# Factors Enhancing the Effectiveness of Cooperative Technological Innovation Networks

Joel Weisz[1]
José Manoel Carvalho de Mello[2]

## Abstract

This text examines the use of cooperative technological innovation networks in the Brazilian Oil and Gas exploration and Exploitation Industry (O&G) and seeks to determine factors of success in this endeavor, and obstacles to its effectiveness. The article studies the management of cooperative technological innovation networks, and the advantages and difficulties in resorting to them. The authors indicate the most relevant features of cooperative technological innovation networks and list factors that motivate participants into joining them. The text studies the concept of social capital as a variable contributing to the effectiveness of networks. This article concludes by indicating some final comments and recommendations that could improve the efficiency and effectiveness of the cooperative technological innovation networks, by adding to social capital through intensified interpersonal, mostly informal contacts between the different organizations that collaborate in the network.

## Key-words:

Networking; social capital; technology transfer; funding; industry-university cooperation, O&G.

## Sumário

Este texto examina o recurso a redes cooperativas de inovação tecnológica no setor brasileiro de exploração e produção de petróleo e gás, buscando determinar fatores de sucesso, nesse esforço, bem como obstáculos a sua eficácia. O artigo estuda a gestão de redes cooperativas de inovação tecnológica, além das vantagens e desvantagens oferecidas pelo recurso às mesmas. Os autores mostram as características mais relevantes de redes e os fatores que motivam os participantes a se engajarem nas mesmas. O texto estuda o conceito de capital social como uma variável que contribui para que as redes apresentem resultados favoráveis. Para concluir, o artigo oferece alguns comentários finais e recomendações visando melhorar a eficiência e a eficácia de redes cooperativas de inovação tecnológica pelo fortalecimento do capital social por meio de contatos interpessoais, de modo geral informais, entre as diversas entidades que colaboram na rede.

## Palavras-chave:

Redes; capital social; transferência de tecnologia; financiamento; universidade-empresa, O&G.

[1] Doctoral student of the Graduate Industrial Engineering Program at Universidade Federal Fluminense (UFF), Niterói, Brazil.

[2] D.Sc. Visiting Professor of the Graduate Industrial Engineering Program at Universidade Federal Fluminense (UFF), Niterói, Brazil.

## 1. Introduction

This article expands on the results of a previous investigation carried out with the participation of the authors, to diagnose inefficiencies and find possible improvements in the management of cooperative technological innovation networks (CTIN) that operate within academic institutions and are sponsored by Brazilian Oil and Gas Exploration and Exploitation Industry (O&G) aimed at developing technologies with a medium and long range horizon. The corporation resorts to in-house research and development (R&D) to meet its needs for immediate results.

The objective of this article is to highlight factors that may respond for a less than satisfactory performance in terms of technological innovation output from cooperative networks. Additionally, this text aims at indicating measures that may ensure the effectiveness of this type of organizational arrangement, especially when it involves big corporations resorting to academia as a source of knowledge for their technological needs. In particular, social capital is examined as a relevant variable.

Basically, this article identifies an aspect that has been overlooked in the Brazilian O&G: behavioral and attitudinal factors that affect the network performance. The text describes a preceding study that was the outset for working out the present article. In the sequence, an item describes the problems identified in the previous study and how the present article arrived at the proposed solutions. The following item describes Cooperative Technological Innovation Networks (CTIN) and how they have been treated in literature. In the sequence, the concept of social capital is used in connection with the management of CTIN. The last item presents the conclusions at which the authors arrived.

This text draws on the results of the interviews and on the observations that resulted in the former study, to further expand on the issue of extracting optimal results from CTIN. For this purpose, literature was consulted, especially on networking for technological innovation and on social capital. For the stated objective it was necessary to define optimality in the case of the networks. The question to be answered was finding where lie the reasons for unsatisfactory innovation results from the networks and how to overcome those reasons. This article studies the function and the role of social capital as a variable for the performance of CTIN, their position in the R&D activities and their treatment in literature.

## 2. Technology in the brazilian oil and gas exploration and exploitation industry (O&G)

Opportunities have opened in Brazil, since 1997, for technological innovation in O&G. For one, the technological challenges faced by the Brazilian O&G are unique for ultra-deep water oil or for exploring and exploiting the pre-salt deposits, found off the Brazilian coast. In addition to the gains by both industry and universities, one further expected outcome is the rise of a regional system of innovation for the oil and gas exploration and exploitation industry (O&G) comprising also the services and goods O&G supply chain, which may at some point become a potential provider for the O&G industry elsewhere, as foreseen in the Technological Tendencies study (Neves et al, 2002). An increased competition among companies from various origins and with diverse strategies would strengthen a local

supplier industry. The recent presence of several O&G operators favors new business opportunities for supplier companies. This is expected to promote a learning process among those firms to operate in a more competitive business environment, “bearing in mind that, similarly to the case of global industries, there is a threat that incoming firms reproduce, in the Brazilian market, their global supply scheme, thus sidelining native industry” (Neves et al, 2002). The 1997 O&G law (Law 9478/1997), upon opening the industry to newcomers, also determined the creation of ANP, the National Oil and Gas Agency, and ensuing legal documents that regulate investment by O&G operators in R&D as a partnership with universities and research centers in order to promote local industry. Cooperative Technological Innovation Networks (CTIN) were conceived as a means to that end.

Furthermore, the legal requirement and incentives, for companies that are granted oil and gas exploration and exploitation concessions, to invest in technology can be viewed as opportunities rather than as a burden for those organizations. The fact that the technological challenges are, to some extent, unique for the Brazilian oil and gas deposits, in addition to the amount of financial resources made available for technological development, it could be seen as an opportunity to build up a critical mass of expertise on those issues. Such a perception together with government incentives or requirements may be the driving force that induces several O&G supply chain companies to invest in R&D facilities in the Technological Park at the UFRJ campus.

The O&G Corporation that underwent the previous investigation has significantly increased the amounts invested in R&D; especially R&D carried out in the form of cooperative technological innovation networks also called thematic networks. In this arrangement, the O&G Corporation sponsors R&D projects carried out by a group of academic institutions. Each of those institutions is expected to be in charge of particular pieces of a project. The funding policies that require the investment on technology by the Corporation became more systematic and the amounts invested on technology greatly increased since 1998 for three basic reasons:

- The first reason was that exploring and exploiting oil and gas from deep-water offshore drilling sites, in addition to other demands brought about a set of technological challenges that had to be overcome. Especially Petrobras, the Brazilian state-owned oil and gas exploration and exploitation (O&G) company and thus the biggest oil producer in the country defined its strategy as striving to be on control of its needed technology. Petrobras defined three key axes as its technology drivers (Fraga, C. T. C., Presentation):
    - Expanding limits, which involves the following technological challenges:
        - New exploratory frontiers;
        - Enhanced Oil Recovery (EOR): techniques for increasing the amount of crude oil that can be extracted from an oil field
        - Ultra-deep water
        - Pre-salt
        - Petrochemicals and middle distillates maximization
        - Logistics

    - Changing the mix, encompassing the following technological challenges:
        - Biofuels
        - Other renewables
    - Sustainability, with the following technological challenges:
        - $CO_2$ management
        - Water reuse
        - Energy efficiency
- A second reason was that with the end in 1997 of the legal O&G monopoly held by Petrobras, new public policies determined that a portion of the income generated for any corporation from the O&G exploitation be invested on R&D related to oil and gas technology. Half of that investment has to be made in academic institutions (Law 9478/1997, and ensuing legal documents);
- Finally, another reason was the fact that the money available for R&D greatly increased due to the higher oil output in Brazil, on top of which oil prices soared since 1997. This resulted in higher income generated by O&G and therefore bigger amounts corresponding to the portion allotted to R&D.

As a result of such an increased funding for R&D projects, some research groups in Brazilian universities were overwhelmed, and had difficulties to absorb those funds efficiently. In the initial stages of this cooperation between O&G industry and academic institutions, most of the funding went to R&D infra-structure and into developing human resources, in order to provide the academic side of the cooperation with conditions to contribute. Most of the O&G money invested in Brazilian universities and research centers goes to R&D activities performed by cooperative technological innovation networks. In those networks, different institutions and the sponsoring company are expected to engage in the development of technology that fits a company interest. Therefore, a study had been undertaken for finding ways to improve the effectiveness of that effort.

## 3. Improving managenment of O&G Cooperative Technological Innovation Networks (CTIN). Recommendations made in the previous study

**Methodology:**

The starting point for this article was a condensation from the interviews that had been held in the preceding study with participants in cooperative technological innovation networks from both academia and the O&G Corporation. Those interviews covered a representative sample of the stakeholders, and were meant to evaluate how the networking was managed. They consisted basically of personal interviews. The written questions had been submitted prior to the interview, and the aim of the interviews was not obtaining statistical or quantitative data, but rather to extract the participants' feeling and recommendations. Therefore, in addition to the list of questions, conversation was also left to flow spontaneously and notes were written down by the interviewers. Opinions were grouped by themes, of which this article focuses on the issue of social capital.

**Problem:**

The main drawback of the cooperative networks studied by the authors is the perception by most people involved that the technological results of the efforts applied and of the invested funds have a proportionally low repercussion on the sponsoring O&G company if weighed against the effort and money spent. There are multiple causes: one of them, as found out upon interviewing the engaged researchers in the universities, seemed to be the rather low reciprocal commitment. Nevertheless, generalizations must be done with care, since the networks comprise a heterogeneous set of projects and people. The interviews with researchers in universities reveal that the sponsoring company is seen in the academic environment as a mere source of funding that supports R&D activities, and not as a project partner, whereas for the sponsoring company, in many cases it means the sheer fulfillment of a legal requirement (Law 9478/1997, and ensuing legal documents).

Researchers in the universities often complain that there is little exchange of ideas and information after the initial agreement is established, and they receive little feedback after submitting their final report. They contend that their counterparts in the Corporation are absorbed by more pressing needs and leave attention to long range projects for a second opportunity. On the other hand, the corporation complains that the researchers' participation in a cooperative network is not always part of their priorities as it does not necessarily add to their academic record. Therefore, both sides have expressed a feeling that the amount of money and effort invested in the cooperative technological innovation networks has not resulted in the corresponding gains for O&G.

Another complaint voiced by some university researchers is that the corporation often views them as additional labor rendering technical services, rather than as partners in developing opportunities or in solving technological problems. Furthermore, due to the perception of the networks by the corporate R&D personnel as a mere legal requirement, bureaucratic requirements became central in their management. This has become a burden for the corporate R&D people who have to spend their energy and attention in filling reports rather than in increasing the exchange of technological information. Partners in academia, in addition to the bureaucratic burden, resent the fact that, as a consequence, their informal contact with the corporate staff is quite scarce.

**Improving the performance of CTIN in O&G:**

This text elaborates on the hypothesis that the reason for a less than satisfactory performance of the cooperative research networks does not lie in wrong technical choices, but rather on issues related to behavior or attitude.

## 4. Cooperative Technological Innovation Networks (CTIN):

As mentioned above, much of the joint effort between industry and universities to develop technology for O&G has been carried out in the form of CTIN. They have also been called Thematic Networks in O&G, to reflect the fact that they are not conceived to work on an academic discipline but rather on technological problems or solutions.

In the last two decades, an increasing number of research and education projects have been undertaken on cooperative terms, in which different institutions assume distinct tasks aiming at a given result. Much has been written on cooperative technological innovation networks (CTIN) or cooperative research networks and yet it is a relatively new experience and there is room for a better understanding of their functioning. Many different forms of networking or cooperative means of doing business have emerged and, as pointed out by Porter, "Competition will be among clusters of related business units rather than among individual business units" (Porter, 1985, p. 364). Moreover, "firms have become more specialized and thus increasingly focus on their core competencies. In consequence, even the largest and more technologically self-sufficient organizations require knowledge outside of their fields and therefore rely more than ever on interactions with various actors." (Shin, J., and Park, Y., 2010)

"Literature on innovation indicates that over the last two decades, there has been a systematic and fundamental change in the way firms undertake innovation activities. In particular there has been a tremendous growth in the use of external networks by firms of all sizes." (Zeng, S. X., et al, 2010, p. 182). The idea of open innovation (Chesbrough, 2003) is recognition that the future of research will transcend national boundaries and corporate walls. This article is not intent in making a review of the literature on networking. The concept of networks is quite flexible. A network may be defined as a loosely coupled organization consisting of different groups linked to each other by various kinds of ties. Networks are typically "non-physical" centers which count on advanced communication systems, to bring together participants with complementary qualifications. (Weisz, J, and Roco, M. C., 1996).

As the cost of technological innovation gets increasingly higher, one stated purpose of networking would be sharing costs and efforts. Nevertheless, strategic considerations play an important role, even if they may be less visible than economic and financial factors. One important motivator for joining a network is profiting from complementary knowledge, expertise or capabilities. "A bundling of competencies can be important in order to stay competitive" (Hussinger, 2010). Furthermore, a network is composed of people or institutions with different backgrounds and interests, thus representing a cross section of the business environment. Therefore, a privileged observation post is granted to the participant of a network for monitoring the universe in which his or her organization thrives. Furthermore, a network provides the possibility to share the risks of investing in R&D, the cross-fertilization that results from the collaboration of people and institutions of different capabilities, or services, in addition to increasing the speed to market, a variable that has gained importance (Clausen, T., and Korneliussen, T., 2012). Chen points to the importance of studying speed-to-market as a function of organizational arrangements (Chen et al, 2010). The presence of different participants in cooperative technological innovation networks, especially companies pressing for quicker returns on their investment, suggests that networks are a kind of organization that favors increased speed-to-marked.

Networks are diverse in their nature, in their format, in the way they operate, in their mission, or in their fields of specialization. In addition, their evolution varies. Some are transient, or come into being for one specific purpose, whereas others expand and take up new tasks. Various types of networks have been described, some of them under different names, such as the '*Collaboratories*' of IBM (Hamm, S., 2009) that join efforts of IBM researchers with those of researchers of academic and

other institutions. Arthur D. Little calls its model '*co-innovation*' (Odenthal, S., et al. 2004). There are the German '*Clusters of Excellence*', as a result of the 2005 Initiative of Excellence (Deutsche Forschungsgemeinschaft, 2010) aimed at promoting cooperation among institutions within Germany and internationally and many others.

Furthermore, although some Cooperative Technological Innovation Networks may renew themselves and engage in new projects, as mentioned above, they are usually expected to have a limited life span. In other words, they are not expected to outlive their objective or to live beyond the reason for them having come into existence. The Riemer & Klein model (Riemer and Klein, 2006) presents the lifecycle of networks composed of six stages from their inception until they either disband or transform themselves, namely: beginning, setting up, implementation, stabilizing, and either transforming for a new mission or dispersing.

Since, as defined above, Cooperative Research Networks are neither "physical", nor legal or hierarchical organizations, their functioning are not based on either authority or on client-supplier relationship. Cooperative technological innovation networks are basically a social phenomenon. Participation in networks tends to be voluntary. Networks comprise social relationships. A good performance for this type of organizational arrangement stems primarily from attitudes such as familiarity, trust, goodwill, commitment, cohesiveness, and identification with common purposes. Those attributes may be grouped under the concept of *social capital*.

## 5. **Social capital**:

Social Capital is a concept from the social sciences. "Social capital … refers to relations among persons that facilitate action, embodied in the collective norms of communities that extend beyond immediate family members and the trustworthiness of the social environment on which obligations and expectations depend." (Jackman, R. W., 2001, p. 14216). Bourdieu defines social capital as "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition." (Bourdieu, P. 1986)

"Social capital can be defined as the goodwill or benefit available to actors within a social network" (Adler and Kwon, 2002). Some articles refer to *Organizational Trust* as a factor leading to individual willingness to use and share information and ideas (DAVENPORT; PRUSAK, 1998; EMPSON, 2001; HENDRICKS, 1999; HINDS; PFEFFER, 2003; HUSTED; MICHAILOVA, 2002; McDERMOTT; O.'DELL, 2001). Organizational Trust carries some of the ideas embedded in the concept of Social Capital. By applying a two-dimensional scale, McAllister, 1995, measured organizational trust in terms of affection and in terms of knowledge and concluded that trust based on affection induces the willingness to share tacit knowledge whereas organizational trust based on knowledge influences the use of knowledge. Those authors, however, focus their attention mainly on the use and sharing of knowledge among people and organizations, which is one aspect leading to success in cooperative technological innovation networks (CTIN). Another author writing on attitudes and their impact on technological innovation was Christensen (Christensen, 2003). He breaks down the capacity for disruptive innovation of an organization into three factors, namely: resources, processes and

values, which he gathers under the RPV acronym. The third of those factors, values, reflects the organizational culture, the written and tacit rules that govern relations within an organization. That latter factor overlaps with the concept of social capital.

Social capital in a cooperative technological innovation network involves emotional endeavor such as trust, cohesion, convergence toward common objectives, and engagement. “Group cohesiveness has a positive and significant effect on team performance” (Huang, Chi-Cheng, 2009). Shin and Park call attention to an intrinsic conflict between two opposing demands within larger networks: “As a network expands, the chances of interaction and innovation will increase because of increased knowledge flow, but at the same time, the level of interaction and innovation might not match our expectations. This is mainly because actors interact with others mostly in their own vicinity, and thus rarely interact with distant actors. Moreover, insufficient social capital makes coordination costs increase and new interaction difficult”. “A large human network typically suffers a shortage of social capital, such as shared vision, explicit norms, and limited channels among other things” (Shin, J. and Park, Y., 2010).

The accessed texts point to a strong relationship between social capital and network performance. “A review of the literature on social capital suggests two major themes: (1) how to connect an actor with a network in possession of specific resources; (2) how an actor uses his network structure to construct advantageous social capital” (Huang, Hao_Chen, et al, 2012). Social capital is an important resource to make a cooperative innovation network be effective.

Rothschild and Darr (2005) mention “informal networks”, meaning informal ties among social actors in universities, incubators and industry. They assert that “informal networks play a central role in the development of emergent technology”. Their idea of informal networks refers to social relationships built over lifelong activities. As mentioned in the previous item, cooperative technological innovation networks are loosely coupled organizations, in which informal ties are more important than formal connections. One aspect that Rothschild and Darr point out is an underlying misconceived notion of a linear model ruling the relation between university and industry. According to this misconception, “basic research is conducted in universities, then transformed into applied research and production techniques in incubators and is later introduced into industry”. Contrary to this assumption, those authors present a cyclical model of innovation management, in which knowledge flow back and forth via social networks. Evidently, such flow, given its informal nature, requires social capital in order to happen. This assertion strengthens the idea that both universities and O&G companies participating in CTIN would draw better results if they viewed themselves as partners in joint R&D projects rather than as on a client – supplier relationship.

Literature consulted by the authors confirms the importance of social capital for developing technological innovation in cooperative networks. It provides a theoretical explanation for the issues studied empirically in the preceding study on O&G cooperative technological innovation networks. It confirms that the networks could have their performance optimized by investing in social capital.

Two questions remain: First, what is optimality regarding the performance of cooperative technological innovation networks. Second, what does investing in social capital mean in the case of networks.

"Optimality is defined as the maximization of overall benefit" to both the corporate sponsor of the R&D effort and the academic participants. Maximum proportion of R&D projects resulting in solutions for industrial operations represents a gain for the corporation as well as for the researchers in academia. "Social capital theory provides theoretical support to the existence of an optimal network" (Shin, J. and Park, Y., 2010). An optimal performance would be a flow of knowledge within a network that would enhance technology transfer and commercialization with improved speed-to-market.

There is a rather vast literature on the impact on University – Industry collaboration and its impact on academic performance. A recent study in Brazil (Alvarez, R.B.P. et al, 2013) indicates that there is no evidence of a strong positive correlation between the intensity of University – Industry interaction and scientific output. That same study cites other articles (Lowe, R. A., and Gonzalez-Brambila, C., 2007) that suggest that more productive researchers are prone to interact with business. Literature suggests that an entrepreneurial university would not have negative impacts on academic research. In addition to the importance of investing in social capital for improving technology transfer, the networks may shoulder the new role of providing social capital that enables entrepreneurship among its participants. In this endeavor, it is appropriate to make the academic participants of the network become partners in the innovation and expose them to the industry challenges, rather than having them remain as mere suppliers of knowledge.

## 6. The concept of social capital applied to O&G CTIN

The concept of a cooperative networks elicits the idea of a joint effort rather than the delivery of a product from one participant to the next one. Furthermore, since networks are neither organizations with strong hierarchical relationships nor one in which participants' commitment derives from piecemeal payments in retribution for a product delivery, one may conclude that positive results are the outcome of participants' attitude. Favorable attitude can be achieved with the proper approach to networking, that goes beyond an initial written agreement, a final report and funding with part of the oil and gas exploitation income. This idea suggests that a more intense engagement between the O&G company and its academic partners would enhance the chances of favorable results.

In this respect, one important conclusion (Hansson, F. et al. 2005) is that the aim is "not to transfer certain research results with particular commercial potential from the university to the regional economy, rather it is to make the university itself an active player in the regional economy, in other words, to place the university 'at the heart of the regional economy'". Likewise in the Brazilian experience and translating the above assertion to industry terms, universities in cooperative technological innovation networks should not be expected to become technology suppliers for an O&G company. They should be seen as partners of the industry in joint technological innovation projects.

For the O&G industry, investing in social capital within a cooperative technological innovation network means promoting or intensifying chances for informal contacts among all participants in the network, in addition to the existing formal interaction in order to improve its performance. The efficiency and effectiveness of cooperative technological innovation networks could improve by

adding to social capital through intensified interpersonal, mostly informal contacts among different organizations that collaborate in the network. Positive mindsets from the participants, such as familiarity, trust, cohesion, acceptance, and compliance with purposes can be obtained by means of informal relationships. Those relationships could be promoted by means of more frequent technical visits, meetings, seminars, and unscheduled gatherings, between O&G operators and academic partners, thus promoting familiarity among participants and the consequent alignment with common purposes, cohesion and trust among participants. Obviously, formal communication cannot be disregarded. However, O&G companies will also benefit from informal exchange of information in addition to formal communication. Therefore, investing in social capital will reflect on improved network performance. This conclusion corroborates the findings of the preceding study on O&G networks.

## 7. Conclusions

Therefore O&G companies would make a better use of the money invested in cooperative technological innovation networks if, rather than viewing it as either the mere fulfillment of a legal requirement or as the payment for a service rendered in the form of technology solutions, they used it as an opportunity for a joint effort with their networking partners in developing technology for the medium and long term. Such approach implies on investing in social capital. Possibly the concepts of social capital applied to O&G as the result of an investigation carried out for an O&G company could apply to any other industry. Universities, in turn would profit from engaging in cooperative R&D with industry, not only as a result from additional inflow of funds, but also from having the application of R&D results as a milestone indicating its success. Whereas the solution of immediate technological needs may be met by the companies' own R&D facilities, medium and long range technological challenges can be the object of collaboration between industry and universities. As mentioned above (Hansson, F. et al. 2005), rather than looking upon the universities as suppliers of finished technology, O&G technology networks provide an opportunity for joint efforts between industry and academia toward achieving technological results. Investing in social capital will favor this kind of interaction

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