95 % confidence interval	
			Lower bound	Upper bound
0.797	0.007	0.000	0.784	0.811

Predicted Probability for ROI = 1 has at least one link between the positive actual state group and the negative actual state group. Statistics may be biased

[a] Under the nonparametric assumption

[b] Null hypothesis: true area = 0.5

(where already there are universities, other businesses and public institutions) "the fourth helix" (citizen) has an important role in classifying the firms with the highest performance (Hypothesis H_1 is confirmed).

Moreover, the majority of firms that operate in Quadruple Helix model and that attribute high importance to the collaboration with private financial institutions in order to finance innovation have a high ROI (Hypothesis H_2 is confirmed).

Fig. 5 ROC curve

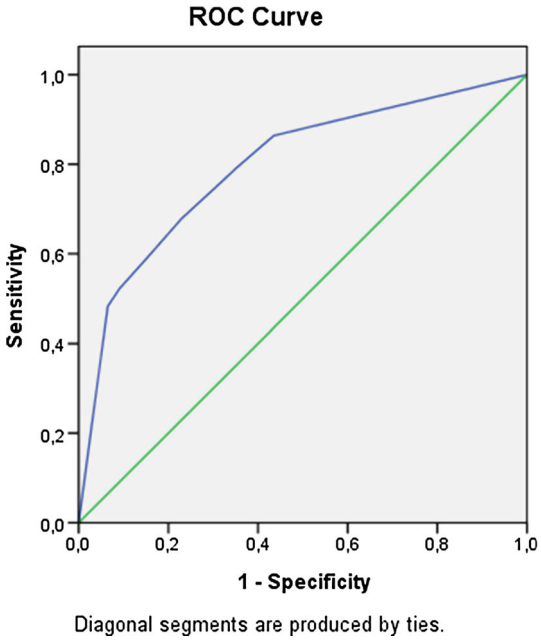

Table 8 Coordinates of the curve

Positive if greater than or equal to[a]	Sensitivity	1—specificity
0.0000	1.000	1.000
0.3104	0.864	0.436
0.4389	0.789	0.349
0.4554	0.753	0.310
0.4989	0.679	0.229
0.5277	0.602	0.162
0.5577	0.522	0.090
0.7358	0.482	0.065
1.0000	0.000	0.000

Predicted Probability for ROI = 1 has at least one link between the positive actual state group and the negative actual state group

[a] The smallest cut-off value is the minimum observed test value minus 1, and the largest cut-off value is the maximum observed test value plus 1. All the other cut-off values are the averages of two consecutive observed test values

In addition, firms with high economic performance in the model of the quadruple helix generate product innovation.

5 Conclusions, implications for practice and further research

An important aspect to be considered is that this approach involves a type of environmental "hyper-determinism" that overshadows the importance of individual action, decision-making processes, social relationships and power, while conflicts and disagreements within

an organization and between organisations tend to become less important, analytically. What emerges, for the purpose of analysis in terms of the Quadruple Helix model, is an additional stream of research. According to this theory, organizations that progressively put in place different sets of rules and regulations tend to bind themselves within an increasingly solid framework of legitimisation, and this encourages investment, profitability and performance.

The topics under discussion are inseparable from the more general problem of recovering efficiency, an aspect that must be resolved if the economic and production system is to join the framework of global competition, as part of the process of integration promoted through the Quadruple Helix model. It, therefore, becomes critical to create the conditions under which capital, as a scarce resource, can be allocated efficiently. An objective on this kind can be achieved by acting on levers that are, basically, linked to mobility of capital, which involves all institutional sectors, from private investors to financial intermediaries (Della Peruta et al., 2014). The issues that need addressing go from matters connected to the financial circuit—which is responsible for the transfer of capital—to those relating to contextual conditions that make the transfer and use of capital either easier or more difficult. The result is close interaction among all players operating in the sector and, in particular, among suppliers of technology and users. This, in turn, produces effective project integration and personalization that precisely targets specific technical requirements. The rapid spreading of new technologies combined with highly efficient technical and organisational solutions is one very specific aspect of an economic system in which the massive, sweeping percolation of innovation can take place. On the other side, it is difficult to evaluate such an event from a quantitative point of view, as there is no systematic empirical evidence to back up any analysis. For example, it is impossible to distinguish between firms that use their entrepreneurial and relational capacities to create new wealth and firms that are, instead, burdened with non-core end objectives that are useless in terms of optimizing performance and return on capital. Mobility of capital becomes important because it can highlight the spreading of financial culture and progressively more mature management behaviour. Restructuring assets, reallocating resources efficiently and making informed decisions regarding collaborations can all contribute towards improving the way in which firms are managed. As a final point, however, there is the need for incentives and input from the outside world, if these aspects are to be fully implemented.

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DICHIARAZIONE SOSTITUTIVA DI CERTIFICAZIONE
(Art. 46 D.P.R. n. 445 del 28.12.2000)

DICHIARAZIONE SOSTITUTIVA DELL'ATTO DI NOTORIETA'
(Art. 47 D.P.R. n. 445 del 28.12.2000)

Io sottoscritto STEFANO BRESCIANI nato a Torino il 22 gennaio 1975 e residente a Torino alla via Fratelli Carando 25, in qualità di coautore dell'articolo Campanella, F., Della Peruta, M. R., Bresciani, S., Dezi, L. (2016), Quadruple Helix and firms' performance: an empirical verification in Europe. The Journal of Technology Transfer, pp. 1-18, consapevole della responsabilità cui può andare incontro in caso di dichiarazione mendace o di esibizione di atto falso o contenente dati non più rispondenti a verità nonché delle sanzioni penali richiamate dall'articolo 76 del D.P.R. n. 445/2000, per le ipotesi di falsità in atti e dichiarazioni mendaci;

- ai sensi degli artt. 46/47 del D.P.R. n. 445 del 28.12.2000;

DICHIARO

che seppur frutto di un lavoro congiunto è a me attribuibile il paragrafo "Results and discussion".

Torino, 8 settembre 2016

(1) ***il dichiarante deve sottoscrivere la dichiarazione e allegare la copia fotostatica (fronte-retro) di un proprio documento di riconoscimento in corso di validità***

VALEVOLE FINO AL 22/01/2027

AX5830005

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COMUNE DI TORINO

CARTA D'IDENTITA'

N° AX5830005

DI

BRESCIANI STEFANO

Cognome BRESCIANI

Nome STEFANO

nato il 22/01/1975

(atto n. 00171 P S 31A 1975)

a TORINO (TO)

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IL SINDACO

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