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KNOWLEDGE AND COMPETENCE MANAGEMENT IN PROJECT BASED ORGANIZATIONS- AN INTERNAL MARKET-BASED MODEL

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ABSTRACT

Recently, project-based organizations (PBOs) received increasing attention as emerging organizational forms, in which projects tend to become the primary business mechanism for coordinating all the main business functions of the firm.

The literature widely recognizes that these organizational structures face peculiar knowledge and competence management and organizational learning issues as well as the risk of internal strategic misalignment.

This thesis addresses these issues by adopting a market-based approach to exchange knowledge and competencies within the boundary of the firm. This kind of approach looks promising as it addresses specific ineffectiveness of the PBOs mainly connected to the presence of the project dimension within the organization, where knowledge and competencies risk to be stuck, against the interest of the organization as a whole. A market-based approach promises to address, among the others, the motivational issue, which is one of the main brakes on the development of effective knowledge and competence management systems, by providing the users with a transparent mechanism based on the law of supply and demand. This approach has received certain attention from the literature over time, but it is generally under-researched in the project management and knowledge management literature, as well.

This thesis aims to investigate this kind of approach in the context of large PBOs.

First, a systematic literature review on knowledge and competence management in project-based organizations was developed.

Second, based on the background of this study, I conducted some case studies in large PBOs in order to highlight the main knowledge and competence management issues currently faced by project-based organizations.

Third, on the basis of the needs and requirements in terms of internal knowledge and competence management emerged from the interviews, I developed the conceptual framework of a market-based internal knowledge and competence management system and, fourth, I submitted it to the respondents of the first round of interviews in order to collect feedback. The feedback was negative. Confronting managers and employees with a market-based approach to exchange knowledge and competencies internally has brought to light aspects of the organizational culture that are deeply averse to this idea. The cases shedding light on several critical aspects of model applicability mainly due to technical, organizational, managerial and cultural issues.

Fifth, an agent-based model of a knowledge market was designed and developed and the preliminary results of working simulations with different initial settings of selected parameters are presented in the thesis. The model is very general in nature and could be applied to describe both an internal corporate market and knowledge trading dynamics among firms in a knowledge ecosystem.

This approach represents an innovative way to address the management of knowledge and opens the way for many future developments.

The thesis is organized in five main parts: a systematic literature review on knowledge and competence management in PBOs, case studies and development of the knowledge market model, design and implementation of an agent-based model of a knowledge market and finally the analysis of data returned by the simulator.

Keywords- Knowledge management, competence management, project-based organizations, internal knowledge market

CHAPTER 1: KNOWLEDGE AND COMPETENCE MANAGEMENT IN PROJECT-BASED ORGANIZATIONS

1.1. Systematic Literature Review of Knowledge and Competence Management in PBOs- An Internal Market-Based Model

Nowadays, a company's success and finally its survival relate with its capability to create an advantage over its competitors in a highly competitive business environment. (Decker et al. 2009). Knowledge and competencies are survival tools in a dynamic and competitive business environment (Fong and Choi, 2009). Knowledge and competencies are survival tools in a dynamic and competitive business environment (Fong and Choi, 2009).

PBOs support combinative capabilities, knowledge integration where both specialization and integration of knowledge are emphasized (Lindkvist, 2005). Knowledge Management in a project context can be defined as the management activities required to source the knowledge asset, create the enabling environment, and manage the knowledge practices to result in an aligned set of project-based knowledge (Reich, et al., 2012). According to the literature, PBOs can be found in a number of industries such as electrical engineering (Söderlund & Tell, 2009, 2011b), telecommunications (Davies & Brady, 2000; Lindkvist, Söderlund, & Tell, 1998), defense (Johansson, Axelson, Enberg, & Tell, 2011), film and TV production (Cattani & Ferriani, 2008; DeFillippi & Arthur, 1998; Ebbers & Wijnberg, 2009; Baden-Fuller, Ferriani & Cattani, 2009; Manning & Sydow, 2011), construction (Hartmann and Doree, 2015; Bresnen, et al., 2004; Styhre, 2006; Winch, 2010), advertising (Grabher, 2002, 2004), consulting (Blindenbach & Van den Ende, 2006), information technologies, including software engineering, etc.

Several authors recognize PBO effectiveness as coping well with the emerging properties of extremely complex products and systems by responding to client needs in real-time due to their flexibility and focus. Nevertheless, they point out peculiar knowledge management (KM) and organizational learning issues (Pemsel et al., 2016; Whitley, 2006; Lundin et al., 2015) as well as strategic misalignment in PBO. In fact, it is generally recognized that PBOs struggle to integrate knowledge and structures when projects are viewed as ''singular ventures'' (Grabher, 2004) and that, taken individually, these typically do not reflect the organization's strategic intent (Thiry and Deguire, 2007).

Specifically, in these contexts, it seems that locating internal knowledge on a specialized topic and pursuing a centralized policy of knowledge resource (i.e. human experts) allocation, aimed at seizing emerging opportunities, is becoming a significant challenge. The larger and more segmented the company, the harder it is to find who knows what inside the organization and to match its people to its problems (Benbya and van Alstyne, 2011). PBO form is more effective than the functional form in integrating different types of knowledge, skill and learning within the project boundary, but it fails in finding the best knowledge resource allocation at the level of organization as a whole, with the consequent risk of losing development and growth opportunities. In order to discuss possible KM strategies used to face PBO weaknesses, particularly the problem of internal knowledge locating, mobilizing and integrating, we must first clarify what kind of knowledge resources are most relevant for PBOs. According to several scholars in most PBOs, a sustainable competitive advantage requires resources that are knowledge-based and intangible (Whitehill, 1997; Nonaka et al., 2000; Jugdev and Mathur, 2012).

We know that PBOs have difficulties in extracting, distributing and applying knowledge across both cultural and structural boundaries. Studies have argued for knowledge sharing in project-based organizations, but have focused to a large extent on the difficulties and complexity of sharing knowledge (Bosch-Sijtsema and Postma, 2009; Prencipe and Tell, 2001). The context of the practice of knowledge management (KM) in PBOs is complex and multifaceted. Project-based learning highlights the problems related to attempting to capture, share and diffuse knowledge and learning on the projects (Prencipe and Tell, 2001).

However, the purpose of this study is to review the literature on Knowledge and Competence Management in Project-based Organizations. We set the contextual limitation to contributions presenting research on their adoption and implementation, including antecedents and consequences. Therefore, the contribution of this literature review is to investigate the knowledge and competence management implementations and issues in PBOs. This analysis includes, what topics are investigated, and what the results obtained. Also, it sheds light on future studies.

The rest of this chapter is structured as follows: methodology, investigation framework, descriptive findings of selected papers and thematic findings, mapping the literature.

1.1.1. Literature review methodology

The present research aims to contribute to the existing knowledge on knowledge and competence management in project-based organizations by reviewing its literature, through a systematic review. Such a methodology is characterized as being a pragmatic, transparent, and reproducible manner of analyzing existing literature. The main goal of a systematic review is to identify, select, and critically appraise relevant research and to collect and analyze data from the studies that address a particular issue. Statistical methods (meta-analysis) may or may not be used to analyze and summarize the results of the included studies (Cochrane Collaboration, 2014). Previous researchers have argued that using such an approach for a literature review can ensure that the systematic error is limited, chance effects are reduced, and the legitimacy of data analysis is enhanced. A systematic review (Tranfield et al., 2002) involves five stages:

(1) Planning the review;

(2) Identifying and evaluating studies;

(3) Extracting and synthesizing data;

(4) Reporting descriptive and thematic findings; and

(5) Utilizing the findings in order to inform research and practice.

Stages (1), (2) and (3) are briefly presented in this paragraph; the descriptive and thematic findings obtained in stage (4) and the content of stage (5) are discussed in the following sections.
Stage (1), planning of the review, includes different phases: (a) the constitution of a panel of experts that will inform the process and assess the findings; (b) the mapping of the field of investigation in order to identify the bodies of literature relevant to the topic; and (c) the formalization of a review protocol that will enable other researchers to replicate the review.

For the present Systematic Review, in step (a) faculty members of the University of Genoa working in the field of knowledge management and practitioners from consultancy were selected as the review panel. Regarding step (b), knowledge and competence management field was defined with the help of the review panel and the following areas of investigation were identified:

Categorize of perspectives of studies;

1. Knowledge management perspective

KM, HRM, Strategy

2. Competence management perspective

Individual, Collective, Organisational

This map of the field had a critical role during the review process to identify those studies that were out of or within the scope of the topic being investigated. The review protocol developed in step (c) detailed how the literature review should be conducted by the research team. The protocol includes the different sources that were used to identify relevant studies, the intended search strategy, the specific criteria to include and exclude studies, the criteria to assess the quality of the studies selected, and any other information that would allow someone else to reproduce the review.

In the following subsections, we describe in more detail step (c) the review protocol, including the source selection, the search string identification, and the inclusion/exclusion and quality assessment criteria.

1.1.2. Review protocol

Source selection

For the purpose of the present Systematic Literature Review (SLR) only published peer-reviewed papers written in English were used as documents, excluding books and unpublished papers or reports. Database of the Web of Science (WoS) https://apps.webofknowledge.com" and Scopus http://scopus.com were the main sources for identifying studies on knowledge management in project-based organizations.

Search string

We developed the search string by specifying the main terms of the phenomena under investigation. A number of pilot searches were performed to refine the keywords in the search string using trial and error. We tried different combinations of words to catch the phenomenon of knowledge management in project-based organizations starting from its components. The main components of knowledge management are Knowledge processes and competence management. For this reason, we included in the query all components. As regards the rules, they are a priori defined and determine knowledge and competence in project-based organizations. For this reason, we included the terms project-based and project-led, specifying the organization.

We tested TS= (("knowledge" or "competenc*") and ("project-based" or "project-based" or "project led" or "project-led")) query on WOS and Scopus with all the restrictions specified in the source selection section, and obtained 338 papers that after the relevance check by the review panel (reading of titles and abstracts), reduced to 150 papers. Thus, we derived that papers dealing with knowledge, competence and project-based or project-led mostly use this exact combination of words.

As second trial we tested the query TS= (("knowledge" or "competenc*") and (("project organisation*" or "project organization*" or "project-intensive" or "project-intensive")) on WOS and Scopus. According to this query, we added 2 papers by the review panel (reading of titles and abstracts). At the end of this process, we obtained 97 papers after the relevance check by the review panel reading all papers.

Inclusion/exclusion and quality assessment criteria

For the selection of relevant studies, the research team used two different sets of criteria: one set of inclusion and exclusion criteria (Table 1); and another set of quality assessment criteria (based on methodology or research design, contribution to the theory or implication for practice, the generalizability of findings).

The basic inclusion criterion was to identify and select peer-reviewed studies related to knowledge management in project-based organizations for our knowledge market design.

We searched and included publications written in English from 2001 until 2017. This was the publication year of the oldest paper found with an automatic search on WoS and Scopus, our main sources.

We reviewed articles on knowledge and competence management in project-based organizations, design, and implementations of knowledge transfer intra-, inter-organizational projects.

- Knowledge transfer from intra-, inter-organizational projects (across projects) and body of knowledge of projects
- Reuse complex knowledge assets
- Knowledge-sharing mechanisms across projects to the wider organization
- The building of project competencies and competence dynamics in project-based firms
- Project-based organizing and HRM, by drawing on capability perspective on project-based organizations
- Team Composition of Project-based works and the different levels of competencies combined and coordinated in PBOs
- Learning and knowledge management processes within project teams
- The success or failure factors of knowledge management (KM) initiatives in project-based companies
- Project-based company's knowledge structure
- The codification and the personalization strategies for knowledge transfer

For each study, we performed a quality assessment based on four quality criteria.

QA1: What research has been conducted on knowledge and competence management in PBOs?

QA2: What research questions can be answered with the subject?

QA3: What theoretical frameworks and references have been applied to study the topic?

QA4: What research methods and approaches have been applied?

Inclusion	Excluding
Published peer-reviewed papers	Grey literature, e.g., technical reports, working papers, project deliverables, and Ph.D theses
Research related to Knowledge management in PBOs	Books, tutorials or poster publications, Conference Proceedings
Research within the scope set by the map of the field	Research that did not pass the quality assessment defined by the review panel
Theoretical and empirical research	Research which is out of the scope set by the map of the field (e.g. information technology, project management, the competence of project manager)
Academic and practitioners research	Publications whose text was not available

Table 1 Inclusion / exclusion criteria

1.1.3. Data Extraction

The information collected from each selected study was: reference details, methodology, (conceptual, qualitative or quantitative), industry, which refers either to the industry where the case study was developed in the case of empirical study, perspective, which could be any of the areas identified during the mapping the field exercise.

Once the search process has been carried out and the relevant studies have been selected, two separate analyses of the information obtained can be produced, namely: a descriptive and thematic analysis. The descriptive analysis helps to clarify the main characteristics of the field that are under investigation (methodologies used, perspectives, etc.). The thematic analysis consists of synthesizing the main outcomes extracted from the literature and its main purpose is to inform future research and practice.

1.1.4. The investigation framework of the review

We categorized the papers according to the perspective adopted. From a preliminary analysis of the papers three main perspectives emerge, which is also mentioned in the literature (see Loufrani-Fedida and Saglietto, 2016): knowledge management (KM), human resource management (HRM) and strategy. In addition, three main levels of investigation emerge for knowledge and competencies: individual, collective and organizational. According to the literature (Loufrani-Fedida and Saglietto, 2016), the three conceptual dimensions of knowledge and competence management in PBOs (i.e. the above-mentioned perspectives) should be investigated simultaneously considering the three levels of competencies in the firm, i.e. individual, collective and organizational. Thus, the investigation schema resulting from the above-mentioned perspectives and levels is adopted to examine the papers of the review (see Fig. 1)

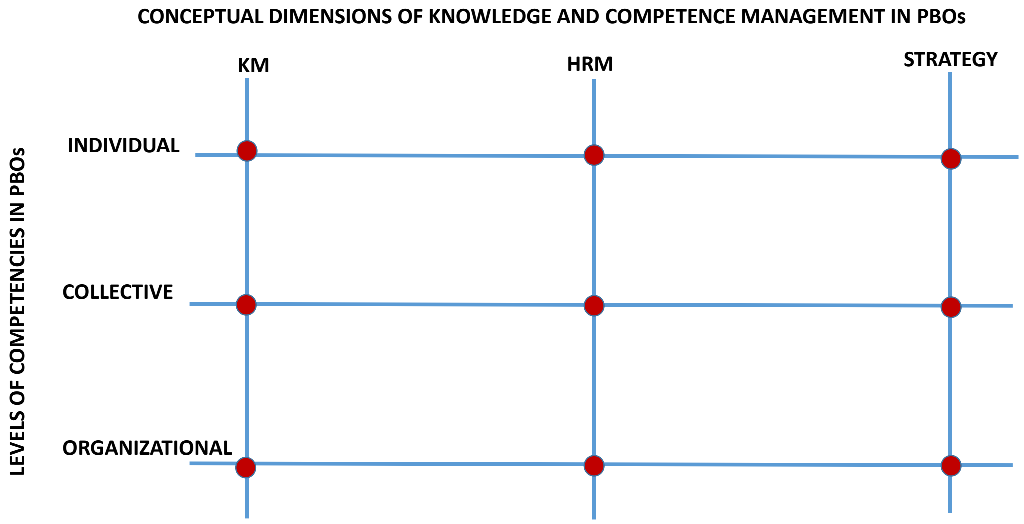

Figure 1 Conceptual Dimensions of Knowledge and Competence Management in PBOs

In the following, I will give some more details of the dimensions and the levels explored in the review, with specific reference to the case of PBOs.

Knowledge Management

The first dimension is Knowledge management (KM) that is the whole systematic process of achieving, organizing and communicating the knowledge of organizational members so that other members can make use of it improve their efficiency and effectiveness (Ajmal, et al., 2010; Alavi and Leidner, 2001). The aim of KM is to ensure that the right knowledge is available in the right forms to the right entities at the right times for the right costs. KM dimension focuses on optimizing the use of internal knowledge resources among projects. KM allows organizational learning and avoids the internal reinvention of the wheel. Several KM models do exist, articulated on several phases from the classical 4-phase SECI model by Nonaka and Takeuchi (1995) (see Figure1), including knowledge socialization, externalization, communication and internalization, to more complex models including more phases, such as locating and acquiring new knowledge and creating knowledge new to the group (see e.g. Andriani and Hall, 2002). Once key knowledge has been identified and codified in some way, a socialization effect occurs resulting in knowledge sharing. Knowledge resulting from this knowledge-sharing experience becomes externalized, resulting in an application of the knowledge. This knowledge is then combined with other knowledge that individuals possess, as well as internalized along with the individual's worldviews and value hierarchy. This should hopefully result in new knowledge being created, which then needs to be preserved as it becomes captured and the cycle begins again.

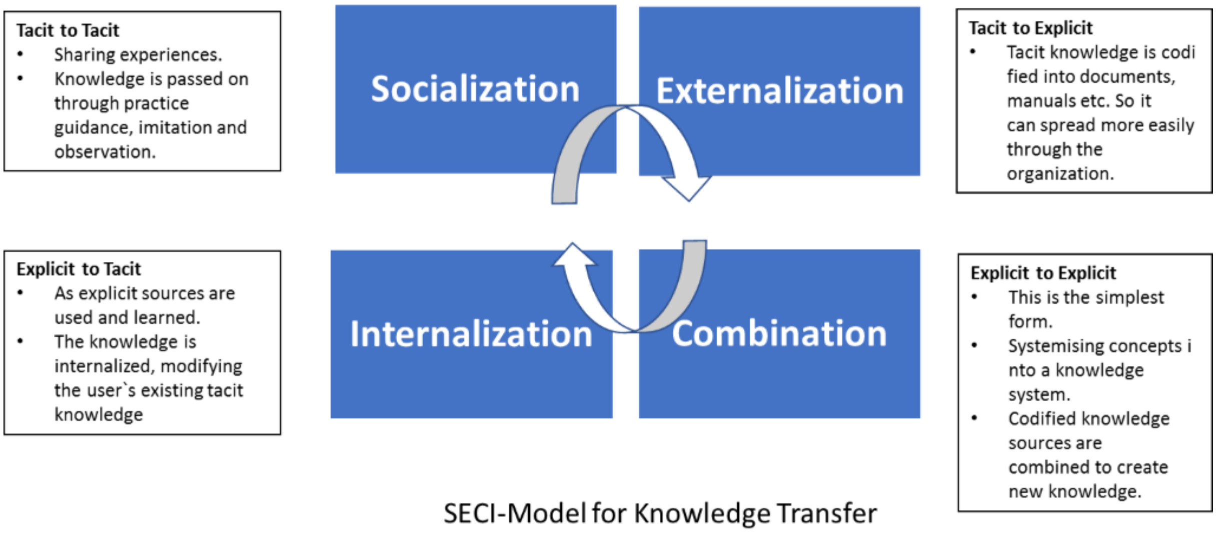

Figure 2 SECI-Model for Knowledge Transfer

In the context of project-based firms, Loufrani et al., (2014) define KM as one of the main dimensions of project management competence mechanisms and identify three main phases of KM: knowledge codification, socialization, and exploration learning. Knowledge codification helps make it usable and store it for future use. Codification of tacit and explicit knowledge helps in making the knowledge understandable and which can be used later. Furthermore, once codified, knowledge can be transferred through projects. Socialization is an important phase of KM. Knowledge is mainly carried by individuals and activated, evaluated and used in a setting where relationships play a key role. The ability to exploit such mechanisms for knowledge transfer is generally attracting attention as an essential success factor in project-based learning (S. S. Andersen and D. Vidar Hanstad, 2013).

KM in project-based organizations is also a complex task. This is because project teams often consist of people with diverse skills, working together for a limited time period; indeed, a project team often includes members who have never worked together previously and do not expect to work together again (Burns and Stalker, 1961). In these circumstances, effective KM is complex but essential. In PBO, there is a lack of mechanisms to capture, store and disseminate knowledge for organizational learning. After a project is finished, the constellation of people working together is dissolved, fragmenting the project knowledge. In contrast to permanent organizations, where departments and divisions act as knowledge silos, in PBOs, routines and organizational memory barely emerge (Loufrani-Fedida and Saglietto, 2016; Lindner and Wald, 2011; Prencipe and Tell, 2001; Kasvi et al., 2003). More precisely, for Prencipe and Tell (2001), organizations consistently fail to learn from projects, as attested by the tendency to “reinvent the wheel”, repeat mistakes, and fail to transfer lessons from one project to another. Project-based learning can be intended as a means to deal with the challenge of sustainable growth of learning capacity. In fact, it allows, developing learning capabilities that enable reasoning beyond the short term and knowledge creation and sharing beyond the individual or team. In the literature, project-based learning highlights the problems related to attempting to capture, share and diffuse knowledge and learning on the projects (Prencipe and Tell, 2001). Hartmann and Dore (2015) highlight the effectiveness of the sender-receiver approach and social learning to the learning between projects. Since projects seem to form distinctive entities of temporary nature within organizational boundaries, which make the transfer of lessons learned between them necessary and plausible, an approach of learning between projects should consider the individual, social and organizational context through which projects are formed and which is constantly produced by project activities. Knowledge transfer across projects can positively influence the capabilities of projects and the project performance of the projects involved in the transfer (R. E. Landaeta, 2008). In order to allow a project to learn, organizations have to manage both substance and context knowledge throughout the whole project process. Particularly systematic project knowledge management is needed, for turning a project organization into a learning organization and for distilling results and lessons from one project and delivers them into another.

Organizations also need measurable impacts from knowledge reuse in order for KM to be successful. A knowledge repository and work practices that facilitate the knowledge transfer between projects. The repository serves as a referral system for seekers. Seekers can gain more benefits from reusing the knowledge asset, especially when the asset is complex.

Creating a common perspective between the knowledge provider and knowledge seeker is also important in knowledge reuse. Asset complexity and individual familiarity with the domain were found to play an important role in affecting the ease with which individuals could reuse knowledge assets (B. Wai Fong, 2008).

Also, the knowledge map provides users with an integrated concept and a convenient portal with a set of proper topic names, through which to access detailed project information. Organizations are implementing a range of initiatives to identify, share, and exploit their knowledge assets. Nevertheless, many project-based businesses lack the expertise to handle their knowledge assets (especially those gained from the experience of previous projects); indeed, most knowledge-management initiatives in project-based firms have failed for a variety of reasons (Chua and Lam, 2005). Alavi et al., (2005) has emphasized that KM initiatives are weak in most organizations because they are overstressed to deploy technology and ignore human, cultural and organizational development issues that are essential to any successful KM initiatives. Focusing on success factors of KM in PBOs, these are as follows: Management and support, organizational culture, information technology, trust, team members, training and education. However, to surmount the complexities of KM challenges impose; organizations must adopt the essential approaches and activities suitable to their business nature. Appropriate, timely and careful responses are important for successful KM initiatives.

HRM

HRM is the second dimension of the knowledge management perspective. In our study, we identified links between HRM and knowledge management regarding the projects as a working form and the project-based company. We have found that regarding some HR processes like development of employees in the company as well as in the project there is already research while for processes, dispersion of the project, very little extant research exists and the issue has only recently been recognized as potentially significant in understanding the HR dynamics of project-based companies. The HRM requirements of the project-based organization are different than those in the classically managed organization.

HRM plays an important role as a relationship builder, developer of organizational processes, and knowledge facilitator between employees and units. Providing the organization with the right members is Human Resource Management's responsibility. In the literature, HRM in project-based organizations has been quite weak. Similarly, the current research regarding projects as temporary undertakings apart from being regular structures in the organizations from HRM perspective is extremely rare (Huemann, et al., 2007).

HRM in PBOs is the ability to manage the relations between people and the organizational context. The ability to build human capital and manage knowledge vital for success in PBOs. (Crawford, 2005; Bellini and Canonico, 2008; Bredin, 2008; Melkonian and Picq, 2011). HRM can improve the management process at the organizational level by increasing employees` skills and abilities, influencing their behaviour and attitudes, and increase their motivation and learning capacity (Scarbrough, 2003).

The firm's organizational capabilities need further attention in project-based settings. Projects are temporary organizations. For every new project, the human resource configuration of the organization must change. Project-based companies have dynamic context. Project sizes are constantly changing, permanent and temporary resources are employed and cooperation with clients, partners and suppliers are organized in teams, some of them are virtual (Sydow J., et. al., 2004). Human capital is the skills and abilities of individuals or stock of knowledge inside an organization. Human capital is necessary for achieving competitive advantage and the knowledge should pass through by individuals. Human resources and knowledge are considered two fundamental factors and valuable assets within organizations to achieve a competitive advantage. Voluntary knowledge sharing is the key mechanism in PBOs.

According to Nonaka and Takeuchi (1995), everyone has to some extent, become a knowledge worker. Non-core employees` knowledge sharing with core employees is important (Kang et al. 2003). A set of people management activities encourage knowledge sharing among a wide range of organizational employees, both core and non-core. Employees are important because it is through their efforts that the company's goals. Human resource management (HRM) is the function that deals with both the flow of people and the flow of knowledge (Scarbrough, 2003) across functional and hierarchical boundaries that it represents bridging senders and receivers of knowledge to foster links between them.

HRM is expected to play an important role in intra-organisational and inter-organizational knowledge sharing. HRM is performed through people management as a complex system of processes, role structures and activities that impact employees. HR practices are particularly relevant in project-based organizations, where a significant part of the HR practices is performed by HR quadriad which are HR specialists, line managers, project managers and project workers in every unit, project, or team (Bredin & Söderlund 2007,2011).

When HR professionals demonstrate competencies in business knowledge, delivery of HR, and management of change, then HR professionals are perceived by their associates as more effective. They are constantly faced with HRM issues. These are team building which is the selection of competencies, achieving long-term competence development, with the appropriate resources, quality of team, performance evaluation, trust-building and managing cultural differences among different individuals, coordination of member in inter- and intra-organizational projects cooperation between different partners in a context of the project-based organizations during the project and after project is over. Ensuring employee well-being and ethical treatment of workers in the project-based company is an issue that is vitally important. People-oriented issues in project management show the importance of HRM. According to Loufrani-Fedida and Saglietto (2016), the most effective people management practices are 1) work design which includes recruiting people, creating teams and team assignments, 2) staffing, evaluating employee performance which includes generating new tasks, peer evaluating, encouraging risk-taking and other procedures aimed at developing individual innovativeness and team performance, 3) rewarding systems which include pay raises, career tracks, promoting and other methods of employee motivating and retaining as social motivations (honouring a commitment, reciprocity, peer recognition, conformity to organizational culture and norms, mimicking leader's behaviour) affect willingness of knowledge sharing (Javernick, 2012) 4) career management which includes development of employees' career goals through continuous learning and training and 5) creating culture which is learning for sharing one's knowledge with others via strong social norms like trust and cooperation according to the business strategy 6) collaborative programs and projects 7) supervisory support 8) time pressure. These practices significantly and positively predict job performance of employees (V. Wickramasinghe and S. Liyanage, 2013) and may encourage and sustain knowledge sharing between individuals and projects.

Strategy

The third dimension is the strategic vision. The strategic vision is less explicit than the two other dimensions. The strategy is a plan on how an organization will manage its information and knowledge better for the benefit of that organization. Knowledge capturing is the beginning of KM. It requires the organization to know where and how can get the knowledge needed when it decides to implement KM strategies. KM strategy is the means by which the exact knowledge determined by a knowledge strategy can flow effectively in corporations. Projects in industries characterized by technologically complex products. The role of different industry contexts and knowledge bases in shaping knowledge management strategies (Cacciatori E.; Tamoschus, D; Grabher G., 2012). The organization should identify and use the related factors and the infrastructure enablers based on the chosen strategy. PBOs are defined as a variety of organizational forms that involve the creation of temporary systems for the performance of project tasks. They need integrative approaches for delivery of strategy and uniformization of knowledge, but they struggle to integrate knowledge and structures. In PBOs, the widespread adoption of a project management approach influences their strategy and governance approaches. Project-based organizations operate mainly on two levels. These are the project level and the organizational level (strategy, top management, cross-project coordination, etc.). H. Scarbrough et. al., (2004) focus on the tensions between learning at the project level and the stocks and flows of organizational knowledge. They indicate the role played by 'quasi-organizational' forms in enabling 'learning-by-absorption' and 'learning-by-reflection' at a project level. Organizations try to implement the strategic level of project management. For project-based organizations (PBOs), defining characteristics such as decentralization, short-term project focus, and interdependencies between project actors and their activities make it especially difficult to manage both explorative and exploitative learning (Cacciatori et al., 2012; Eriksson, 2013). Keegan A. and J. R. Turner, (2001) defined the existing practices and these practices promote between variation, selection, and retention for project-based learning. People learn a lot during their practice In the intra-organizational and inter-organizational projects and there is a risk that the wheel in the organization, in the network or in the field, will be reinvented over and over again. In order to bring learning across projects, firms or inter-firm collectivities may, however, use a variety of strategies and means for knowledge transfer. In project-based organizations, require partnerships as project teams come together collaborating to develop and evolve knowledge within the project and to share knowledge across project boundaries. Strategies make knowledge visible and visual practice to align the project with exploring and exploiting opportunities (Whyte et. al., 2008). The literature recognizes that PBO's main strength, which lies in effectively coping with project risks and uncertainties and responding quickly to changing client needs, can also work against the wider interest of corporate strategy (Hobday, 2000; Thiry and Deguire, 2007).

This implies difficulties in defining and implementing a corporate strategy to manage knowledge-intensive resources, which are strictly connected to a human resource area of expertise, in order to allow better internal resource allocation and pursue the interests at both project and organizational levels.

An organization should select and emphasize KM strategy for knowledge sharing. Hansen, et. al., (1999) argue that there are basically two strategies for managing knowledge. These are "codification" and "personalization" strategies. Codification and Personalisation strategies for KM is related to Nonaka & Takeuchi's SECI framework for KM. The Codification is very much related to the Knowledge Capture (mostly: Socialization + Externalization + Combination) while the Personalization is mostly related to Knowledge Transfer/Sharing (mostly: Combination + Internalization + Socialization).

Codification strategy is the re-use of knowledge. The underlying idea is to extract the knowledge from people and store it somehow. Employees can understand where they can find the desired information or enter their experiences (people-to-documents). This strategy makes it easy to search for the documentation of previous results, which, if similar enough, can help in the current situation. The factors determining the use of codification supports the transfer of knowledge across projects.

The most convenient organizational strategy that can be used to manage knowledge resources is personalization (Hansen et al., 1999; Venkitachalam and Willmott, 2015). Personalization refers to the personal development of tacit knowledge that is based on insights, intuition and personal skills for solving complex problems. Personalization strategy focus on people and their direct communication among each other. Especially in project-based companies, that follow flat organizational structures, internal communication is important. Encouraging employees to exchange ideas and experiences is the main principle here. Thus, the employees continuously build up and improve their social network inter- and intra-organisational projects, which they utilize to localize desired knowledge or experts in the case of need (goal-oriented). Following personalization, strategy provides to support creative and individual approaches to unique tasks in project-based companies. It faces only very special problems, embracing the difference of each project and customer in order to provide a specialized solution, where different levels and areas of expertise are important. Therefore, knowledge management is more focussed on connecting the employees (person to person). Personalization strategy concentrates on customized solutions of high complexity and quality. It is very common for this kind of company to have different customers in different domains. Hansen et al. (1999) point out that the corporate network is then used to find people with expertise (e.g., knowledge, experience, interest, etc.), who then share their knowledge. The result is that specialists work on solutions and share their knowledge, which increases the company-wide expertise.

Competencies Level

Another key perspective in the literature specialized in competence management in PBOs is the level of competence to mobilize (Ruuska and Vartiainen, 2003; Crawford, 2005; Suikki et al., 2006; Söderlund, 2005, 2008; Bredin, 2008; Melkonian and Picq, 2011). Intellectual capital (human capital, social capital and organizational capital) and knowledge management (knowledge creation, knowledge transfer, and knowledge integration) are the bridge between people management practices and core competencies, and that dynamic capabilities are the renewal components that, over time, connect people management practices, intellectual capital, knowledge management and core competencies (Medina and Medina 2015). Competence is defined skill whenever related to humans in practice work-related knowledge, knowhow and attitudes (personal characteristic) within a specific context (Medina and Medina, 2015) as the combination of resources. According to prior researches, “Competence” is defined as the ability of an individual, a team, or a company to mobilize and combine resources (Loufrani-Fedida, and Missonier, 2015). Thus, the three levels of competencies (individual, collective and organizational) appear crucial in PBOs. Each of these three levels has been studied extensively. A multilevel approach is developed to competencies in PBOs, from the types of project capabilities as individual, collective and organizational levels, influencing each other and creating dynamic loops of interdependencies (Melkonian and Picq, 2011).

Individual Competencies

The first level of competencies is individual competencies. Individuals work in a project team is important in PBOs. Project capabilities are defined as the internal ability of PBOs (Davies and Brady, 2000). Effectively managing competence leads to a win-win for the company and individual. Inside PBOs, individuals work in a team project, are part of a network of multiple, interrelated projects that fulfil the firm's overall organization and strategy (S. Loufrani-Fedida & S. Missonier, 2015). Organizations can go forward via developing competencies in a dynamic business environment. The competency is not the only attribute of a jobholder, but it also attributes of the job. For job effectiveness, the identification of competencies is important. Competencies are important at the individual level for defining job or work content. It is necessary to define both technical and behavioural requirements to be successful in the role. The performance management can be developed which includes the reference to the job requirements, personal behaviours, and the role context. It is particularly suitable for measuring managers’ performance in dynamic team-based environments (Cheng et al, 2005). The project management competencies are required by individuals differ according to the project roles to be fulfilled. The following project roles can be performed by individuals: project owner, project manager, project management assistant, project team member, and project contributor. Project participants are considered as actors. The project actor`s role is to rebuild the network of relationships to support knowledge use (d'Armagnac, S., 2015). Accordingly, the project management office is important to possess capabilities in brokering and managing project knowledge to be able to facilitate coordination and implication. The project management office acts as a knowledge broker between projects and top management if the PBO understands and supports project managers' learning and knowledge sharing processes (Pemsel, S. and Wiewiora, A., 2013). According to Suikki et al. (2006), project management competence consists of understanding the project management knowledge areas, leadership skills, and business environment. PMI (2013) organizes project management competencies into ten basic project management knowledge areas: integration, scope, time, cost, quality, human resources, communications, risk, procurement, and stakeholders

The specific project management functions to be performed by a project manager can be described in a role description. Mostly researches focusing on individual competencies deals mainly with the competencies of project managers. A project manager is more effective if his/her individual competencies are in line with the proposed project (Muller & Turner, 2010).

The relationship between performance and the manager's competencies is getting crucial in project-based organizations. It is essential to identify the competencies of a manager like job-task and generic competencies. The generic competencies, which can be applied to all types of projects which are critical competencies for project managers: leadership, the ability to communicate at multiple levels, verbal skills, written skills, attitude, stress management, emotional intelligence, conflict management and the ability to deal with ambiguity and change. These are essential in dealing with project complexity. Job-task competencies in which a project manager operates for a particular role that enables them to be effective (Cheng et al. 2005). The selection of the project management methods appropriate for a given project, the selection of the appropriate communication structures and the selection of the participants are crucial for a project manager role. They affect whether the project will be a success or a failure.

A project manager may successfully balance the competing demands of scope, time, cost, quality, resources and risk. Also, the project management competence of a project manager is the capability to fulfil all functions specified in the role description. Besides the project management knowledge and experience for a given project type, a project manager needs product, company, and industry knowledge, cultural awareness, and language knowledge are also prerequisites.

A project manager requires knowledge and experience by applying project management methods and, also to design the project management process. On the other hand, project manager competencies alone do not guarantee project success. The diversity and complexity of mobilized competencies during a project means that it is not enough to adopt an approach that focuses only on team members applied individually or only to the project manager (Midler, 1995)

Collective Competencies

The fundamental characteristic of a project is precisely its collective dimension. The notion of collective competence can be defined as “a group's ability to perform together towards a common goal, which results in the creation of a collective outcome, an outcome that could not be accomplished by one member due to its complexity” (Ruuska and Teigland, 2009). The combination of several individuals’ competencies constitutes a mutual knowledge base for collaboration. Skilful interaction is seen as the way the work is carried out in practice between several individuals cooperating or collaborating for a common purpose. It is claimed that this competence is at the group level and a collective competence that combines both practical and interpersonal competence. Practical competence refers to the ability of project members to integrate individual competences and solve problems together. Interpersonal competence refers to the ability of project members to interact and collaborate with other members in the performance of the tasks of the project. The collective competence is vital for the success of project teams. Collective competence is about more than the people on the team and how they function as members of that team. The importance of this situation if individuals can work with the awareness of each other, and if they can function with the awareness of various structures and resources that support or prevent their work in the system. That is why, on the team level, studies have reported the effects of team competence on projects' performance (Melkonian and Picq, 2010). Collective competencies are playing a key role between individual competencies and organizational processes. Achieving collective competencies leads to successful projects. For improving project performance, it was necessary to go beyond individual competencies and combine them into a common effort. Successful projects are projects that can provide collective competence. The interaction between individual competencies and organizational competencies occurs the collective competencies. The collective competence does not exist at the beginning of the project; it is built during the project as a result of the interactions between individual and organizational competencies, and the development of collective mechanisms. Thus, collective competence is not simply built by the gradual expansion of resources but instead emerges from within the system in a process that varies according to different contexts (S. Loufrani-Fedida, S. Missonier 2015).

Organizational Competencies

The third level of competencies is organizational competencies. This level of competencies represents the company's strengths or capabilities. Söderlund (2005) uses the term “project competence”, defined as the firm's ability to generate/select and implement/execute projects skillfully. In other words, the organizational competencies are beyond one project`s boundaries. Organizational level competencies are described as to combine the skills, information, performance measures and the corporate culture that an organization uses to achieve its mission (Melkonian and Picq., 2011). Literature shows that hat PBOs must develop “project capabilities” (Brady and Davies, 2004; Bredin, 2008; Davies and Brady, 2000; Melkonian and Picq, 2011; Söderlund, 2005). It means that the internal abilities of PBO based on multiple projects. These abilities are seen as multiple project-driven at the strategic and organizational levels. Mostly, organizational competencies are things that the employees of the organization to demonstrate to be effective in their job, role, function, task or duty. These things include job-relevant behaviour what the employees say or do which result in good or poor performance, motivation how the employees feel about a job, organization, or geographic location, technical knowledge, and skills what the employees know regarding facts, technologies, their professions, procedures, jobs, and the organization, etc.

Organizational competencies can be divided into three categories and these are core values, technical competencies, and core competencies. Core values mean that the organizational values which are the shared principles and beliefs. Technical competencies are those specific competencies that are usually required to perform a given job. Technical competencies cover the various fields of expertise relevant to the specific work carried out in the organization. Core competencies summarize the capabilities which are important across all jobs and which the employees believe collectively contribute to the organizational overall success. At the same time, the importance of core competencies can vary according to the specific job duties and requirements.

1.2. Descriptive Findings

The number of journal publications is shown in Fig.1 and the “International Journal of Project Management” published the highest number of papers on the related subject. The distribution of the articles by year of publication is shown in Fig.2. In 2015, the number of published papers peaked.

Fig. 3 shows the distribution of paper methodology. Qualitative and quantitative methods are the most used methodology in the literature. In 61% of total papers, researchers adopted qualitative methods and %21 of total papers researchers adopted quantitative methods in studies. Fig.4 shows the classification of papers according to the perspective adopted, as defined by the research team in “mapping the field” step. According to this classification, 52% of total papers (50) show the knowledge management in PBOs from the perspective of knowledge management processes which is 1-1 perspective KM.

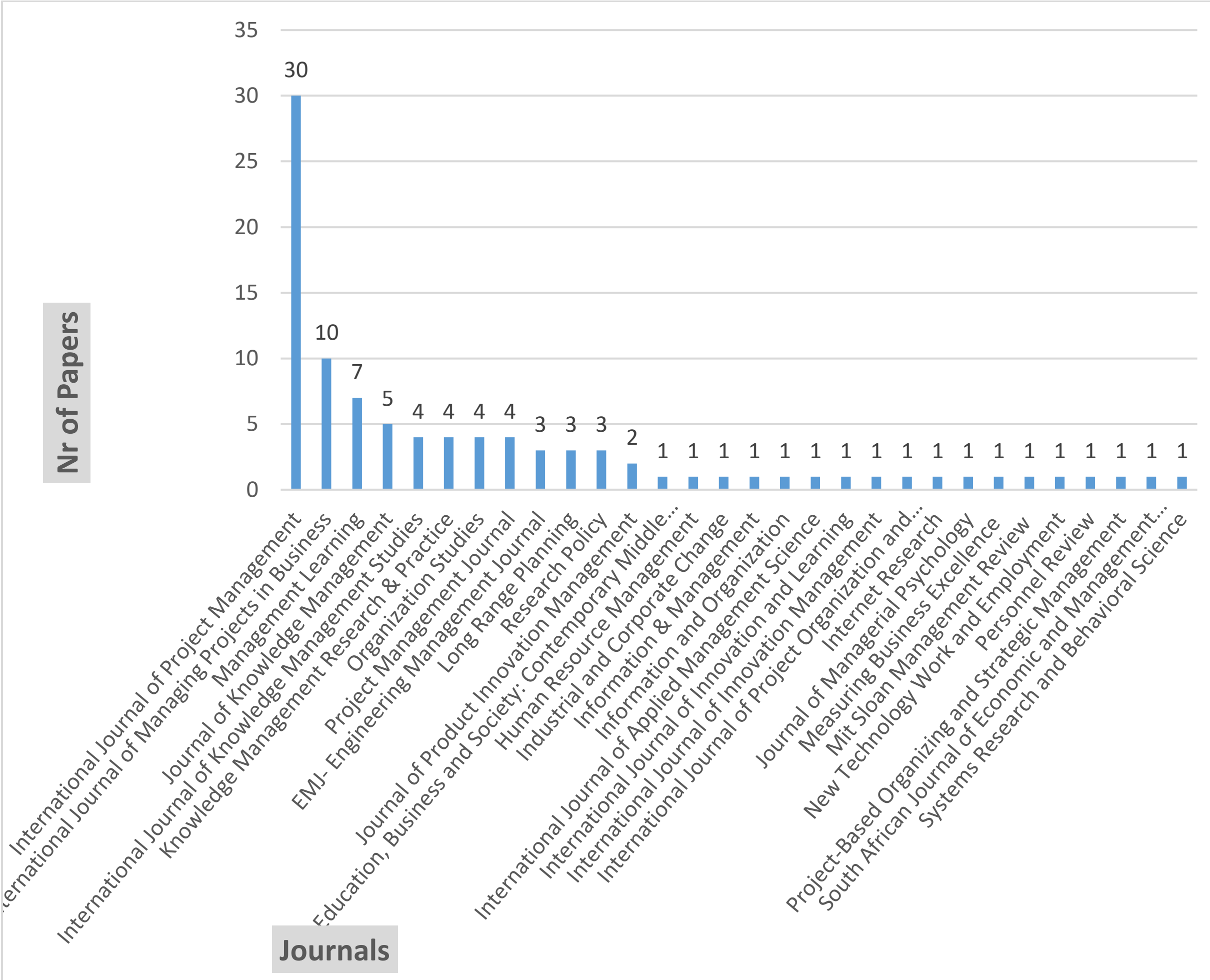

Figure 3 Number of Papers in Journals

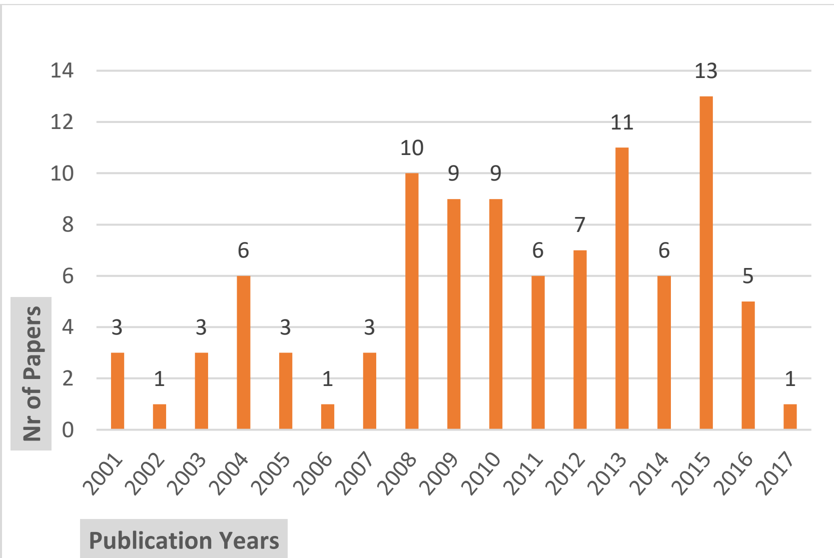

Figure 4 The Distribution of Papers by Years of Publication

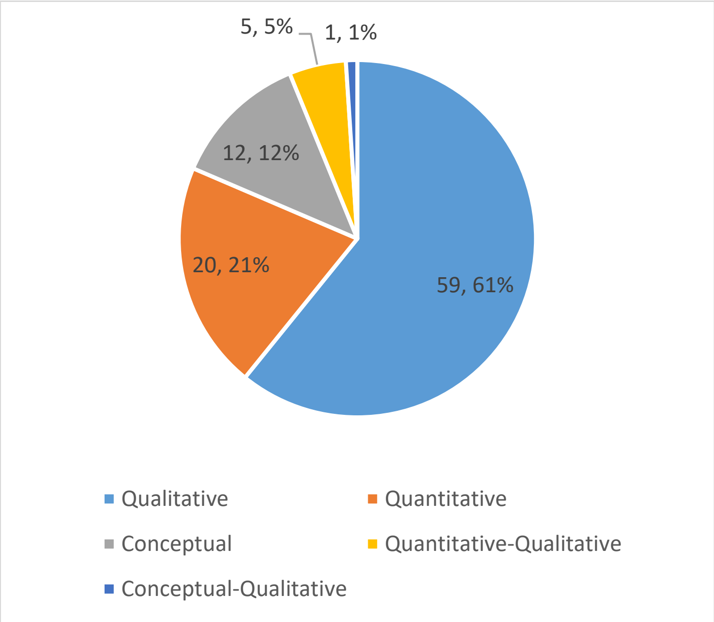

Figure 5 The Classification of Papers by Methodology

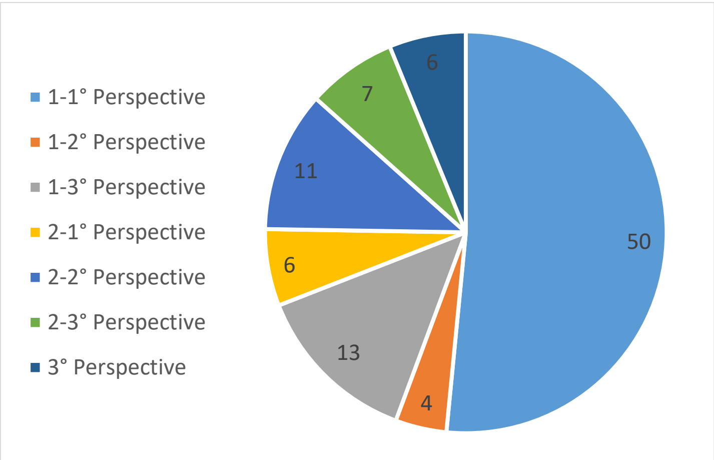

Figure 6 The Classification of Papers by Perspective

1.3. Mapping the Literature

The topic of KM is mainly studied as a process that develops on the following steps: the creation of knowledge and competences, transfer across individuals and across departments, and companywide strategies to store, improve, reproduce and reuse knowledge and apply competences.

Table 2 summarizes the framework of analysis and the research questions.

	Knowledge	HR	Strategy
Individual-level	RQ1a.How is knowledge/competence created, accumulated and stored at the individual level?	RQ2a. How the human resources, know-how, and talents are managed and transferred at the individual level?	RQ3a. How long-lasting strategies to create, preserve and spread knowledge/competence are envisioned, planned and built at the individual level?
Collective-level	RQ1b. How is knowledge/competence created, accumulated, stored and shared at the collective level?	RQ2b. How the human resources, know-how, and talents are managed and transferred at the collective level?	RQ3b. How long-lasting strategies to create, preserve and spread knowledge/competence are envisioned, planned and built at the collective level?
Organizational-level	RQ1c. How is knowledge/competence created, accumulated, stored and shared at the organizational level?	RQ2c. How the human resources, know-how, and talents are managed and transferred at the organizational level?	RQ3c. How long-lasting strategies to create, preserve and spread knowledge/competence are envisioned, planned and built at the organizational level?

Table 2 Framework of Analysis and research questions

In the following, I will describe the different approaches and levels on which the studies are based, summarizing the research questions and the central ideas.

RQ1a. How is knowledge/competence created, accumulated and stored at the individual level?

A set of papers that I have examined during the review focus on this question of knowledge/competence is created, accumulated and stored at the individuals level and reach certain conclusions. First of all, papers investigating how knowledge/competencies managed at the individual level (e.g., Ayas & Zeniuk, 2001; Damn & Schindler, 2002; Koskinen, 2010) focus on knowledge/competence creation and production. Here, knowledge/competence creation/production may be defined as the acquisition of new technology, the discovery of the usage of technology or the discovery of the way of ‘doing things’, and storing this knowledge in mind in a systematic way, for this knowledge to be reusable. On an individual level, knowledge/competence might be created either by a new workforce that is hired to a company or as individual learning within the company.

Experience accumulation might be considered as another form of individual knowledge/competence management. Papers highlighting experience accumulation (e.g., Prencipe& Tell, 2001) usually deal with the gradual increase of knowledge/competence over time. These papers state that at the individual level, the experience is accumulated as individuals spend time applying new knowledge, as they get trained on the usage of the new knowledge, or as the application of this new knowledge is reiterated. Knowledge storage might also be another dimension of knowledge management, as knowledge turns into a value as long as it is stored. Extant literature on this issue treats knowledge storage as the third step that comes after knowledge acquisition and knowledge distribution (Fong & Choi, 2009). At the individual level, knowledge storage occurs as workers record and store their knowledge/competence, in a tool that can be reached by other individuals in the company.

Another highly important aspect of knowledge/competence management at the individual level is how different individuals` differences create, acquire and store knowledge. Here, several papers (e.g., Andersen &Hanstad, 2013; Koskinen &Aramo-Immone, 2008) focus on the individual differences in knowledge creation and storage, either in the form of differences in perception, differences in the personal notes that are written, differences in the oral explanation of knowledge, and differences in the ways knowledge is evaluated.

Several papers (e.g., Akhavan, Zahedi, &Hosein, 2014) also indicate the importance of individual barriers to knowledge management. These individual barriers include lack of time, low awareness on the level of personal knowledge/competence, individual differences, poor verbal or written communication skills, and lack of self-confidence or over-confidence.

Central idea

Knowledge/competence management at the individual level within an organization is mainly related to the creation/production of the knowledge, the accumulation of the experience over time and the storage of knowledge. The main reasons behind the variety of ways to manage knowledge/competence are the differences in how knowledge/competence is perceived and recorded. The major barriers that prevent the efficient management of knowledge/competence at the individual level are usually worker-based factors such as lack of time, low awareness of personal knowledge, individual differences, poor verbal or written communication skills, and lack of self-confidence or over-confidence.

RQ1b. How is knowledge/competence created, accumulated, stored and shared at the collective level?

At the collective level, the most important aspect of knowledge/competence management is the transfer and sharing of knowledge/competence among individuals. Here, several papers focus on the transfer and sharing of knowledge/competence (e.g., Andersen &Hanstad, 2013; Obembe, 2013; Wiewiora, Trigunarsyah, Murphy, & Coffey, 2013) as the most important aspects of knowledge/competence management at the collective level. For a team to effectively perform together to reach a collective goal, knowledge/competence should be transferred evenly and transparently, based on the responsibilities of the team members. At that point, finding the balance between sharing insufficient knowledge/competence or sharing knowledge/competence that is unnecessary is highly critical. When insufficient knowledge/competence is shared, knowledge/competence diffusion would be weak and the team cannot perform at its optimum. On the opposite, whenever unnecessary knowledge/competence is shared, team members might feel overwhelmed or the differences between the responsibilities of team members might get blurred.

Several lines of research show that the level of emotional intelligence is highly important in the way knowledge/competence is managed collectively (e.g., Decker et al., 2009). Here, emotional intelligence might be defined as the ability to form effective interpersonal relationships. In terms of knowledge/competence management, emotional intelligence may be used to transfer the knowledge/competence between individuals in an appropriate way. Emotional intelligence also helps to remove the boundaries within the same project team to diffuse knowledge/competence within the team effectively and; the boundaries between projects to transfer knowledge/competence between projects. The barriers between projects may be classified under five categories, which are individual, organizational, technological, contextual and inter-project. Contextual and inter-project barriers are the type of barriers that are most effective at the collective level (Akhavan, Zahedi, &Hosein, 2014). These barriers include lack of comprehension on the collective goal of the team, lack of the context of the work done, inability adapt to the context, insufficient mechanism to extract knowledge from the project reports, insufficient communication between different project groups, unwillingness of project managers to evaluate or criticize peers, lack of constructive criticism, and of feedback mechanisms.

Having diverse competences and being able to share/exchange them among each other, and sender/receiver mechanisms are also highly important in the management of knowledge at the collective level (Bosch-Sijtsema&Postma, 2009; Hartman &Doree, 2015). According to the sender/receiver approach, when an individual (here in the position of the sender) in an organization have competence in one area, he/she has a tendency to transfer this knowledge to the receiver and expects the receiver to appreciate him/her. Here, for this mechanism to work appropriately, the receiver has to understand the sender's message appropriately. For this knowledge to be useful to the organization in the long term, the receiver should also be able to acquire, store and learn how to apply this knowledge. For this to turn into a mutual competence, every single individual within an organization should have competence in some specific area and should be able to transfer this knowledge/competence to the others effectively, to be able to reach organization goals on the collective level. The extant literature (e.g., Bettiol&Sedita, 2011) also shows the necessity of forming a knowledge network, which shows the knowledge and competence of each worker. An effective knowledge network allows a more efficient application of the sender/receiver approach. This implies workers to know where to find knowledge/competence they are looking for, where to transfer them and with whom to form collective working groups. As mentioned in several papers (e.g., Lech, 2014) this leads to meta-knowledge, which means knowledge of what others know. It is worth considering that meta-knowledge is critically important in solution formation.

Central idea

As regards knowledge/competence management at the collective level, the most critical aspects are knowledge/competence sharing and transfer. Here, having sufficient emotional intelligence to be able to form strong interpersonal relationships, removing contextual and inter-project barriers and engaging in mutual competence-based sender/receiver relationships are important elements to effective knowledge sharing and transfer.

RQ1c. How is knowledge/competence created, accumulated, stored and shared at the organizational level?

The centralized/decentralized structure and the flexibility of the organization are highly important for knowledge/competence management (Gann, Salter, Dodgson, & Phillips, 2012; Muller, Pemsel, & Shao, 2015). Here, one of the biggest trade-offs is between flexibility and control. If an organization is flexible enough, knowledge/competence might spread rapidly, but the drawback of this situation would be that control on knowledge/competence might be lost, or knowledge/competence might reach departments or individuals that should not own this knowledge/competence, or even reach competitors. In more decentralized firms, the control on knowledge/competence is lower but the flexibility is higher, while on more centralized firms, the central control is high but the flexibility is low, and the knowledge might not easily be transferred from a central source throughout the entire organization. Meanwhile, knowledge governance, which means creating organization-wide systems that build, optimize and share knowledge and competence in an effective way, might be more effective in centralized organizations (Pemsel& Muller, 2012). In addition, the local embeddedness, which describes a situation in which the organization is interdependent and surrounded by local resources, local know-how and competence, local context and local actors, of the organization, is referred to as important in the literature (e.g., in Javernick-Will, 2013). When the organization is low in local embeddedness, then it has more formal and global knowledge/competence management strategies, which enable the organization to transfer knowledge/competence among different departments.

At the organizational level, the barriers to knowledge/competence management are technological and organizational in nature (Akhavan, Zahedi, &Hosein, 2014). Technological barriers include lack of technical support, insufficiency of IT structure, reluctance to use IT systems, unrealistic expectations from workers, unbalance between the available technologies and workers' needs, and lack of training and education on new technologies. Meanwhile, organizational barriers can be: lack of integration between knowledge/competence management strategies and the incentives that are given to employees, lack of transparent rewards, lack of sharing culture within the company, unavailability of workspace needed to produce or spread new knowledge, inappropriate working conditions and prejudice or mobbing against workers within the organization. Here, extant literature (e.g., Akhavan, Zahedi, & Hosein, 2014) points out that the first step to removing existing barriers is to remove organizational barriers, by revising organizational strategy, organizational culture and organizational structure and by making them more suitable to knowledge/competence management strategies.

Central idea

The centralization/decentralization ratio of the organization, the balance between flexibility and control mechanisms as well as technological and organizational barriers are determinant for the creation and spread of knowledge/competence at the organizational level. In addition, local embeddedness and the global perspective of the organization affect companywide knowledge/competence management.

RQ2a. How are human resources, know-how, and talents managed and transferred at the individual level?

At the individual level, human resources, know-how, and talents are managed and transferred each time a worker acquires new knowledge, develops a systematic approach to transfer this knowledge and decides to share this knowledge (e.g., Ayas&Zeniuk, 2001; Damn & Schindler, 2002; Koskinen, 2010). Here, the perspective of the individuals towards newly hired workforce determines their openness towards receiving new knowledge/competence from them. Similarly, their perception and awareness of their own knowledge/competence (i.e., the meta-knowledge) determine the workers' ability to transfer and spread knowledge/competence to the others. In addition, individual differences between workers, for example, the differences in oral and written communication styles are worth capturing. These differences cause workers to develop different strategies to acquire, manage and transfer knowledge/competence, thus understanding these differences appropriately is also important at the point of managing the talents and workforce (Andersen &Hanstad, 2013; Koskinen &Aramo-Immone, 2008).

Central idea

In terms of HR management at the individual level, realizing that every single individual has a different perspective, different perceptions, different sources of motivation, and diverse communication styles is highly important. Additionally, the awareness of individuals towards their own competence and towards others' competence should be closely investigated.

RQ2b. How are human resources, know-how, and talents managed and transferred at the collective level?

At the collective level, the most important determinant of HR management and know-how transfer are the interpersonal processes that occur between individuals within a group. The literature (e.g., Decker et al. 2009) indicates that the emotional intelligence of the workers turns out to be effective in this respect. Mutual competence and sender/receiver relationships are also effective in HR management at the collective level (Bosch-Sijtsema&Postma, 2009; Hartman &Doree, 2015). Here, it is highly important to create diversity within a group. As the communication style and sources of the motivation of the employees are also effective on the way the information and know-how are being exchanged within a team, including employees having diverse competencies and skills, and also caring about the diversity of these employees' temperament and communication styles are also worthy of consideration.

Central idea

In HR management at the collective level, the most critical aspects are the interpersonal relationships within a group and the diversity of the talents and communication styles. While managing the human resources collectively, the relationship between the organization and the employee and the relationships between the different employees are also important. Talents and know-how are also expected to spread gradually, by being transferred between the people in the same team.

RQ2c. How are human resources, know-how, and talents managed and transferred at the organizational level?

The literature indicates that in order to manage human resources at the organizational level, the flexibility of the organization and the centralization/decentralization of the structure are highly important (Gann, Salter, Dodgson, & Phillips, 2012; Muller, Pemsel, & Shao, 2015). This may be explained by the fact that know-how and talents can be easily transferred in a flexible organization, while it is difficult to spread talent in a rigid organization. Similarly, in a decentralized structure, know-how might be spread within departments but it may be difficult to spread know-how among departments. However, from a different perspective, in a centralized structure, it might be easier to copy and standardize the know-how, which would decrease creativity and originality.

In addition, several papers show that the culture of the organization can support the management of HR at the organizational level (Ajmal& Koskinen, 2008; Ajmal et al., 2009). Organizations that are able to accept, adapt and utilize new know-how and new human resources, knowledge spreads more rapidly. Here, cultural diversity should also be investigated carefully. Cultural diversity might contribute to the effective spread of know-how and knowledge management, provided that the stereotypes are low within the organization and employees are open to accepting diverse cultures, but, on the contrary, if the organization is rigid towards diverse cultures, barriers between employees might increase and this might cause deficiencies in HR management.

Central idea

To manage HR at the organizational level, the flexibility/control balance, centralization/decentralization systems, and organizational culture are highly important. Here, the diversity of knowledge and competencies contributes to the organization as long as the organization is ready to accept diversity.

RQ3a. How long-lasting strategies to create, preserve and spread knowledge/competence are envisioned, planned and built at the individual level?

Strategies are either developed by individuals and transferred to the organization in an inductive manner, or either the individual adopts the strategies that are developed by the organization, in a deductive manner. The literature on hand (e.g., Gann, Salter, Dodgson, & Phillips, 2012; Muller, Pemsel, & Shao, 2015) points out that centralization/decentralization balance is highly effective at that point. For instance, in a centralized system, it is difficult for every employee to be aware of the strategies that are developed by the organization, while in a decentralized system individuals might easily adopt organizational strategies. However, in a decentralized structure, it is difficult for an employee to transfer the strategy that is developed by himself/herself to the entire organization.

Central idea

Individual competencies and knowledge are vehicles of strategic development, and, on its side, strategic development determines what competencies and knowledge the company should build/acquire. Individuals, with their knowledge and competencies, develop organizational strategies and spread them to the organization, or they adopt the organization strategy that has been developed by the others. Here, one of the main determinants is the centralization/decentralization level.

RQ3b. How long-lasting strategies to create, preserve and spread knowledge/competence are envisioned, planned and built at the collective level?

On the collective level, the success of strategy development lies in the nature of the interpersonal relationships within the collective team (Decker et al. 2009) and also on the level of transparency within the team. Also, the leading and communication style of the team leader and the equality of the right to speak predict the effectiveness of strategy development and spread within the team (Gann, Salter, Dodgson, & Phillips, 2012). For example, in the collective teams that members have equal rights to speak, strategy envisioned and developed by one member might be transferred and developed by the others, while a monopolistic structure would harm the creation process of a new strategy.

Central idea

The dynamics of the group directly affect the development of new strategies. Here, the intra-group dynamics recognized as the most important are transparency, equality of right to speak and high-quality communication.

RQ3c. How long-lasting strategies to create, preserve and spread knowledge/competence are envisioned, planned and built at the organizational level?

Literature indicates that strategy development on the organizational level is usually being done by the organization-wide decisions that are made. The decision of consortium and project-based outsourcing are among these strategies that are developed by the organization (Currie, 2003). In this way, the organization might decide between spending time and effort on developing knowledge within the organization by training and educating its own human resources, or spending money on buying the know-how from outside. Additionally, creating knowledge inventories also appears as a worth-considering strategy in several lines of research (e.g., in van Donk &Riezebos, 2005), which means determining the core operations of the organization and storing them systematically.

Central idea

One of the ways the strategy development occurs at the organizational level is consortium/outsourcing. Another decision that might be made by the organization is to create knowledge inventories for the core operations of the organization. Here, the ultimate goal of the organization might be stated as to turn the organization into a learning organization.

CHAPTER 2: CASE STUDIES

This chapter aims to investigate several case studies. Based on the findings of case studies, the conceptual framework of an integrated knowledge management system is developed. Specifically, the research focuses on possible strategies to localize and transfer different types of knowledge resources in project-based organizations and internal barriers to knowledge and competence management. This chapter introduces a knowledge management system based on the market mechanism in the PBO context.

2.1. The methodology of case studies

The research investigates three case studies of large and distributed PBOs, which manage, almost exclusively, very complex projects, frequently with international partners. Due to their requests for keeping confidential some of the information provided to us, we refer to these organizations as A, B, and C.

A is a global high technology company and a key player in helicopters, aircraft, aerostructures, airborne & space systems, land & naval defence electronics, defence systems, security and information systems.

B is a global ERP (enterprise resource planning) company, catering to over 1000 companies with more than 30.000 concurrent users across diverse industries in more than 30 countries. Its core competency has always been quality consciousness and providing innovative solutions that can be delivered quickly and cost-effectively in a complex environment. With over 250 professionals, consultants and excellence R&D centres, B has subsidiaries in Germany, India, Turkey, UAE, and Korea along with business partners all across the world. It has played an important role in helping companies gain Operational Excellence in Industries such as Automotive, Aviation & Defense, Printing, Packaging, Textile & Garment, and Machinery & Industrial Automation.

C is an assurance, advisory, tax, and transaction advisory services company. It works with more than 200,000 clients in 150 countries, from start-ups to multinationals across all sectors, helping them to meet their most pressing challenges.

In order to develop and successively screen the concept of an internal knowledge and competence market, we conducted two rounds of semi-structured, in-depth interviews, six months apart, with internal key-informants, followed by the Delphi approach to elucidate some apparent divergences.

8 key informants were selected from the main hierarchical levels of each company that are involved in the company core business. Their ages ranged from 35 years to 50 years and they were equally

distributed between males and females to manage any gender bias. Interviews, typically, lasted for one hour. All interviews were recorded with the permission of the participants, transcribed and then checked for accuracy. It was, therefore, possible to check that the views of participants wanted to bring across, were actually received as intended, without distorting their meaning.

Informant	Company	Sector	Interviewee Position
A1	A	Helicopters, aeronautics, electronics, defence, and security systems, space	Project Manager
A2	A	Helicopters, aeronautics, electronics, defence, and security systems, space	Project engineer
A3	A	Helicopters, aeronautics, electronics, defence, and security systems, space	Project engineer
A4	A	Helicopters, aeronautics, electronics, defence, and security systems, space	Project engineer
B1	B	ERP software	Project manager
B2	B	ERP software	Project Leader
C1	C	Assurance, advisory, tax and transaction advisory services	Tax manager
C2	C	Assurance, advisory, tax and transaction advisory services	Audit manager

Table 3 Key Informants

The first round of interviews supported the idea generation stage and was aimed to reach a deep awareness of the “as-is” ways of managing knowledge and competencies within the company, possible methods and tools in use, people attitudes towards the issue, current needs and possible requirements for a “to-be” internal knowledge and competence management system. A questionnaire served as a guide for the face-to-face interviews. Regarding data analysis (see, for example, Sahay & Robey, 1996), the method for analyzing the interview data was intended as a process of progressive refinement, moving from raw transcribed interview text toward more general theoretical inferences.

We began with a simple coding scheme that included broad categories that were further refined to include more specific positions, expressed by respondents. For example, for the first round of interviews, the coding scheme shown in Table 2 was developed through an iterative process whereby the members of the research team independently read sample transcripts, coded text into preliminary categories, discussed and refined the scheme. Using this scheme, all interviews were split into coded segments. Similarly, labelled segments were then combined and assigned new labels that reflected the common theme of the combined statements, i.e. a unifying idea representing the interpretations found in multiple coded segments. Themes were then aligned with relevant social groups. Relevant groups formed around departments (e.g.) organizational levels (e.g. project managers, BU managers), disciplines (e.g.), and functions (e.g.).

Specific actions performed on interview data included coding and splitting in order to align emerged themes with the relevant social groups that formed around departments (e.g.) organizational levels (e.g. project managers, BU managers), disciplines (e.g.), and functions (e.g.).

Broad coding category **AS-IS situation:**	**Further coding**
1) Level of satisfaction with current methods and tools available to manage digital knowledge goods, expert advice and talents inside the company	Perceived effectiveness in daily routine and in case of unexpected events/opportunities Interpretations about the existing inefficiencies in current methods and tools to manage the different kinds of knowledge resources inside the company
2) Level of satisfaction with current methods and tools available to manage knowledge created-accumulated in projects	Perceived effectiveness of knowledge transfer and reuse processes both in terms of digital knowledge

	goods and of competencies generated and accumulated in project execution
Wish list:	
1) What kind of *desires* people expressed about a possible future service to manage digital knowledge goods, expert advice, and talents inside the company	Needs Possible impacts on daily work and in case of unexpected events/opportunities Perceived internal obstacles
2) What kind of desiderata people expressed about a possible future service to manage knowledge created-accumulated in projects	Needs Possible impacts on daily work and in case of unexpected events/opportunities Perceived internal obstacles

Table 4 Coding Scheme for Idea Generation Interviews

The results of the first rounds of interviews and the insights from the scarce and fragmented literature on knowledge markets supported the development of a conceptual framework for an internal knowledge and competence market ideally suited to the context of PBOs.

The second round of interviews supported the idea screening stage. We submitted the conceptual framework of the market to the same informants of the first round, in order to receive feedback, comments and knowledgeable opinions on its possible applicability in their organizational context.

The analysis of interview data allowed us to identify a set of impediments to the possible applicability of the model proposed to the organizational context under the exam. We analyzed these impediments, compared the positions of the interviewees in order to isolate elements that are strictly dependent on the specific context from those that we can assume as more general of PBOs. We discussed the main issues that emerged in round tables with interviewees in order to identify possible solutions and improve the applicability of the model. As a result, we developed a set of guidelines and recommendations for tackling the issue of knowledge and competence management in PBO by means of a market approach. We are aware that generalizability is not a prerogative of qualitative research, even more so of the single case study. Further validation in a larger panel of cases, followed by a quantitative study, is needed, an endeavour that we postpone to future research.

The methodology used for collecting and analyzing the data is discussed in more detail below.

2.1.1. Data Collection and Analysis

The fieldwork lasted 6 months for each phase (idea generation and screening), during which a total of 8 interviews were conducted. See Table 2 for details interviews with employees

The interviews were conducted with the help of questionnaires.

For the idea generation phase the interviews had two main objectives:

1) Verification that the structure of the company was actually PBO and that the type of projects covered fell into the category of complex projects

2) Investigation of the current knowledge management methods in the company and related issues

The interview questions are in Table 5.

PBO and KM
Do you agree with the following statements? Project-based organizations can also operate in contrast with the largest goals of the organization, for the following reasons:
Difficulties in capturing and transferring knowledge generated in projects, limiting or hindering organizational learning (true/false, why?, to what extent? What's your experience?)
Lack of incentives to bring young resources up (true/false, why?, to what extent? What's your experience?)
The recruitment of the best resources on projects occurs more frequently for the persuasiveness and seniority of some project managers than for the real advantage of the company
Uncertainty of young resources regarding their career path due to the dispersion of technical leadership on projects.
Lack of coherency control on different projects by senior management. The basic set of formal control tools are often not adequately applied (e.g. risk management, cost, and design review, etc.)
Knowledge and Competence Management
How do you build the team for a project? Where do you look for the right competencies? Are there any tools to identify who knows what inside the firm? Do you think this is a problem in your company? How does the company face it? Do you think it is effectively managed?
Do you have tools to manage profiles within the company? Do you use them? Are they effective?
What kind of tools do you use to find the needed profiles outside the company? Is there a centralized service to find the resources? Do you think this is a problem in your company?

In case of unexpected events, if you need new competence profiles to add to the project (due to an extension of the projects or new emerging opportunities) where do you look for them? Do you have difficulties in finding them? What tools do you have to face the problem? Are they effective? What would you need?
What organizational, managerial and technological tools does the company adopt to manage the knowledge that is created and accumulated in projects?
Do you use any tool to manage project documents?
Do you have any tools to transfer knowledge across the organization (periodic meetings, central repositories, blogs, forum, question & answers tools…) Are they effective?

Table 5 Interview questions

The idea screening phase took place by presenting the model to the interviewee and capturing the reactions to the concept. In this phase, the questions asked to the interviewee had the objective to understand the applicability, the potential utility, possible obstacles to the adoption of the instrument. Particular attention was paid to understanding the level of satisfaction and the nature of the obstacles for each part of the proposed system, trying to identify with the interviewee also possible solutions or amendments to the system.

The interviews were all recorded, transcribed and analyzed separately by the members of the research team.

Regarding data analysis (see, for example, Sahay & Robey, 1996), the method for analyzing the interview data was intended as a process of progressive refinement, moving from raw transcribed interview text toward more general theoretical inferences. Specific actions performed on interview data included coding and splitting. The members of the research team began with a simple coding scheme that included broad categories that were further refined to include more specific positions expressed by respondents. For example, for the idea generation phase, the coding scheme shown in Table 2 was developed through an iterative process whereby the members of the research team independently read sample transcripts, coded text into preliminary categories, discussed and refined the scheme. Using this scheme, all interviews were split into coded segments. Similarly, labelled segments were then combined and assigned new labels that reflected the common theme of the combined statements, i.e. a unifying idea representing the interpretations found in multiple coded segments. Themes were then aligned with relevant social groups. Relevant groups formed around departments (e.g.) organizational levels (e.g. project managers, BU managers), disciplines (e.g.), and functions (e.g.).

On the basis of the insight emerged from data we developed the model and then we tested it with the second round of interviews.

2.2. Results of the first round of interviews

First, for each company, an analysis of the current situation of KM was done. This was to understand the current approach to KM. The interviewees showed their diverse opinions on KM, but they all had a general concept of KM and already realized its importance.

In a word, they recognized that KM was to store and transfer the knowledge for further reuse. Interviewees claimed that KM was very important for the organization to accumulate the knowledge and it could help improve the employees. The correct understanding of KM is good for KM implementation in the enterprise. Understanding KM importance is the first step to implement it. In the current situation, interviewees share their knowledge and experiences via a lot of existing materials, general courses, seminars, phone meetings, meetings during projects and after projects and social platforms.

The need for a tool to support localizing and mobilizing of knowledge and competencies, clearly emerged from several parts in interviews. An important finding of this first round of interviews is that all the interviewees recognize difficulties in finding "who knows what" inside the organization, as well as the lack of information on projects and research followed by different departments.

As concerns KM, an efficient and effective tool to optimize the use of internal knowledge resources among projects, potentially improves the whole company performance, allowing organizational learning and avoiding the internal reinvention of the wheel. The lack of systematization and storage of the knowledge created and accumulated in projects in a form suitable for reuse is an issue that emerged as critical in the interviews. In fact, several interviewees admit that they generally do not have clear procedures to archive project documents and, even though they have them, as for software generation and versioning, they normally do not follow them.

According to the interviewees' opinions about the concept and importance of KM that indicated KM is used as an information system to transfer the knowledge. For example, it is used as a database to manage and store knowledge for employees to use and share. Thus, KM was very important since it could provide knowledge for employees to learn to improve themselves. Beside, KM could help the company accumulate the knowledge that was the most precious asset. The aim of knowledge management was to accumulate and transfer knowledge. Interviewee B1 pointed out KM is important for three reasons. Firstly, it is an effective way to hand over the knowledge to new employees. Secondly, it offered a good platform for employees to communicate with each other. Thirdly, KM provides good opportunities for those who wanted to obtain knowledge. And another one said that KM was about organizing the knowledge according to various categories and through the way of classification and researching to get the knowledge needed more easily. Therefore, its importance was that, through KM, people could find the information conveniently. Employees, also emphasized they should learn new and cutting-edge knowledge in order to catch up with fast-developing information technology; hence, effective KM would help them to update the knowledge timely and efficiently.

2.3. Conceptual Framework

This section introduces a conceptual framework for an internal knowledge market, which may suit the context of PBOs. In developing such a framework, we consider the main KM issues in PBOs that emerge from the literature review and the results in terms of needs and requirements of the first round of interviews.

To construct a knowledge market model, we must go back to the nature of knowledge goods and their characteristics. As already noted, Müller et al., (2002) introduced a separation between goods of material nature and those that can be traded but have no physical substance.

The first is digital products, i.e. information that is already stored in a completely digital form and can be transferred over communication networks (Luxem, 2000). These products include documents, manuals, procedures, rules, and links to external resources, etc.

The second category is "intangible goods", such as advice, guidance, consulting, concepts and know-how. In the area of intangible goods, we introduce a further distinction of goods into those that can be easily and conveniently made explicit in order to be transferred and those that cannot. To this purpose, the literature distinguishes between the knowledge that has not been formalized or made explicit (Zander and Zander, 1993), and the knowledge that cannot be formalized (Popper, 1972; Nonaka and Takeuchi, 1995; Howells, 1996; Hansen et al., 1999). The first kind includes, for example, the knowledge that can be easily translated in explicit answers that experts can provide online to colleagues (seekers) in order to help them to solve a specific issue, and thus potentially saving time and money. The second kind is tacit knowledge that is at best difficult, and at worst impossible, to articulate, as it is highly situated in a context and abstracting it from its context of application results in losing much of its intrinsic meaning and value (Kakabadse et al., 2001). It is precisely this tacitness which makes this knowledge difficult to imitate or import from organization to organization and, therefore, makes it an important organizational resource in securing competitive advantage (Grant, 1996). As we claimed in the introduction, this kind of knowledge is the most relevant for PBOs and it requires direct interaction between expert and seeker in order to be shared. In fact, we should make a further distinction between cases in which the interaction needed to transfer tacit knowledge could conveniently occur online, e.g. a Skype conference, and cases in which knowledge transfer would require more time and a deeper sharing of 'mental models' (Johnson-Laird, 1983) as they are strongly context-specific and complex. In the following, we will consider only the latter situation that, as already noted, is usually the case in PBOs. Moreover, in the context of PBOs, knowledge transfer does not necessarily imply knowledge sharing, as the goals of knowledge absorbing and learning are not paramount concerns. In this case, project managers are interested in temporarily acquiring talented knowledge resources to complete their project teams, in order to satisfy emerging customer needs and seize new opportunities in the market. For all these reasons, knowledge transfer through online interaction is usually infeasible in the context of a PBO, while it needs the temporary relocation of the expert in a new team.

This distinction of knowledge goods in digital products and easily explicit-able knowledge goods, i.e. digital goods, on one side and tacit knowledge embedded in people's minds, on the other, has important implications for the design of a proper knowledge market. It is worth noting that, as reported in Figure 1, both the types of knowledge goods are based on expert time, which the literature (see e.g. DeFillippi and Arthur, 1998; Jugdev and Mathur, 2012) as well as the interviews recognize as a key resource for PBOs. By focussing on the internal trade of this strategic knowledge good, we aim to address a specific gap in the management literature. In fact, the literature, while recognising that managing knowledge-intensive resources is a critical issue in PBOs (see e.g. Dubois and Gadde, 2002; Lindkvist, 2004; Whitley, 2006), largely neglects the market-based approach to deal with it (see Verbeke et al., 2011 and Bryan et al., 2006 for some notable exceptions).

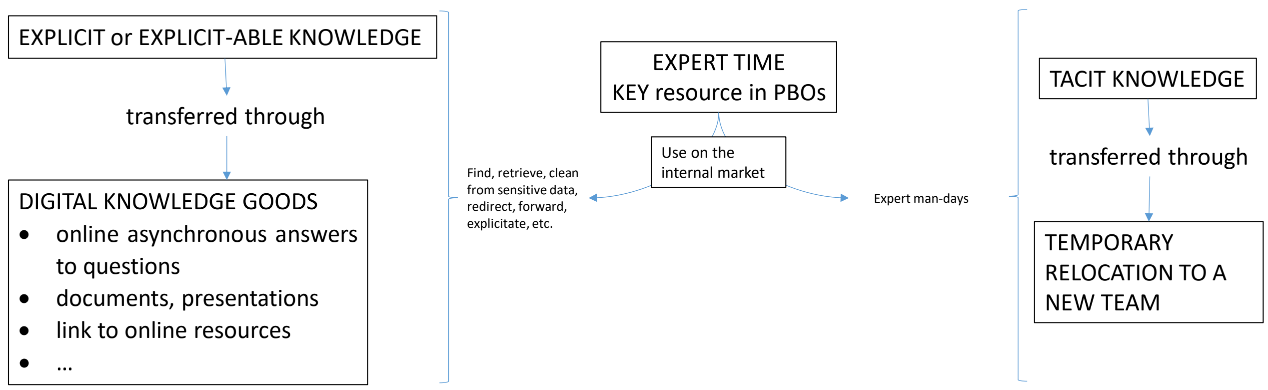

Figure 7 Types of Knowledge Goods Exchanged on the Market

The need for a tool to support localizing and mobilizing of knowledge goods, of both types, clearly emerged from several parts in interviews. All the interviewees recognize difficulties in finding "who knows what" inside the organization, as well as the lack of information on projects and research followed by different departments. As regards the use and development of internal human resources in projects, some interviewees report an "internal war for talents" that systematically favours more powerful and persuasive PMs to the detriment of the weaker, with unavoidable consequences on the respective results. What seems to be missing is a win-win mechanism to exchange knowledge goods internally. Talented people tend to be considered "inalienable property of the managers", in the words of a manager, regardless of the use they make of them, with obvious consequences on missing market opportunities, dissatisfaction, and leakage of talents, overall waste of money. Moreover, the pace of work is tight and when people spend time supporting colleagues who are working on different projects, it takes place on a voluntary basis and it is not necessarily appreciated by the management.

In the following, we will analyze an internal market model for expert-time developed taking into consideration the needs and requirements expressed by the interviewees. We can imagine two main sections of this market where expert-time is embedded in two different kinds of knowledge goods to be exchanged. In the first section, the resources exchanged are digital knowledge goods (as asynchronous answers posted online in response to specific questions). In the second section, the resources exchanged are human beings, i.e. experts, who are temporarily relocated to a new team to carry out specific tasks. The two sections of the market are synergic but we can imagine slightly different working mechanisms for them i.e. different currencies, incentive structures, and organizational support, for the different knowledge goods. Moreover, the market structure should fit with different perceptions of the KM issue within the company, at different organizational levels and for different areas, reflecting, for example, on different motivational drivers and impacts on current business. We propose a single model that integrates the different perspectives and approaches in the literature on knowledge markets and tries to meet the needs emerged in the interviews.

2.3.1. The market for Digital Knowledge Goods

Digital knowledge goods include documents, presentations, link to online resources as well as expert advice, once made explicit as answers to specific questions. Both providing documents, which are already stored in digital form, and expert advice, in the form of written answers, require expert-time, the former to search for, customize and remove sensitive data from documents, the second to be prepared, at least in their first instance. Since expert-time is a scarce resource, we argue that they are "economic goods" until they are stored in a database for further use, thus becoming full-fledged "public goods". In fact, according to definition (Robbins, 1935), a good is "economic" when it is scarce and has alternative uses. This definition applies perfectly to the expert-time needed for reading and understanding the request, searching for the digital knowledge goods to satisfy it and possibly customizing them, or preparing a proper answer, and, finally, posting them on the platform. On the contrary, once these knowledge resources are available to everyone, stored in databases, and the seeker is entirely charged for the cost of finding and customizing them, they become public goods, for which markets have proven to be a failing solution (see e.g. Kogut and Zander, 1993). If we agree that digital knowledge goods can be treated as economic goods the very first time they are provided, we know that their value could be easily and conveniently expressed by a price that represents the meeting point between supply and demand.

Nevertheless, we have to separate the individual level from the project level, in order to design a proper market for these kinds of knowledge goods in a PBO. In fact, while tacit knowledge embedded in digital knowledge goods belongs to individual experts, expert-time belongs, to some extent, to the project and must contribute to its success. Thus, we can imagine two separate mechanisms working at the individual and project levels.

At the individual level, social rewards, such as recognition, peer rankings and professional identity (Boudreau and Lakhani, 2009) usually work to drive participation in internal knowledge markets. Some scholars (Benbya and van Alstyne, 2011), however, claim that participation increases substantially when you can combine three factors: social rewards, intellectual rewards (e.g. learning, problem challenge and autonomy) and material rewards (e.g. frequent flyer points, money or some type of virtual currency).

According to the interviews, the main obstacle to internal collaboration and knowledge sharing across projects is lack of time. Pressed by deadlines, overwhelmed by work, people cannot find time for an activity that could even be disliked at the project level. In the words of an interviewee: "The most important thing here is to meet milestones, we are assessed on them, and frequently this is nothing more than window-dressing: to meet the milestone we overlook the quality of the work. Even if I wanted to, I could not spend time to support colleagues outside the project, it is a matter of respect for my team and my boss would not understand. This is why I do not ask, I do not want to embarrass anyone. I realize that there is something wrong here, but it has to change in high places." Another aspect emerging from interviews is the difficulty for employees to reach visibility at the company level, outside the boundaries of the project. The innovation prize, once a year, and the lunchtime seminars are considered as unique opportunities to break the "project cage" and to be recognized, in some way, as experts of a topic. The problem is that this social recognition is not connected to any form of material rewards such as career opportunities, professional growth, better working conditions (e.g. more autonomy, empowerment, decisional power) or, last but not least, money.

In the light of the interviews and taking account of literature, we claim that employee participation in knowledge markets is, basically, an organizational culture issue that affects the project level, first, to reach ultimately the individual level. At the individual level, the basic condition to participate is to have time specifically allocated for this kind of activity and to feel that the organizational context appreciates and, to some extent, incentivizes knowledge sharing. Of course, motives vary by individual, and incentives must be culturally appropriate. As internal visibility emerged as a critical point in the context examined, we imagine a voting mechanism, which can contribute, positively or negatively, to expert reputation. Importantly, the voting mechanism must be properly designed, as it may lend itself to manipulation and misuse. Reputation gained in this market should be connected to some forms of material rewards to be managed by the HR department. Moreover, expert reputation plays a fundamental role also within the market for talents (detailed in the following section).

The project level emerges from the interviews as the most critical with respect to knowledge and competence management issues. In fact, the costs, in terms of expert-time investment, and the advantages, in terms of problem-solving support, of knowledge transfer have an impact mainly at the project level. Project managers emerge from the interviews as figures strictly focused on their projects' achievements and success, who tend to adopt a "possible consumer" more than a "producer" approach towards knowledge management issues. In the words of a top manager: "Very often what he (the program manager) does is not aligned with what the others do and with the company itself. His goal is his project and his client and, to this end, he could work even against the interests of the company, for example selling products of third parties or giving outside activities, parts of the business, which could (and should) remain inside, allowing potential competitors to enter." The literature confirms this project manager's attitude, as well, which contributes to a systematic strategic misalignment in PBOs (Grabher, 2004; Thiry and Deguire, 2007). Thus, the challenge is to create a win-win mechanism, which fosters the use of the market by project units, both as providers and as seekers of knowledge goods. As the expected advantages of effective internal knowledge markets are mostly at the organizational level, along the three main conceptual dimensions of KM, HRM, and strategy, it is reasonable to assume that the company subsidizes the market to stimulate its use and improve the quality of knowledge goods (Benbya and van Alstyne, 2011). In this context, the subsidy takes the form of a certain amount of some type of virtual currencies, initially assigned to each project unit, to spend on the internal market. Then a market price mechanism, with floating prices based on the offer and demand law to guarantee efficiency (Hirshleifer et. al., 2005), should regulate the exchanges. In fact, market price represents the correct value of a knowledge resource, which takes several aspects into consideration, including its strategic worth for the business, its scarcity (or even uniqueness), its current allocation, the demand for it, and so on. Market price not only guarantees a fair exchange between the parties but it also gives objective value measures to knowledge goods. Of course, in order to work, virtual currencies must correspond to material rewards for the project units, such as resource allocations, opportunities, roles and responsibilities, and so on.

At organizational level, localising strategic knowledge resources, following their paths (who buys what and from whom), being able to measure their value in a rather objective way, and providing a strategic direction through the reward system are fundamental achievements, which affect the three conceptual dimensions of knowledge and competence management in a PBO (i.e. KM, HRM and strategy).

As concerns KM dimension, an efficient and effective tool to optimize the use of internal knowledge resources among projects, potentially improves the whole company performance, allowing organizational learning and avoiding the internal re-invention of the wheel. The opportunity to exchange knowledge goods on the internal market favours the systematization and storage of the knowledge created and accumulated in projects in a form suitable for reuse, an issue that emerged as critical in the interviews. In fact, several interviewees admit that they generally do not have clear procedures to archive project documents and, even though they have them, as for software generation and versioning, they normally do not follow them. Notable exceptions are European Projects, which force participants to produce a lot of documentation, or specific projects with foreign partners or very demanding customers. In these circumstances, an interviewee recognizes (speaking of a job for a client in Singapore), “We started to work properly. They forced us to systematize and archive everything. It was tough, but we learned a lot from that experience”.

Human resources management is a key dimension of the market. The problem that also emerged from the interviews is that often the corresponding organizational function (HR) is weak compared to the structure for projects and does things that are perceived as useless. They would like to act transversally to the projects but do not succeed, they often do not know who does what and every attempt they made to map the skills became obsolete before being used. The human resources function with respect to the market is one of the main "internal customers" that have the motivational levers necessary to make it work. The location of the most active areas, the identification of the dead areas, the givers and the takers, the internal gaps should inform the reward system, the internal distribution of resources as well as the recruitment and training planning. The most important aspect of this synergy between market and HR is that it is based on daily operations, on exchanges that take place as a meeting point between emerging needs in the daily business and knowledge ready and available to satisfy them. The precious knowledge of the internal network of exchanges and the value attributed to each knowledge good in a given circumstance is a by-product, perhaps even more important, of the exchanges themselves. No less important is the active role of the HR management system in the development of the market, through the above: the informed distribution of internal resources and development planning through training, recruitment or external collaborations. In this type of action, the dimension of HR and that of strategic development go hand in hand. Programs and projects are recognized by the literature as vectors of strategy. Shenhar et. al. (2001) emphasize that projects and especially project portfolios are “powerful strategic weapons” as they can be considered as a central building block in implementing the intended strategy (Dietrich and Lehtonen, 2005; Grundy, 2000).

We can imagine that strategic development is based, among other things, on the recognition of core areas of competence most urged by business development, those that take on the role of giver nodes in other areas in the internal knowledge market. It should be noted that these are not skills on the card, but "active" skills that are currently used in projects. The recognition of the uncovered and less stressed areas assumes importance. This knowledge complex, besides informing the HR action, can also play an important role in the development and implementation of the corporate strategy in PBOs, which consists, in large part, of evaluating, prioritizing, and selecting the "right projects "(Morris and Jamieson, 2005; Shenhar et. al., 2001). Selecting projects to invest in means strengthening those specific areas of knowledge, making precise positioning choices in a coherent way and at the level of the entire organization. According to the interviews, this aspect is largely neglected, as well as an organizational strategy, in terms of technology development. In the words of a manager: "The customer even guides us in the technologies to be explored. If there is a technological map of what we will have to know tomorrow, well it often comes from the customer, who tells us, deepen these technologies because I know that I will need them. Instead of being the drivers, the proponents ".

This outwardly focused strategy largely neglects the importance of internal knowledge resources, which, on the contrary, large streams of the literature put at the heart of strategic thinking. In fact, according to the knowledge-based view of the firm (see e.g. Grant, 2002), which builds upon and extends the resource-based perspective (Penrose, 1959; Wernerfelt 1984, Barney 1991, Conner 1991), knowledge is the most strategically significant resource of a firm. This rich stream of the literature claims that a sustainable competitive advantage derives from mapping organizational knowledge resources and capabilities against strategic opportunities and threats, to better understand points of advantage and weaknesses and to act consequently (see e.g. Prahalad and Hamel, 1990; Kogut and Zander 1992; Zack, 1999). More recently, the open innovation concept, far from denying the value of the resource-based view and the knowledge-based view, extends these perspectives adding an external focus. Whereas the resource-based view and the knowledge-based view emphasizes that a firm's competitive advantage results from difficult-to-imitate bundles of resources within the boundaries of the firm, open innovation stresses the interdependence of complementary resources of firms to introduce innovations in the market (Vanhaverbeke et. al., 2008).

2.3.2. Market for Talents

The second form of knowledge exchanged on the market is tacit knowledge embedded in people's minds, thus not separable from individuals. Therefore, expert time itself is a scarce resource that can be quoted and transferred from one project unit to another. Thus, we imagine a market for expert-time in the context of PBO whereby project managers trade time slots of "their" experts, i.e. man-days of knowledge-intensive human resources currently allocated on specific projects. In fact, what usually happens in PBOs is that experts, even if they are not best allocated (or not full-time best allocated), risk remaining stuck within a project border for several reasons, including scarce visibility and a misleading concept of "property" that some managers develop over human resources. This situation has emerged several times in the interviews and is confirmed by the literature. For example, an interviewee reported the case of a brilliant colleague that was under-employed in his project unit and so he looked for a new opportunity inside the company. He found it in another division, took contacts with the pm, who really needed him and would be an enthusiast to take him on board in his project. Unfortunately, when the "new" pm made the request to the human resources, which agreed and asked for him to his current boss, this latest did not let him go. People are power also recognized in the literature. Sometimes, a project manager simply does not want to lend a valuable resource to a colleague in exchange for nothing. Thus, prices, as already observed in discussing digital knowledge goods, seem to be the best way to guarantee fair transactions and give fair value to a knowledge resource, in this case, represented by expert-time. Moreover, charging the cost of an internal expert on a project budget is not such an awkward issue in a PBO. However, it is worth noting that the internal transfer of money from a project budget to another has nothing to do with the expert wage. In fact, as some scholars observe, the objective of a business is to maximize profits per worker rather than wages per worker (Bryan et al., 2006). If the internal market for experts allows for improved allocation in terms of value per hour and, especially, in seizing new market opportunities and expanding the business, then it is clear that it also pursues the objective of maximizing profits per worker.

Also, in this case, it is possible to make evaluations concerning the three levels, individuals, team and organization and the three dimensions of knowledge and competence management in PBOs. Many considerations are similar to those made for the digital knowledge goods market and will not be repeated.

In the following, we will try to highlight any differences with respect to the previous case and aspects not previously found.

At the individual level, as already noted in the previous section, recognition and reputation are powerful motivational drivers provided that the company implements synergic organizational and managerial policies. In fact, internal knowledge markets can bring evident advantages to companies that succeed in building them, yet, on the other hand, they require commitment and specific investments. At the individual level, the opportunity to gain experience outside the project unit, in different contexts, in contact with different pm and teams, helps to enrich individual skills and professional maturity. The opportunity for human resources to grow internally, acquiring greater autonomy and responsibility in relation to the results obtained, especially if related to material recognition such as career paths and remuneration, contributes to increasing professional satisfaction and reducing the risk of escape

At the project level, the main motivational drivers are connected to the possibility of extending current business and catching new opportunities on the market, leveraging on internal resources that should be available at lower transactional costs than external ones. A possible alternative to internal resources is hiring new resources, an approach hardly taken due to its high permanent costs compared to the uncertain returns of new businesses. A second possibility is to involve other companies as suppliers or partners. In an interview, a pm admits: "For me, a project manager, often the external resource costs me less than an internal resource, as well as being easier to find, without having to ask colleagues for help. The problem is that we often find resources that are also very good, the customer binds to them and continues to ask us but these do not always remain available to us a little because, luckily for them, after a while they evolve and leave, a little "because the companies themselves that sell them get smart ...".

In fact, this latter choice may seem more convenient from the strictly economic point of view (if one looks at the mini-balance sheet of the project), but it entails hidden costs connected to the risk of opening the path to possible competitors. Even in the case of an apparently solid business, in which the company is an incumbent actor, the risk of disruptive competition can't be neglected. Thus, leveraging internal resources to extend current business takes the meaning of sharing the risks as well as the connected returns within the enterprise. The market mechanism should make the resource convenient for the buyer, compared to the external market, and, at the same time, should give an economic return, on top of the current project, to the seller. A project unit may accept to temporarily deprive itself of a valuable resource, provided that it is adequately remunerated.

It is important to emphasize that the unit that sells the expert internally, given that his skills are central to the value chain of the project, is generally able to cover his lack with similar skills within the unit, thus optimizing the use of internal resources. If the unit that sells should also cover the lack by buying from outside, it would be a better buyer, more aware and informed than the unit he buys. In fact, the latter is buying a resource that is outside its value chain and therefore has fewer tools to evaluate it and is more likely to buy above its real needs

At the organizational level, the same applies to the knowledge goods market. The knowledge of the internal network of exchanges, the evidence of possible skills gaps, of the most active areas and of those less central to the business is fundamental to set up reward mechanisms, the internal distribution of resources, human resources development policies such as programs of training, recruitment, and internal growth paths. A typical role of human resources but, as emerges from some interviews, they are currently unable to play. From the interview with a pm: "The human resources function is very weak and does not manage to get into this (to support the internal search for profiles and facilitate internal resource movements etc.). They would like but can't. They do things that help themselves and are also partly mandatory. Last year they let us all do a CV online but when I needed about twenty CVs for a project and asked them, they couldn't get it back. So I picked up the phone and asked my colleagues directly ". In this case, the internal market supports the localization of skills and their mobilization within the company. In this case, however, unlike the knowledge goods market, the organization does not finance project units with money to spend on the domestic market, it can do it initially to get it off the ground but then it should support itself. The organization, in this case, supports the use of the internal talent market, through the recognition, accompanied by measures of premiums, of the most central areas of knowledge for the company, the givers, the takers of the dormant areas, and individual performance.

We believe that, both in terms of knowledge management and skills, human resources management and strategic development, the market can bring to the organizational level the necessary knowledge, deriving from real interactions, to set appropriate growth policies and of competitive positioning.

Figure 8 shows the framework of the whole market, i.e. the market for digital knowledge goods on the left side and the market for talents on the right, and highlights the three main levels and conceptual dimensions involved.

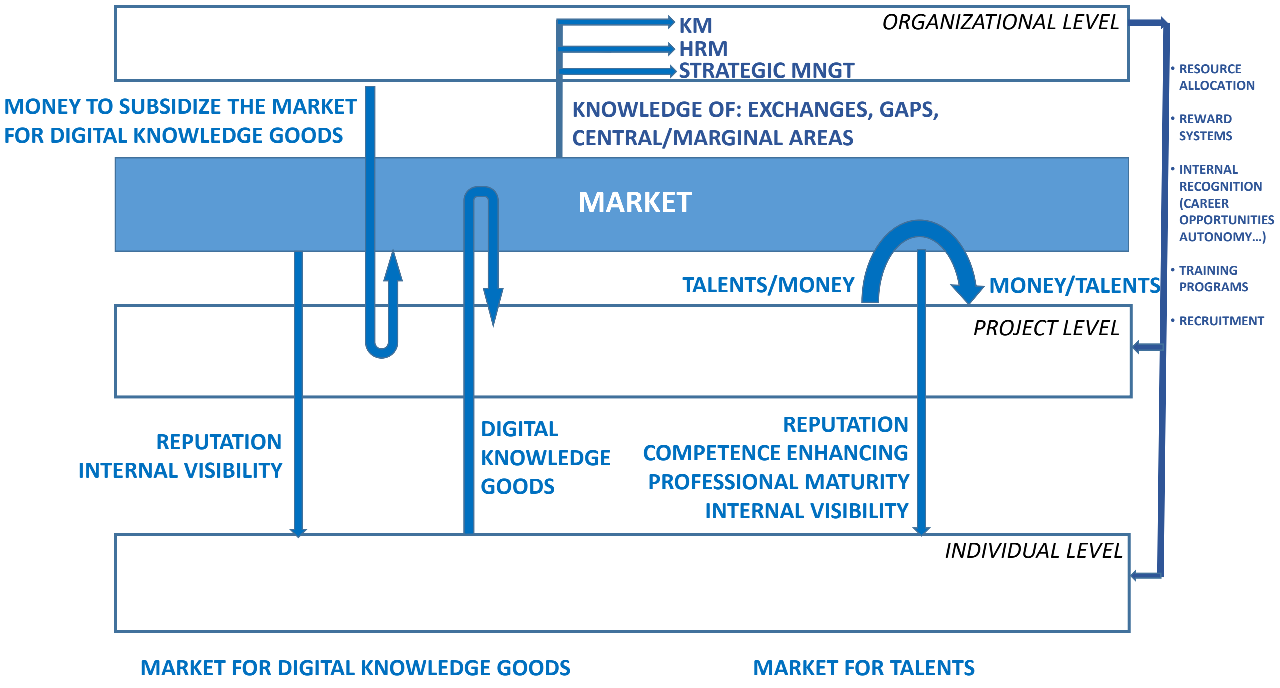

Figure 8 Conceptual Framework of the Market

2.4. Second Round of Interviews and Discussion

When we presented the framework to the interviewees during individual face-to-face interviews, we had a substantially unanimous response to the current inadequacy of the company to adopt a knowledge and competence management system of the type proposed. The reasons, attributable to elements of organizational culture, have emerged, accompanied by examples taken from previous experiences, with extreme consistency at all the hierarchical levels taken into consideration, with more or less critical tones. Surely the companies, due to the peculiarities of the sectors in which they operate, present, in some cases, internal obstacles that are difficult to circumvent. However, we believe that the examination of the main obstacles emerged and of the possible hypothesized solutions, also in the light of the literature on PBOs, may have a more general validity compared to the single case and concern, perhaps with different intensity, a wider set of business situations. We will, therefore, try to discuss the main points that emerged and to draw up appropriate guidelines and design caveats for a knowledge management system in this type of company.

There are internal barriers to the possible adoption of the system. The interviewees pointed out several organizational and managerial critical issues for knowledge and competence management inside the organizations.

According to the interviewees, the main obstacle to internal collaboration and knowledge sharing across projects is lack of time. Pressed by deadlines, overwhelmed by work, people cannot find time for an activity that could even be disliked by managers at the project level. There is no time dedicated specifically to KM activities. However, projects rarely go as planned (in terms of time), and PMs (teams) may work on several projects simultaneously, and/or start a new one right after finishing a previous one. In that case, they rarely spend time even on formally acknowledged project reviews. Another finding is that due to mostly informal nature of knowledge sharing the interviewees on the team members level reported to spend a few of overall working time either searching/asking around for required information or consulting their colleagues. Especially it is topical for active implementation phases of projects. Similarly, to the perception of the overall KMS, the views regarding the time issue are different on the management level and the project level. On the one hand, some managers believe that it is a personal responsibility to create place and time for learning more and that there are formal ways to report the time spent on knowledge sharing. On the other hand, when it comes to, many interviewees state that they do not have time to post information or answer a question regularly and to do it with the proper quality. Explicit and tacit practices of individual time management are an important component of how professionals complete project tasks within their daily routines. Project managers play an important role in leading a successful project, and their time orientations directly affect all project phases (D. Wu and K. Passerini, 2013).

Interviewees recognize that the structure of an organization can have a major impact on project management. PBOs organizational structure combines a team of experts from different disciplines to achieve a common goal within a given amount of time and resources.

According to interviewees, the project manager ensures the availability of the right kind of person for their projects. It is also seen that some projects appoint experts on a full-time basis even though the full-time participation of the person is not required. Under these circumstances, the project manager finds it difficult to divide the job equally among his team members. It is also found the scope of individual learning is very limited in project organization structure due to the non-availability of repetitive jobs. The literature confirms this project manager attitude, as well, which contributes to a systematic strategic misalignment in PBOs (Grabher, 2004; Thiry and Deguire, 2007) In this case, project managers are interested in temporarily acquiring talented knowledge resources to complete their project teams, in order to satisfy emerging customer needs and seize new opportunities in the market. For all these reasons, knowledge transfer through online interaction is usually infeasible in the context of a PBO, while it needs the temporary relocation of the expert in a new team. Managerial support is the major success factor for knowledge transfer across the projects. Managers can enhance team capabilities and performance via their strategies to support knowledge transfer across the projects. Regarding senior management support and leadership, the interviewees all indicated that although there was no specific strategy for knowledge management implementation, the top management encouraged employees to share the knowledge; besides, they delegated an internal IT team to support the enterprise knowledge management, for example, to maintain the network and system in order to ensure IT facility satisfied for KM.

In the light of the interviews and taking account of literature, we claim that employee participation in knowledge markets is, basically, an organizational culture issue that affects the project level, first, to reach ultimately the individual level. Interviewees confirm the literature that a company`s organizational culture encourages knowledge sharing. The process of knowledge sharing can be supported by the organizational culture which is a set of values and norms giving identity to each organization.

Communication is an important issue in the literature and it is confirmed by interviewees. One interviewee believed his company provided an open-minded environment for employees to discuss and share their own opinions. Everyone could propose its viewpoint, even against others; and they respected those diverse thoughts. The team members in the project team frequently communicate with each other. Moreover, the project team also held regular meetings to share experiences and sometimes invited experts to give lectures to transfer technical knowledge. But communication between different teams was a little poor because each project team was responsible for a different project.

When the interviewees were asked about their impression on the teamwork relationship among the colleagues, they showed diverse views. Some interviewees claimed that the personal relationships within their team were good, and team members were keen on communicating with others to solve the problems together. On the contrary, they thought the cooperation and sharing between the project teams were not enough developed. Moreover, they agreed that there was a lack of communication across the teams. They considered that the communication between teams was not frequent because of two reasons; one was that employees were very busy with project deadlines, even though they were willing to share the knowledge. The other reason was that people were shy to share knowledge and personal views with others especially those not related to their own work. A trustworthy personal relationship is a significant condition for people to communicate with others. Due to companies` culture, people were afraid of conflicts. As we can see, a trustworthy personal relationship is important anyhow. Constructing a trustworthy personal relationship is long-term work, at first, employees should give trust and respect to others. Besides, the organization should create an open-minded atmosphere for knowledge sharing, so that employees can be encouraged to speak out their diverse opinions. Firms are now focusing on mutually gaining access to the knowledge bases of their partners, by developing a stable relationship based on mutual trust as their main governance mechanism.

From the interviews, IT support is important for project teams to manage documentation. Normally, the information would be spread by email, but email was not an effective way to deliver the news. Since the employees would receive amounts of emails, so information is lost inside these emails. Except for email, employees used social networks for information sharing. In order to improve communication, the knowledge market could be a good platform for employees to discuss technical issues and share knowledge. ICT-systems can effectively support communication, storage, and retrieval of knowledge in a temporary project environment. The literature identifies three types of boundaries in the PBO context – within projects, between projects and between project (s) and the organization - and show, in particular, the role of ICT in managing those boundaries (J. Yeow 2014). The use of a collaborative Web-based tool, which is easily accessible, intelligible and user-friendly, allows more effective sharing of project knowledge and overcomes existing problems with lessons learned (A. Wiewiora and G. Murphy 2015). The internal knowledge market is a platform that people can use to share their knowledge even if they have limited time, thanks to market price and voting mechanism.

From the interviews, we know that most companies don`t provide any training on KM such as delivering the knowledge and principle of KM or giving guidance to show how to use related systems and tools. The employees learned the technological tools during the use. Although they could handle the tools since they had an IT background, it was not efficient because they had to spend time familiarizing themselves with them. On the other hand, since it lacked-of formal training on KM, the employees couldn't gain enough knowledge, it was hard for the company to carry out the KM activities. For example, one interviewee mentioned that some forms of knowledge in the database were not read easily because the templates of documents were not unified and the forms of knowledge storing were various. If the company could provide prior training to teach the employees how to store the knowledge in a unified format with a structured template, this problem could be addressed. Besides as indicated above, many employees had a general conception about KM, but because of lacking related training, they didn't know about exactly what KM actually did and what their roles were in KM activities; hence, it would hinder successful KM implementation. Proper training not only helps to construct awareness of how to define the knowledge and perception of how to think about KM but also helps the individuals to cognize their roles for managing knowledge.

Interviewees report when new employees were on board, some experts and old employees would teach them the necessary knowledge in order to make them handle the work quickly. Also, project teams would invite experts to give lectures to transfer knowledge. In this situation, experts play a vital role in employee development and facilitating share of knowledge. Some scholars suggested companies set up communities of practice especially in a team-structured organization in order to capture and spread ideas and knowledge. They pointed out communities of practice as an effective way to drive strategy, to solve problems, to spread knowledge, to promote best practices and to complete projects efficiently. It's better to create a community of practice to bound these experts together. There are two benefits of a community of practice. On one hand, it can promote best practices effectively such as lectures so as to spread and share knowledge. On the other hand, it also can help drive the strategy to implement KM successfully; and at the same time, this organizational form won't destroy the organization structure.

Another aspect is human resource management in PBOs. The key role of HR in managing competences in PBOs and underline that human resource policies are not only administrative procedures for managing human resource flows but behavioural patterns that underpin the HR capabilities The knowledge of the internal network of exchanges, the evidence of possible skills gaps, of the most active areas and of those less central to the business is fundamental to set up reward mechanisms, internal distribution of resources, human resources development policies such as programs of training, recruitment, and internal growth paths. A typical role of human resources but, as emerges from some interviews, one they are currently unable to play. One interviewee said that the human resources function was very weak and did not manage to get into this (to support the internal search for profiles and facilitate internal resource movements). They would have liked but couldn't. They did things that helped themselves and were also partly mandatory. Project managers cared using proper human resources in projects as a vital part of project success. As regards the use and development of internal human resources in projects, some interviewees report internal knowledge good exchange is a missing part. Because talented people are considered the main resource for successful projects and taking market opportunities, it is a strategic issue. Moreover, people that were considered talented individuals got failed when worked in a team environment with wrongly allocated human resources. This is an important human resource issue faced by most of the project managers. In fact, human resources are vital parts in PBOs and human resource management is crucial according to interviewees` answers. People are power. Project success depends on the right skill maps in the project. Managing human resources involves recruiting people, developing people, maintaining the right mix of people, and creating conditions that will result in high motivation of individuals. Interviewees report human resource issues in project management. One interviewee said that delegating responsibility and authority is crucial. A team needs to be able to develop and grow as individuals and as a whole, not be held back by low expectations or ego. Building a team is important. Each member of the team should be clear on their role, know where they fit in and feel as though they can depend on one another. Also in real-time feedback is important. If you do something wrong you should know it immediately. Regardless of right or wrong, the further removed feedback is in time, the less effective it is. The identification of gaps is important for distributing internal resources, as well as the recruitment and training planning. The most important aspect of this synergy between HR and market is that based on daily operations, on exchanges that take place as a meeting point between emerging needs in the daily business and knowledge ready and available to satisfy them. HR management system in the development of the market, through the above: the informed distribution of internal resources and development planning through training, recruitment or external collaborations. In this type of action, the dimension of HR and that of strategic development go hand in hand.

On the other hand, people don`t want to support and to share their knowledge with colleagues without any incentives and being appreciated by the management. Knowledge sharing originates from individuals, thus knowledge is intimately and inextricably bound with people's egos and position (Davenport and Prusak, 1998). Economic reward and reputation are powerful motivational drivers provided that the company implements synergic organizational and managerial policies. Interviewees report that economic reward and reputation have a significantly positive relationship between improving the quantity and quality of knowledge contribution and sharing. The voting mechanism, which can contribute, positively or negatively, to expert reputation must be properly designed, as it may lend itself to manipulation and misuse. Reputation gained in this market should be connected to some forms of material rewards to be managed by the HR department. Feedback reputation plays an important role in knowledge sharing. Employees choose to do other assignments that are directly related to the reward system and performance evaluation criteria rather than sharing the required knowledge requested by others. In addition, reputation makes individuals know that their knowledge can help others, which increases their sense of honour and peer recognition and a sense of pleasure. Moreover, the main motivational drivers are connected to the possibility of extending the current business and catching new opportunities on the market, leveraging on internal resources that should be available at lower transactional costs than external ones. One interviewee said that the internal knowledge market could solve the problem without asking colleagues for help. People can find the resources easily via price and voting mechanism. Price not only guarantees a fair exchange between the parties in the market but reputation via voting mechanism provides a fair exchange. However, we claim that participation increases substantially when you can combine three factors: social rewards (career opportunities, professional growth, better working condition), intellectual rewards (e.g. learning, problem challenge, and autonomy) and material rewards (e.g. frequent flyer points, money or some type of virtual currency).

In order to evaluate the current status of KM in different companies and explore the problems to seek the possible solutions to improve the KM implementation, the analyzed results from the interviews were listed as themes. All the themes emerged from results. From the different categories of interview questions, the themes of training, top management support, knowledge sharing, and trustworthy personal relationship, information technology, human resource management, employee involvement and motivation, and organizational culture directly emerged. With the interviewees' answers to the concept and importance of KM, and competence management. Internal knowledge and competence management is a particularly critical issue in large PBOs dealing with complex products and systems. The theme of understanding of knowledge management was created in order to analyze how interviewees' understanding of KM would influence KM implementation in the organization. From the analysis of the interviewees' answers to the concept and importance of KM, and competence management, the employees result to be aware of knowledge management and realize its importance. Moreover, the experts in a project team should help spread knowledge. Systematic training on KM is lacking; for example, there is no training on storing knowledge in a structured format; as a result, knowledge is not stored properly. Furthermore, it hinders knowledge sharing. Proper training on KM is required in organizations because it, not only helps to construct awareness of KM but also helps the individuals to cognize their roles for managing knowledge. In an organizational structure, top management's leadership is very important. Top management should take leadership including creating the vision, strategy, and process of KM for organizations. Only strong leadership could provide clear direction and deploy KM activities successfully. Moreover, with formal KM process can define and implement the activities in a systematic way. If there is a problem happened during KM implementing, it will be easy to check with a systematic process. Although the employees cooperate well with others within the project team, the communication across teams is not effective and frequent. To solve this problem, a trustworthy personal relationship is essential. Specific traits of PBO's culture, which are frequently associated with inefficiencies, distorted behaviours, and strategic misalignment, reject the idea of an internal market for knowledge and competencies. The organizational culture encourages knowledge sharing and values teamwork, it provides an open-minded environment for communication. What it should do is to support the construction of trustworthy personal relationships and enhancing of communication among the project teams so as improving knowledge sharing. Confronting managers and employees with the conceptual framework of a possible internal knowledge and competence market is useful to shed further light on these cultural aspects and to introduce win-win mechanisms in the market design in order to overcome and possibly leverage them. Using a reward system to motivate employees to create and share knowledge is important. But the only reward system is not enough to involve employees in KM implementation in their daily work. The employees are not obliged to document their activities. Thus, knowledge storing is not made in a timely manner. To address this problem, linking KM activities to performance measurement would be a good solution. Moreover, maybe human resource management is the most important issue than others. Right human resource allocation helps to manage and share knowledge. Human resource management covers competence management and it is important to manage projects successfully. The result of this research can be referred to as the analysis to find a solution to address current problems and it shows that KM and competence management is crucial for project-based organizations.

CHAPTER 3: UML MODEL FOR INTERNAL KNOWLEDGE MARKETS

In this chapter, we focus on knowledge assets that are shared or traded in the internal knowledge market, use case diagram of market and phase-based Sequences of Operations UML model of internal knowledge market. We considered the phases of knowledge transfer or sharing between expert and seeker. With the UML method, we show each phase of knowledge transfer in the internal knowledge market.

3.1. Internal Knowledge Markets

The idea of the internal knowledge market is a possible solution to manage knowledge transfer inside the organization. It helps to match the knowledge seekers (consumers) with the knowledge sources (experts/solvers). This matching can be at the organization level (Ex: branch offices and headquarters) and also individual level (seekers) and experts). For matching, the most important thing is information sharing. Because of that, there are incentives such as material or social incentives. These are all for encouraging information sharing.

Internal knowledge markets are based on the pricing mechanism. The price for the knowledge object is directly related to demand and there is a direct proportion, meaning that it increases or decreases with demand. But if there is no demand, also there is no reward, while a high demand directly affects high revenue.

Inside the company, demands are individuals. So we can say that internal knowledge markets are highly similar to “peer to peer” (P2P) KMSs. These systems always support knowledge transfers, and also provide incentives to the experts and at the same time attract the knowledge seekers and preserve the quality of the tradable goods.

The internal knowledge market is a kind of platform that is IT-supported and the value of the platform has a direct proportion with the users. More users mean more valuable platform. It grows more when more users start to register. With the advice seeker and expert registration, the knowledge market can grow and we can say that it is a connection tool between users and experts and also expertise they might not know.

Knowledge goods in digital products and easily explicit-able knowledge goods, i.e. digital goods, on one side and tacit knowledge embedded in people’s mind, on the other, has important implications for the design of a proper knowledge market.

3.2. Knowledge Assets as Tradable Goods

A knowledge asset is any type of knowledge held or in use by an organization. Let us consider knowledge assets in the context of electronic marketplaces. They may be classified as non-commodity goods traded in e-markets under labels as “digital products”, “nonmaterial goods”, and “information assets”. To reduce complexity, we limit ourselves to only two kinds of knowledge assets to be traded on the market: digitally documented knowledge and expert advice, i.e. a digitally traded service.

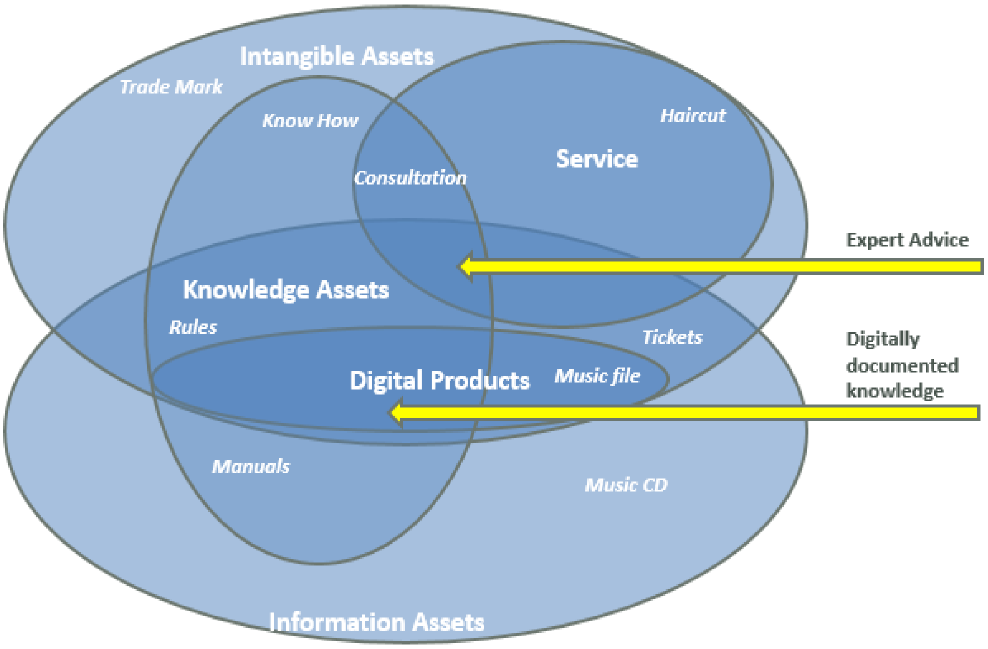

Figure 9 Knowledge Assets

3.2.1. Digitally Documented Knowledge

Digitally documented knowledge is a digital product that information is already stored completely in digital form and can be transferred over communication networks as a file or a set of files (Luxem, 2000) Digital rights for a service or a material product, such as concert tickets, airline tickets or similar certificates, are excluded from digital products as the object of the right is not a digital product.

Manuals, documents, procedures, presentations, project drafts, applications, libraries, etc., are digitally documented knowledge.

This knowledge can be easily translated in explicit answers that experts can provide online to colleagues (seekers) in order to help them to solve a specific issue, and thus potentially saving time and money. (Kakabadse et al., 2001).

3.2.2. Expert Advice

Expert advice is a digitally traded service, which is created during the settlement phase in interaction with the advice seeker. Expert advice may include the instant answer from an expert delivered online as well as the expert support in finding/elaborating a solution for a business problem. As regards transferability, the first is similar to a delivered product while the second needs more time to be dispensed and, normally, enduring interaction with the seeker (online or offline). This kind of knowledge is the most relevant for PBOs and it requires direct interaction between expert and seeker in order to be shared.

3.2.3. Digitally Documented knowledge VS Expert Advice

Digitally documented knowledge and expert advice are different in many aspects that impact on their tradeability, thus requiring different strategic choices on the design of the trading process. For example, they differ for individualization degree (digital documented knowledge is low, expert advice high degree for individualization), transfer mode and cost structure.

Both kinds of knowledge assets are tradeable on the knowledge market, but some differences exist between them. For example, different pricing schemas could be imagined for them, taking into consideration their different cost structures (high fixed and low variable costs for digitally documented knowledge and the opposite for expert advice) and reusability (easy for documents and hard for expert advice).

3.3. A framework for Peer-to-Peer Knowledge Transfer

There are four general transaction phases that are valid for both documented knowledge and expert advice. These four phases are related to transaction costs that incur trade.

The four phases are the information phase, agreement phase, settlement phase, and aftermarket phase.

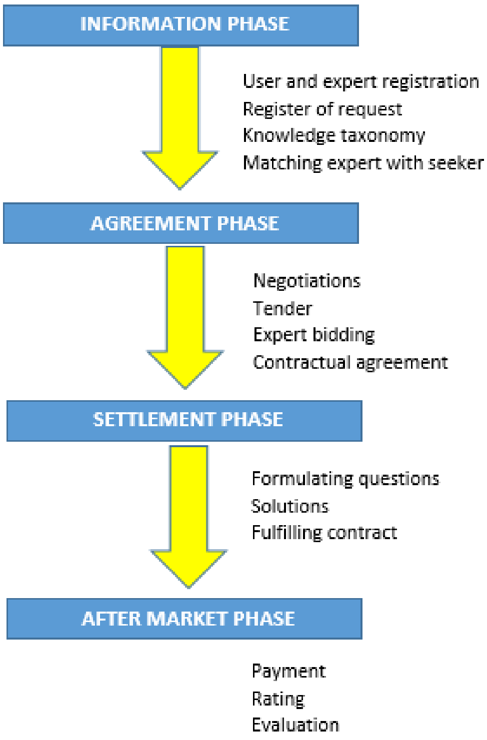

Figure 10 Framework for Peer-to-Peer Knowledge Transfer

The first phase is the information phase. In this phase, consumers (seekers) create a question and system create solvers' competencies list for seekers that help to find appropriate solvers for their requests (questions) according to their competencies. The aim is the perfect matching among advice-seekers and solvers. For the matching, questions are decomposed to separated words and queried inside the list of the competencies with these keywords. These relevant presented competencies can be added and deleted by the advice seekers. Then the system matches the experts according to the right competencies. In this phase, search costs are incurred that can be minimized by matching services. The aim is providing information to the buyers and sellers about the market participants such as their trustworthiness, expertise and the traded goods, quality of the information. Sellers (solvers) can publish products and services and buyers (seekers) can search and the system matches the right supplier to the buyers. Also, demanders (seekers) can publish their information needs. Sellers can recognize these needs and make a request for supplying information needed by seekers.

The second is the agreement phase. Negotiations are concluded in this phase. It means buyers (solvers) and sellers (seekers) negotiate about the conditions of requests and bids. Experts get bid from the seeker and they can agree or make a counter bid to the seeker. This continues as long as one side accepts the other bid or drops out of the negotiation process. In the end, a legal binding contract can be made if expert and seeker agree on the conditions. Negotiations can continue between several possible experts, which are chosen from the list.

As a market mechanism, negotiation can be simple like fix price (take or leave it) offers or auctions that more difficult. In electronic markets for knowledge goods have different market mechanisms. First, the buyer to obtain the knowledge asset, can ask for a tender or make a bid. Second, the sellers can publish their projects and disseminate a call for tender and as a third mixture of both. The price can be fixed or negotiable or the result of an open or closed auction. For the agreement phase, negotiations can increase transaction costs, which can be lowered using market mechanisms.

The settlement phase is the third one. In this phase, seekers formulate their questions and the expert sends an answer to the question. The contracts are fulfilled and goods and services are performed. In an electronic market, the knowledge assets would be transferred. Digitally documented knowledge will be transferred as a file or a set of files. Online expert advice is also performed during the settlement phase in interaction with the advice seeker.

The settlement phase involves transaction costs connected to the time consumed between contract and supply, or adoption of knowledge by the consumer.

The last phase is the aftermarket one. In this phase, the seeker pays the expert and the expert and the seeker rate each other. Payment or the usage of guarantees is performed. In electronic knowledge markets with a quality control system, advice-seekers rate the knowledge assets in this phase. Costs incur when the transaction is disputed in quality or refunds are needed. Quality assurance systems like reputation systems can lower this type of transaction costs.

3.4. Use Cases Diagrams

Interactions among actors (seekers and experts) and the knowledge market are the most important. These interactions are depicted using UML (Unified Modelling Language) use case diagrams based on the transaction phases.

Actors: are expert and advice seeker and both are playing

3.4.1. Use Case Diagram for the Information Phase

User registration, expertise registration, and matching are the three important use cases for the information phase. Firstly, users have to complete registration. This registration includes basic user information like name, e-mail, password, etc. If the user of the system is an expert and want to trade their expertise, the additional information is necessary. The expert has to write about expertise. On the other hand, seekers have to formulate their problems in the knowledge market for perfect matching with the appropriate experts. This matching causes to start of the agreement phase.

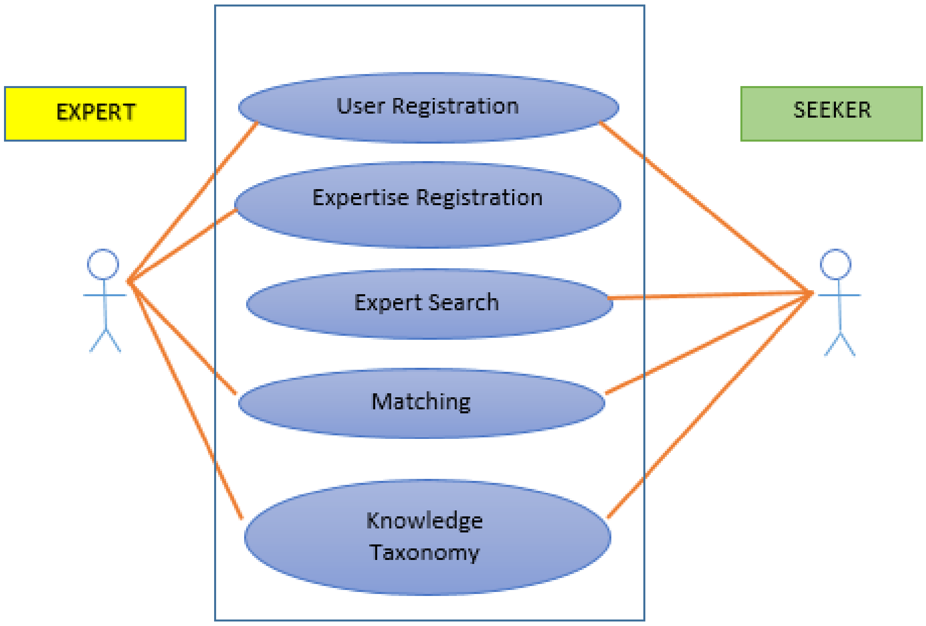

Figure 11 Use Case Diagram for the Information Phase

Linkage	Expert	Advice Seeker
User Registration	YES	YES
Expertise Registration	YES	NO
Expert Search	NO	YES
Matching	YES	YES
Knowledge Taxonomy	YES	YES

Table 6 Linkage cases with actors in the information phase

3.4.2. Use Case Diagram for the Agreement Phase

There are two important cases for the agreement phase. These are tendering and acceptance. This phase has negotiations and the main idea is exchanging the price bids in this negotiation process. The aim is to agree with the price that has to satisfy both sides. When the actors (experts and seekers) accept the price, then the agreement phase ends with the contractual agreement.

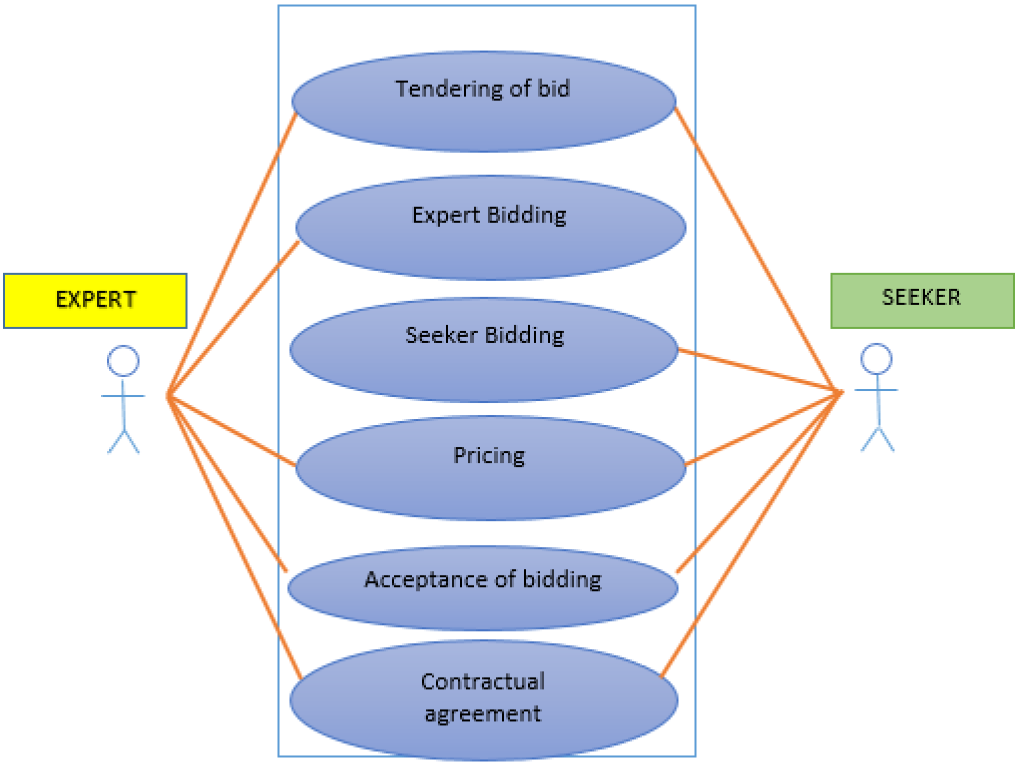

Figure 12 Use Case Diagram for the Agreement Phase

Linkage	Expert	Advice Seeker
Tendering of price bid	YES	YES
Expert bidding	YES	NO
Seeker bidding	NO	YES
Pricing	YES	YES
Acceptance of bidding	YES	YES
Contractual agreement	YES	YES

Table 7 Linkage cases with actors in the agreement phase

3.4.3. Use Case Diagram for the Settlement Phase

There are two main cases in the settlement phase. Submit the questions and responses and the acceptance of advice are the main case. The expert and advice seeker communicate in this phase. Actors interchange questions and responses. The expert's idea is solving the question of the seeker. The question of the seeker is going to be solved as a result of one or more answers from the expert and seekers will evaluate their question as solved. This is the acceptance of the advice. This acceptance will mention the end of the settlement phase and then the last phase will start.

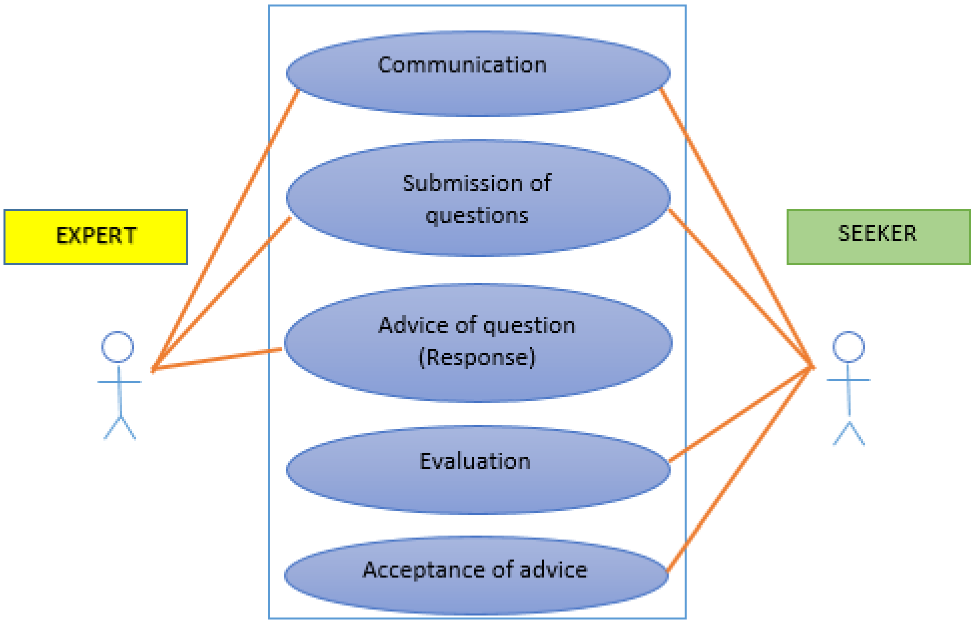

Figure 13 Use Case Diagram for the Settlement Phase

Linkage	Expert	Advice Seeker
Communication	YES	YES
Submission of question	YES	YES
Advice of question	YES	NO
Evaluation	NO	YES
Acceptance of advice	NO	YES

Table 8 Linkage cases with actors in Settlement Phase

3.4.4. Use Case Diagram for the After Market Phase

This phase is the payment phase. The payment that is agreed upon is made to the expert and evaluation is made by both actors. Costs incur when the transaction is disputed in quality or refunds are needed. Reputation systems as quality assurance systems can lower this type of transaction costs. After the exchange occurred, payment and usage of guarantees process during the aftermarket phase. In the electronic knowledge markets, seekers rate the knowledge assets with the quality control system.

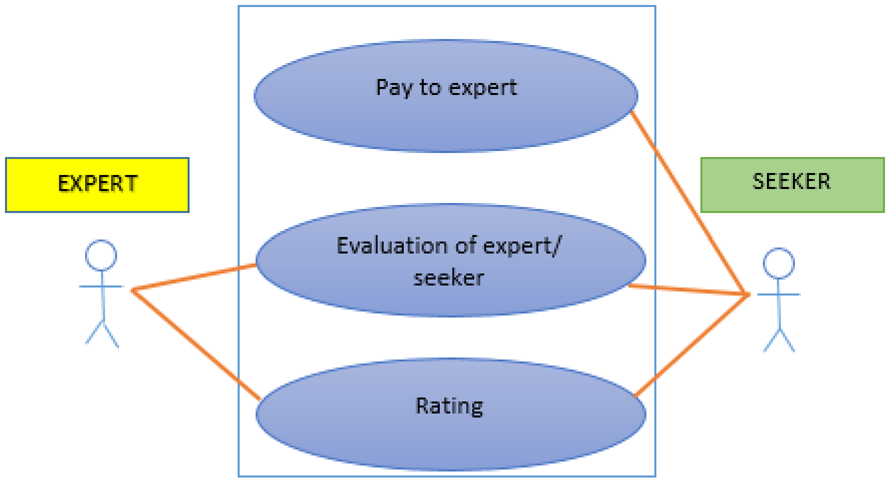

Figure 14 Use Case Diagram for the After Market Phase

Linkage	Expert	Advice Seeker
Payment	NO	YES
Evaluation	YES	YES
Rating	YES	YES

Table 9 Linkage cases with the actor in After Market Phase

3.5. Phase-based Sequences of Operations

3.5.1. Operations for the Information Phase

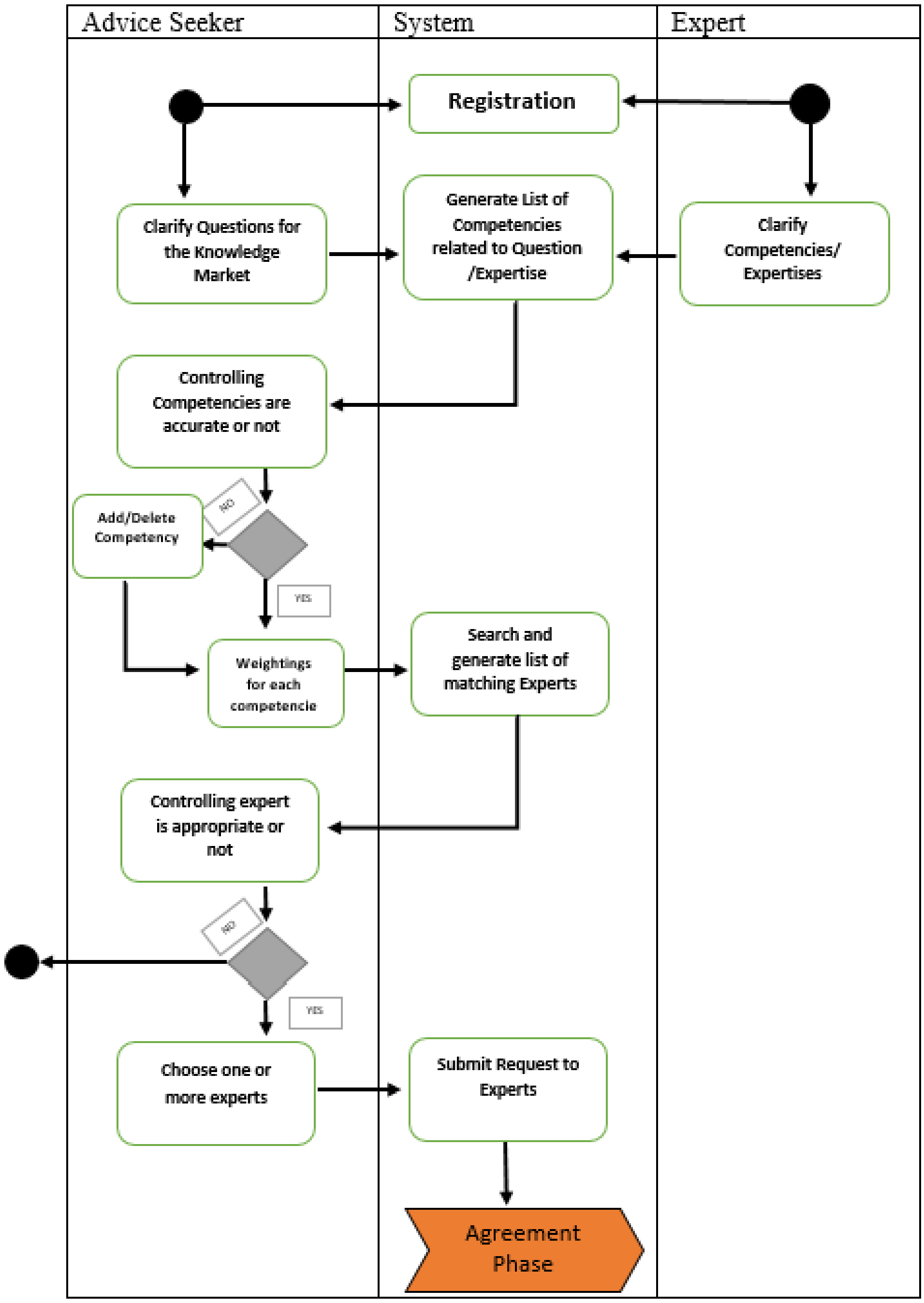

Figure 15 UML Model of Information Phase

The information phase helps providers and advice seekers to get information about the market participants such as expertise, reliability, and quality of the traded knowledge. After the registration of both sides, the first transaction is formulating and clarifying questions for the knowledge market by a seeker. In the information phase, the market participants try to find appropriate trading partners. This can be achieved by simple full-text search, browsing of categories or matching. Matching in the context of electronic markets can be defined as a function that has as arguments a finite set of supply profiles and one demand profile. The output is a ranking of the supply profiles. After the formulating, the system provides a list of the competencies which are related to the question of the seeker. Decomposing is the best way for this. The system decomposes the text of the question as a separated word and queries the competency taxonomy with these keywords. These competencies that are related to the question are presented to the seeker for adding and deleting competencies. Surely, seekers cannot delete permanently a competency from the list of firm competencies. They can refine the list for choosing the best match with their request. Seekers can also suggest new competencies. After the evaluation of the competencies, weightings for evaluated competencies in the list are defined by the seeker. In the next step, the system is put into use at that point and it matched the appropriate experts related to the required competencies. After the system matching, the list of experts is presented to the seekers for checking the value of experts. If it is not, seekers can quit. This means there is no one in the company that could solve the problem and shares their knowledge. In that situation, the system can suggest an external consultant to the user that is known as an expert. But if it is ok, the seeker chooses one or more experts for further negotiations. The last step is submitting requests to the experts. In this phase, search costs are incurred that can be minimized by matching services.

*** We have to define exactly how this list of competencies/expertise is generated. This is a very important step in system design. From the organizational point of view, the current list of competencies/expertise available in a company has not to be taken for granted at all. A big problem with companies today is that they don’t know what they know and, most of all, they don’t know what they don’t know! Our system wants to address this problem providing a dynamic list of competencies.

Tag generation/application/validation

Initially, several sets of tags are developed, which describe the current competences of the firm. A central committee, that includes members from each organizational unit, is in charge of developing these initial sets that can be organized with different logics - such as the technological domain, market domain, product domain, etc. - and level of detail. Each expert can be linked to several tags based on the competences which he claimed to have.

When the seeker digits a request, the system can suggest some proper tags to be applied, also in the Boolean combination. If the request cannot be tagged with existing tags, the seeker suggests new tags to be applied to his request. In case the request is tagged with tags that are already in the system, the request is sent to the experts linked to those tags and the negotiation process starts. Otherwise, the request is broadcasted to all the experts. In case someone can answer, he can validate the new tag or suggest a new one that may better address the question. Then the negotiation process starts and a new tag is included in the system. If nobody can answer, the organization is informed of the knowledge gap. In case a tag has not been used for a long time, it can be deleted.

User Registration and Expertise Registration

In this phase, expert and seekers must register themselves as a member for getting the most value from the system. Seekers and experts can create, participate or only read contents, blogs, discussions, forums, wikis, etc. With the registration to the system.

On the other hand, they can communicate with each other as people and also as content. It means, they can follow people, contents, topics and also can rate each other or can 'like' content. Being a member gives an opportunity to see all the content for the target area. Membership gives open access to the entire system of the targeted area which gives an opportunity to meet with the experts or learn from the other seekers.

For the registration process, seekers and experts have to use one special user ID to log on. They can search as a guest but it gives a limited use for the system. Getting a new account and log on is very easy. There is a register button to start the process for the new account.

They have to fill the fields that are required in the registration process. These fields are First name, Last Name, System name (Optional), e-mail address and passwords.

Passwords should contain numerals and punctuation marks for having a strong password.

After choosing an ID and password, seekers and experts have to accept the System Rules& Privacy Policy (Read and accept part).

After getting ID and password, seekers and experts have to improve their own profiles. They have to upload a profile photo as an avatar of the system. Photo is not an obligation but it helps to make their profile more interesting and trustable. The photo can help to increase recognition in the community and also the system.

Creating a profile is the first process for joining the system and participation in the community. Because profiles are the best way to learn about your competencies, experience, interests, and skills. Users have to write in-depth and correctly. Because User profile can be sent in the search results when the seekers search with keywords contained or matched with the experts' profiles. Users (Seekers and experts) can update their profile information. Users can not update or edit certain fields such as user name. Only the system response can change it for the user. Profiles can be found when seekers search through keywords for competencies, skills, interests or topics. Because of that users have to fill their profiles as much as they like. For the best and easiest matching, if the users have some professional skills or interests, which help others to know more about them, they have to be edited to the profile. On the profile page, users can show their personal social pages such as LinkedIn, Twitter, etc. These pages can be accessed on the system.

Expert Search and Matching

The system is very dynamic and there are various subjects. With the registration process, users' competencies and all the profiles can be matched with the searching with keywords. Members of the system are like part of a family. As being an active member, seekers can find the solutions for their questions, to improve their knowledge, to create a reputation. They can find experts easily. Experts can also improve their knowledge. They can improve their expert reputation with the seekers' feedbacks. They can add new competencies to the system. One of the most important things is they can socialize themselves. They can be friends. So participation continuity is really important. It helps to improve your connection between users and the system. Participation continuity gives a chance to good feedback, making friends, finding solutions, interactive discussions and also rewarding the system. This rewarding helps to give a decision to the seekers about the experts and their competencies. The rewarding system means users can get points. These points can get automatically when the user completes some missions. These missions can be linked with the contribution of the users. Contribution means, writing documents, posting in the blog, creating blogs, wikis, answering the questions, etc. If the documents or blog contents have high quality, users can get extra points with the high ratings and more likes. If your writing got good ratings, users will take more points. The posted answer can be chosen as Correct or Helpful. These also give an extra point to the author.

Moreover, the system gives a reward to the members with points and also badges. These badges and points are directly related to the missions that are completed by the users. Users can have these points and badges forever. There is no expiring date for them. With these points, the user can have a good ranking on the leaderboard. The leaderboard helps users for the recognition of the system. With these leaderboard and award system, seekers can choose you as an expert. Leaderboard can be changed about the last 6 months' contributions. The aims of this are, improving the contribution, completing the mission, continuity of the participation, improving the knowledge sharing and competitive for the high quality all the time. The most important thing is the users' contribution to the system. It is essential.

With the points, users can improve their status on the system. These statuses are directly related to the point range of the users.

All these statuses can be improved with the new missions that are always renewed. Points and badges can be earned with the completion. Missions can be log-in, continuity, updating, viewing, following, posting, etc.

Seekers and experts can improve their profile reputations with all these activities. These all help to find appropriate experts. Finding appropriate experts can be called perfect matching.

Seekers always want this perfect matching. They have to use keywords for searching an appropriate expert or experts. Seekers can choose more than one expert after controlling that experts are appropriate or not. Finding an appropriate expert can be achieved by simple search with keywords, category browsing or matching. Matching is a function that has an argument that includes a finite set of supply profiles as an expert and one demand profile as a seeker. Related with the leaderboard, there is an output for the supply profiles (experts). Seekers have to choose the experts which are appropriate with their demand. It is a comparison between the expert alternatives. Ranking between alternatives have to be performed by the seekers for making a decision according to the question. The quality of the matching can be described by the quality level of expert skills.

3.5.2. Operations for the Agreement Phase

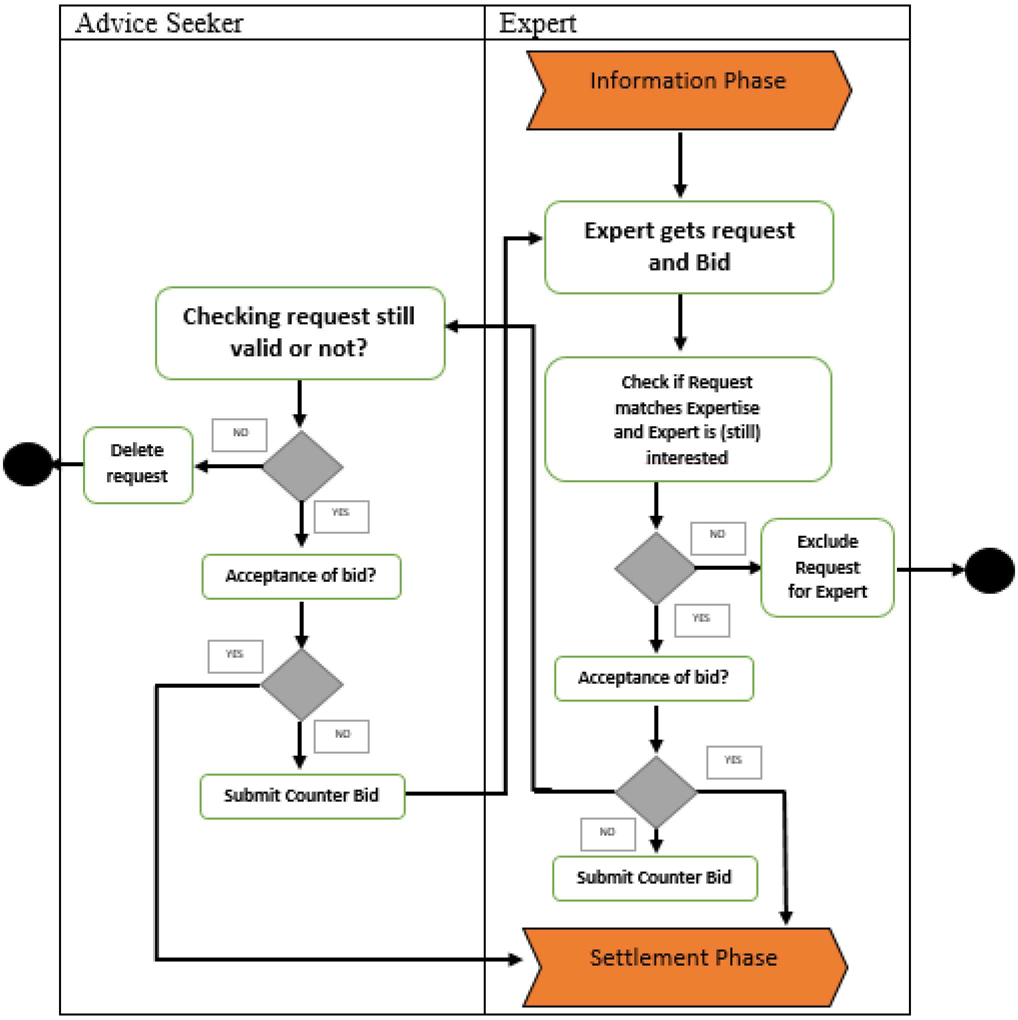

Figure 16 UML Model of Agreement Phase

The second phase is the agreement phase. Negotiations are concluded in this phase. It means buyers (seekers) and sellers (solvers) negotiate about the conditions of requests and bids. Experts get bid from the seeker and they can agree or make a counter bid to the seeker. This continues as long as one side accepts the other bid or drops out of the negotiation process. In the end, a legal biding contract can be made if expert and seeker agree on the conditions. Negotiations can continue between several possible experts at the same time which is chosen from the list.

As a market mechanism, negotiation can be simple like fix price (take or leave it) offers or auctions that more difficult. In electronic markets for knowledge goods have different market mechanisms. First, the buyer, to obtain the knowledge asset, can ask for a tender or make a bid. Second, the sellers can publish their projects and disseminate a call for tender and as a third mixture of both. The price can be fixed or negotiable or the result of an open or closed auction. For the **agreement phase**, negotiations can increase transaction costs, which can be lowered using market mechanisms. This phase ends with the legal contract. The settlement Phase comes after the agreement phase.

3.5.3. Operations for the Settlement Phase

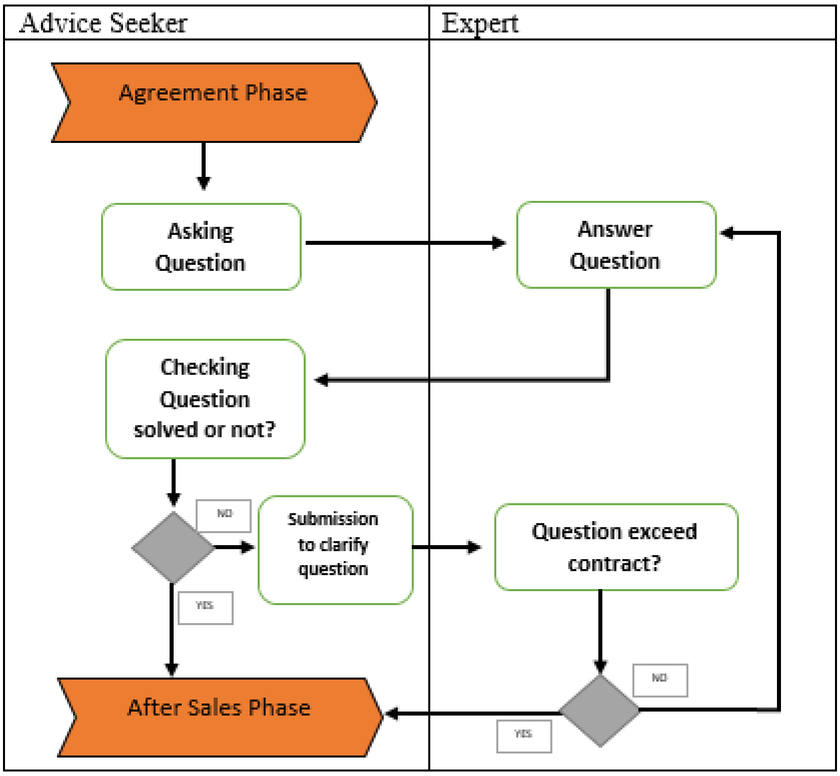

Figure 17 UML Model of Settlement Phase

In the settlement phase, seekers create a question and expert answer it. The seeker has an opportunity to clarify questions until the answer solves or the number of questions exceeds the contract. The contract is fulfilled in this stage. The aim is goods and services exchanging. Digitally documented knowledge would be transferred as a file or a set of files. Online expert advice is created during the execution phase in interaction with the advice seeker. After the settlement phase, After Sales phase comes.

3.5.4. Operations for the After Sales Phase

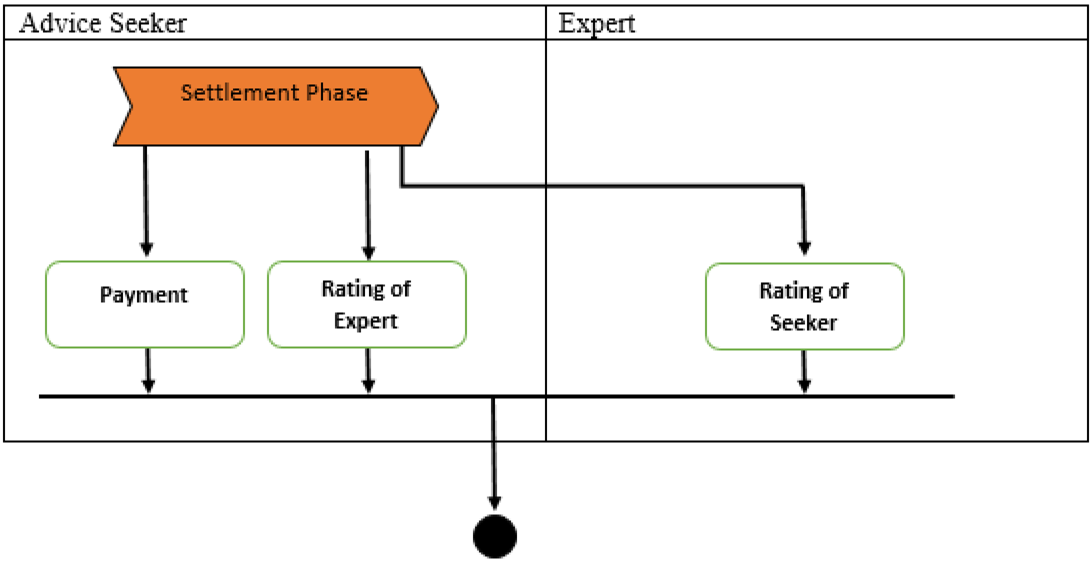

Figure 18 UML Model of After Sales Phase

In the after-sales phase, seekers pay the experts. Also in this phase, seekers and experts rate each other at the end of the process.

CHAPTER 4: AGENT BASED MODEL FOR KNOWLEDGE MARKET

In this chapter, an agent-based model of a knowledge market is designed and developed. The simulations of the model results are shown using different initial settings of selected parameters. The model can be applied to the internal corporate market and knowledge trading dynamics among the firms in a knowledge ecosystem. The approach offers us an innovative way to address knowledge management. It opens the way for future developments.

The analysis of the model and the simulations show some critical aspects that have emerged as well as the parameters which mostly affect the system itself. Limitations of the model and several research directions to refine it are discussed in the report.

4.1. Why Agent-Based Modelling?

I decided to develop and design the agent-based model of the knowledge market. It is designed to get more realistic decisions and results from the current academic perspective. The main reason why I chose ABM is that it provides a natural description of a system composed of entities that have specific behaviours. This helps to make the model closer to reality. Moreover, it is flexible and it continues along the multiple dimensions. For example, adding more agents to the model is very easy. ABM provides a framework for testing strategy. The flexible framework helps to answer questions such as: why is this happening? What happens if these trends continue? What will happen next? Furthermore, another reason for the choice is that it is cost-effective and time-saving. Finally, I want to take advantage of Agent-based modelling such as perfect rationality, easiness to simulate, rational expectations and results.

It is worth noting that we expect to create a general context of the knowledge ecosystem. The introduction of market logic in knowledge exchanging represents a possible innovative way to address specific and well-known problems in knowledge management (KM) application and open the way to possible further development, both theoretical and empirical in nature. Moreover, the designed model can be adapted to work both inside a large and distributed company, thus as an internal knowledge market, or within inter-firm networks, i.e. a knowledge ecosystem such as a cluster or a district. I mean the model is very general in nature and helps to describe both an internal corporate market and knowledge trading dynamics among the firms in the ecosystem.

I describe the general structure of the model developed and present the Flexible Large-scale Agent Modelling Environment (FLAME) that describes all the agents in the market and runs the model that will be explained later in depth. But as an introduction, the FLAME framework can automatically generate simulation programs that can run models efficiently. The FLAME framework is a tool to enable to develop agent-based models on the computing systems ranging from laptops to high-performance computers.

The agent simulations enrich my research. For instance, they allow analyzing the properties of theoretical models of the world around testing the validity of using them to your computer. These are models of agents, built in the form of mathematical relationships of variables that are measurable physical values in reality.

The simulation allows agents to simultaneously simulate with the same model different aspects of reality.

The goal is the search for the model specification that leads to generating the desired macro-structure.

The ABM attempts to create "micro-worlds" in order to determine how the interactions and behaviours of individual agents produce structures and "pattern". [Casti, 1997. On the Reliability of Computer Simulation and the Validity of Models. John Wiley & Sons, Inc., Vol. 2, No. 5]

Knowledge markets have to be well integrated within the daily work. The model has to be simulated before the integration. As it is mentioned before, I proposed an Agent-Based Modelling and I used FLAME (Flexible Large-scale Agent Modelling Environment), so that the knowledge market can be easily simulated and the results can be easily integrated into other programs such as MATLAB, Database tools, virtual machine tools, etc. It is worth saying that the knowledge management system is examined from the point of view of knowledge management system applications.

It is worth saying that this tool helps us to test some settings by changing one or more variables, analyze the results that are returned by the simulator and identify the parameters with the greatest impact as well as the most informative settings for my research.

Briefly, a multi-agent model of Knowledge Market is developed. In that model, I have analyzed the matching of seekers and experts according to their needs and competencies. For getting true matching, several components should come together.

4.2. Agent-Based Model of Knowledge Market

In this study, a multi-agent model of the Corporate Knowledge Market is developed. Two main research questions are followed during modelling processes. First, ‘How to design appropriate structural and behavioural aspects of the knowledge market?’ and ‘Which parameters affect knowledge market dynamics and in which directions?'. In order to answer these questions, an agent-based model of the knowledge market was designed and developed and a set of simulations with different parameters was performed and analyzed.

There are two different types of agents: Worker and System Agents. The project aims to facilitate knowledge transfer between seekers and experts, represented by worker agents, using the market mechanisms. The system agent acts as an all-knowing agent that keeps in memory all the information about past exchanges and about the agents and provides them under the requirement. This mechanism ensures that knowledge sources are ready to trade their knowledge with the "right" price, corresponding to the matching point between demand and offer.

The main goal of the project is to reach effective knowledge transfer from experts to seekers with the pricing mechanism.

The designed model can be adapted to work both inside a large and distributed company, thus as an internal knowledge market, or within inter-firm networks, i.e. a knowledge ecosystem such as a cluster or a district. In the following, the model will be detailed with reference to the more general context of the knowledge ecosystem. The introduction of market logic in knowledge exchanging represents a possible innovative way to address specific and well-known problems in knowledge management (KM) application and opens the way to possible further development, both theoretical and empirical in nature.

The structure of the model that is developed on the Flexible Large-scale Agent Modelling Environment (FLAME) is used to create workers and system agents and their functions. The model based on the iterations that are working on simulations. In the model, agents run on functions that work as an event-driven. It means an agent is working with the function in that action for their current states on the model. Worker and System agents communicate with each other via messages.

The KM approach suggested in this research is focused on connections and addresses the issue of motivation introducing a market logic for knowledge exchanges. The introduction of market logic in a KMS provides several other advantages that will be detailed in the following sections.

Technology infrastructure is considered as an essential enabler in the knowledge-based economy. Such infrastructure plays a vital role in the knowledge management system of an organization. To create and use new knowledge, the sharing of the existing knowledge needs to be facilitated by incorporating various technological platforms. (Abouzeedan and Hedner, 2012; Nishimoto and Matsuda, 2007; Sridharan and Kinshuk, 2002; Zhang and Jasimuddin, 2012) emphasize on technology infrastructure as an element crucial to the knowledge sharing in organizations. Recently, there has been a trend toward the application of advanced technology (e.g. the Internet, intranets, Web browsers, data warehouses, data mining, and software agents) to facilitate knowledge-sharing activities. Knowledge-sharing tools such as social media (FB, Twitter, Wikis, GoogleDocs, etc.), content repositories, dynamic web sites, space for project management, etc. are critically important in knowledge sharing, storing, dissemination and maintenance. The use of technology in supporting knowledge management opens new capabilities in business processes.

Technology plays a role in KM depends on the approach taken; Knowledge can be transferred and it is contained in the stock approach and it sees knowledge as a product. In this case, IT has a predominant rule and KM uses knowledge systems, databases and other forms of information storage. The second approach is the flow approach. In this, knowledge is seen as a process and it is dependent dissemination on the actors and IT helps to facilitate interaction among people. In the thesis view, knowledge management must integrate both approaches. So knowledge management is more than managing knowledge assets or workers. Through this view, a model combines both approaches and shows the combined value.

Information technology (IT) is considered an indispensable tool that supports the discovery of useful knowledge. Collaborative tools such as intranet-based systems allow people to work together and collaborate interactively. Individual knowledge is thus converted into organizational knowledge through knowledge sharing with the help of IT. The effective use of IT ensures timely access and exchange of knowledge so as to facilitate the decision-making process.

4.3. Brief Notes on Agent-Based Modelling

Agent-Based Modelling and Simulation (ABMS) belongs to a category of computational models that use the dynamic actions, reactions and intercommunication protocols among the agents in a shared environment, to assess their performance and understand their behaviour and properties.

The “Model” is an abstract and simplified representation of an assigned reality and is used to examine phenomena or to forecast it. The “Simulation Model” is the manifestation of a model, by means of a computer program that includes the computing algorithms and mathematical equations that describe the behaviour and performance of a system in the real-world scenarios.

The ABMs or multi-agent systems (MASs) consist of a set of elements (agents), characterized by some attributes, which interact with each other in a given environment through the definition of appropriate rules.

It is worth defining that the main actor of this model, an agent consists only a set of logical rules of behaviour and a list of internal states, representing, for example, its memory, the mood or capabilities. All of the agent's combinations collect information about his current situation, both internal and external and then match this input with the set of rules infer his reaction to the situation.

To understand better social systems, it is important to say that all populations of the agents can be social. Because they interact and influence each other when they are combined in a computer simulation. So it is possible to study deeply the development of their interactions in time.

Using agent-based modelling, users can establish interactions between the agents in their environment, then to develop their own real-world system models. An Integrated Development Environment (IDE) is a standalone application programming environment that includes a typical code editor, compiler, tester/debugger, and visualizer or interactive Graphical User Interface (GUI) builder.

These models permit to visualize on the user interfaces the agents' overall behaviour following their micro-level actions. These actions have direct effects on the macro-scale properties of the entire unit. Therefore, the dynamical interactions among the agents, the changes on each agent due to these interactions and the effect on the overall system performance can be visualized on the user interfaces.

ABMS toolkits often require the knowledge of the programming languages, such as C/C++, Python, Java, Smalltalk, Basic but there are commercially available toolkits with ready-to-use Application Programming Interfaces (APIs), add-ons and libraries.

Furthermore, the description of the agents are not enough to create an ABM, the development of an Agent-based Model requires a complete description for a set of basic elements/building blocks, it can be derived from Billari et al., (2006) and Weiss (1999).

- *The object of the simulation.* It has to be clarified what is the phenomenon/problem to be reproduced, defining the space in which the simulation takes place.
- *The agents' population.* The agents can be grouped in different categories with common characteristics that reproduce the various components of the system.
- *The adaptive capability of each agent category.* How the agents of each category behave in certain situations, in other words, Agents of each category present a specific adaptive capability, namely the degree of reactivity and pro-activity.
- *The interaction paradigm of agents.* Each agent can interact with the agents of the same or other categories and in this context, agents can competitive, cooperative or negotiable if they have conflictive objectives. (If they have not, agents can not be competitive.)

A characterization for an ideal application of the ABM technology was produced by Parunak (1999) and follows, which connects with the basic characteristics previously explained for the general simulation models.

Firstly, it must be modular. In the sense that each entity has a well-defined set of state variables that is distinct from those of its environment and that the interface to the environment can be clearly identified.

Secondly, it must be decentralized. It means that the application can be decomposed into autonomous software processes that are able to perform useful activities without a continuous direction from another software process. The third, it must be changeable. It means modifiable. In the sense that the structure of the application can change quickly and frequently. The fourth is ill-structured. In other words, poorly structured. It means that all information about the application is not available when the system is being designed. The fifth and the last one, it must be complex. In the sense that the system presents a large number of different behaviours that can interact in sophisticated ways.

Sets of packages, put together within the common standardized graphical Integrated Development Environments (IDEs), facilitate the creation of interactive simulation models by means of visual programming IDEs. These are Altreva Adaptive Modeler, AgentSheets, AnyLogic, FLAME, Framsticks, Mimosa, PedSim, Repast Simphony, SeSAm, StarLogo, and Sugarscape.

4.4. FLAME

The model was implemented using the Flexible Large-scale Agent Modelling Environment (FLAME) developed by Simon Coakley, Mike Holcombe, and others at the University of Sheffield.

From the point of view of application, domains deal with ABMS tools, we can note that FLAME represents an ideal solution when the ABMS scope lies in the wide categories of Social & natural sciences, Dynamic computational Systems, Business, Marketing, Economics, Planning & Scheduling, Enterprise, and organizational behaviour and Traffic Situations.

The FLAME framework allows developing agent-based models that can work on Large-scale parallel/Distributed computing clusters and high-performance computers (HPCs). The computational model used to develop the agent-based models is called (extended finite) state machines. The FLAME tool permits to create an agent-based model defining software behaviour by means of state machines with transition functions between those states. The agent/machine goes from a start state to an end state in a time step or iteration, passing through several states with the own transition functions.

Each agent has variables in its memory. Transition functions allow us to read and write to variables in the agent's memory and also read incoming messages and write outgoing messages. The agents communicate via messages.

The communication between agents drives the coordination of agent function execution since FLAME works with agent models in parallel and on different processors.

The Figure shows an agent machine. It starts with a start state and finalizes with an end state and one transition function which takes it from one to the other state. The transition function can access the agent memory (i.e. modifies the variables) and receives input messages and generates output messages.

This is the brief figure that explains an agent-based model that includes the individual steps for the creation of the model. The individual steps are;

- Determine the agents and functions
- Determine the states that forward some order of function execution
- Determine the memory. It means the set of variables that access the functions directly with possible conditions on these variables for the functions to be formed.
- Determine the messages as input and output for each function with the filters if they need it.

When a model is created with agent functions with these criteria, the C programming language is written as the source code of the implementation process. In the simulation phase, FLAME is used for the model description to create a program that executes agents and communication in parallel.

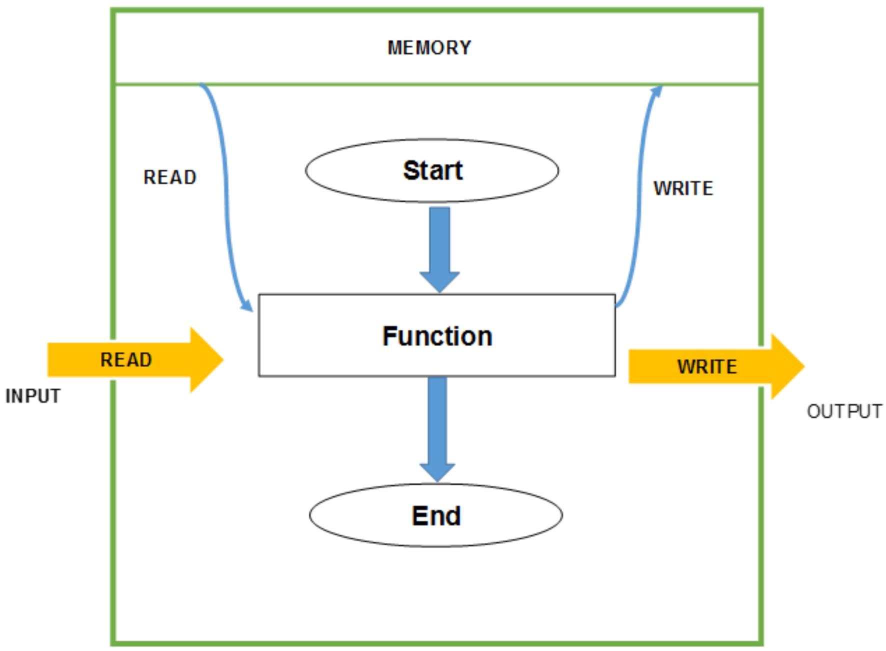

Figure 19 Agent Machine

Figure 20 below shows the state mechanism of operation. The circles are the states and the rectangles are the functions. The states, representing the memory, send continuously memory to the functions which are written on C files and represent the behaviour of the agents for every process. If there are conditions, states decide OK or NOT. Functions perform or not, related to the answer to the conditions. This process continues until the end state. During the processes, agents communicate with each other by means of the messages. Messages contain variables that are defined by XML files. XML files are the models or the sub-models.

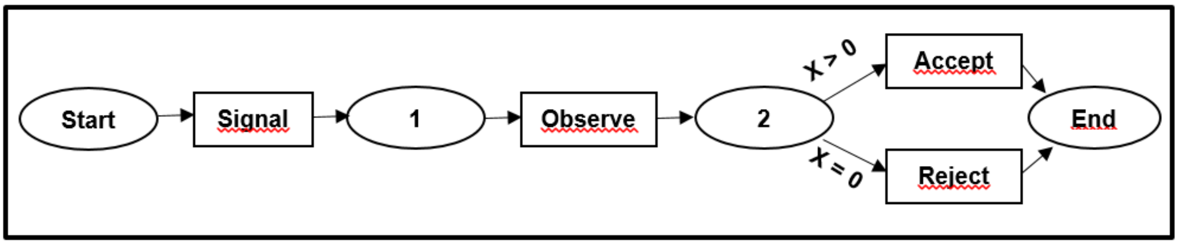

Figure 20 State Mechanism of Operation

There are several steps to developing a model. They include the identification of the agents and their functions; the identification of the states in order to establish and sequence of function execution; the identification of the variables into the agents' memory changeable by functions; the identification of the input messages and output messages of each function.

To produce the agent model and to be able to implement the simulations, the FLAME is chosen as a framework. It is a generic system of the agent model that can be used for the development of applications in various research areas. The main idea is that it gives the capability to produce complete agent applications that can be compiled and generated on the computing systems.

The template engine takes input from the XML model description and agent functions. The initial agent population settings are set in 0.xml file read during the simulations.

Communication between agents is achieved through the use of messages.

Using a distributed memory model, single program multiple data (SPMD), the framework is able to handle deadlocks through synchronization points which ensure all data is coordinated among agents. In the case of the GPU simulation, distributed message communication is not required as all data is maintained on a single device. Instead, a number of highly optimized communication algorithms are defined allowing optimal performance to be achieved.

FLAME includes a parser program that parser a model described as XMML into a simulation program source code (Figure 21). Then, this source code and the agent functions implementation source code are compiled. The compilation takes place using the compilation script 'Makefile' using the 'make' build automation tool. The program 'make' refers to the 'gcc' C compiler.

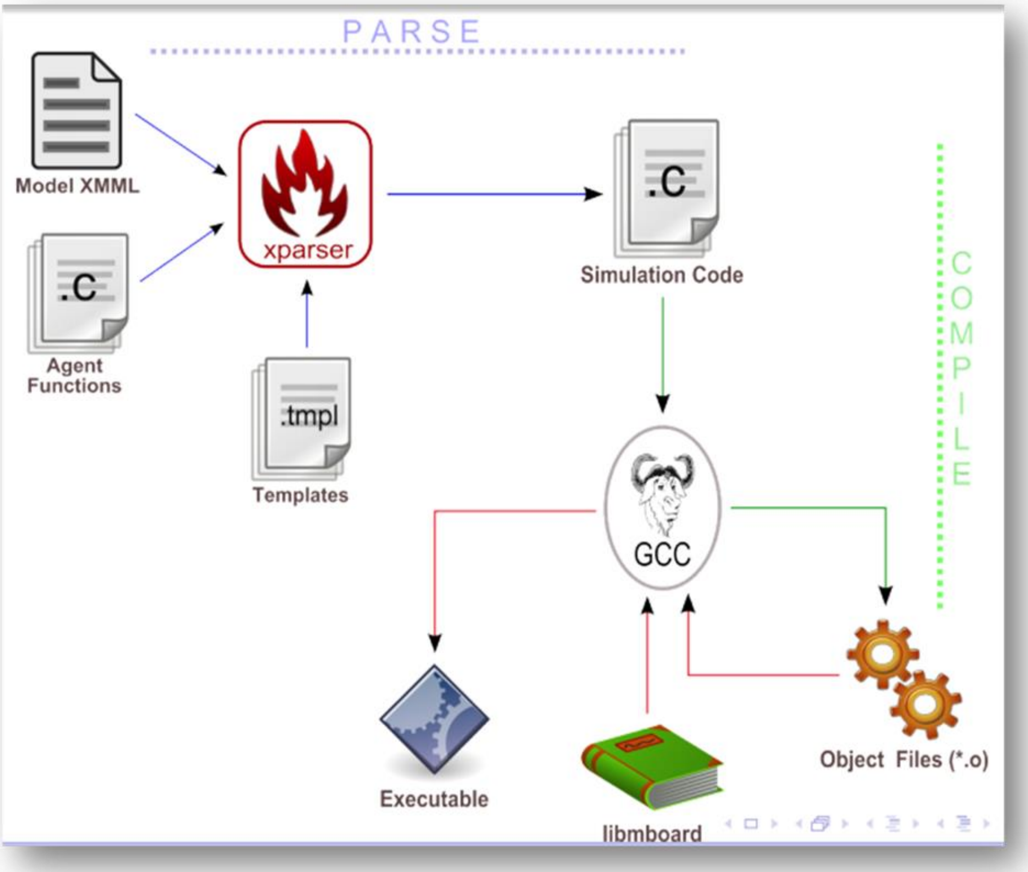

Figure 21 Schema of the simulation structure

To compile a model the message board library is required. The compiled program is called 'main'. The parameters necessary to run a simulation are the number of iterations to run for and the memory of agents which is a formatted XML file.

4.5. System Dynamics of the Model

The model aims to simulate knowledge asset trading between different entities within a knowledge ecosystem.

The model consists of two types of agents: agent worker and agent system.

The first represents all the subjects, called workers, who participate in the market (as seekers or experts, i.e. knowledge owners). The second is a single agent that stores agent data, knowledge assets, the information needed to the trading system and transaction data

Thus, three main elements characterize the model: knowledge assets ("what" is exchanged on the market), worker agents ("who" exchanges knowledge assets) and the system agent that acts as a memory of the system enabling transactions.

Knowledge Assets

In a knowledge market, we can assume that different types of knowledge assets can be traded. A knowledge asset is any type of knowledge held or in use by an organization. Assets may be classified as "digital products", "nonmaterial goods", and "information assets". In my thesis, to reduce complexity, I limit my analysis with two kinds of knowledge assets that could be traded on the market that we modelled: digitally documented knowledge and expert advice (i.e. a digitally traded service) Digitally documented knowledge is a digital product. It means information that can be stored completely in digital form and can be transferred over communication networks as a file or a set of files. Manuals, documents, procedures, presentations generating, etc. Expert advice is a digitally traded service, which is created during the settlement phase in interaction with the advice seeker. A knowledge asset is any type of knowledge held or in use by an organization. 'Digital Products`, 'nonmaterial goods' and information assets are classified as knowledge assets.

Worker Agents can have a dual role: Expert and Seeker. Experts sell knowledge assets to Seekers that require them to complete their tasks. Each worker agent can be an expert and seeker at the same time.

System Agent is an agent that stores the data of the agents, knowledge assets and information needed to the trading system and transaction data. It acts as a memory of the system enabling transactions.

At any system iteration, a fraction of the total number of worker agents is activated to receive a task, i.e. a set of knowledge assets to execute in a given number of iterations. Each task is described by a list of knowledge assets and a deadline.

In order to be activated to receive a task, a worker agent must satisfy some conditions. First of all, the agent cash must be positive, otherwise, it cannot buy the knowledge assets d it needs; second it must not have other open tasks or be busy as Expert, i.e. it must have completed its assigned task as well as any work for others (expired_task = 0 and first_day_free = 0); finally it must not have "pending" knowledge assets (the meaning of which will be described later).

The activated worker agent, in order to perform the assigned task, first has to cross-analysis between task required knowledge assets and those held in its "portfolio"; later it proceeds to the following checks:

If the needed knowledge assets are already in its portfolio, it will proceed with the execution of these. Therefore it will decrease its time budget of the time needed to perform the knowledge assets and will update their last use time (the more it is updated the more the agent is competitive on the market and has better chances to be selected as Expert). As long as the task is not concluded, the agent can't be selected to be assigned a new one. However, it can respond as "Expert" to other agents (the Seekers). In this way, it can increase its cash, update its knowledge assets (as a consequence of their use) and increase the value of the first_day_free to consider the time needed to perform the knowledge assets it sold. If the required knowledge assets are not in their own "portfolio", it will turn to the market becoming a Seeker. To buy a knowledge asset on the market, it posts the request together with an expiration date and a price. The price is calculated for each agent using the following procedure: the Seeker requires the Market Agent the price history for the knowledge asset it needs to buy, considering a time-window arbitrarily decided by the Seeker. Then the seeker post a price that is equal to $p = \mu + \xi \mu$ where: μ = average of the price history in the time-window; ξ = random.

The expert complete list has compiled by the system following a set of rules:

- The Expert will appear in the list of some knowledge assets only if the price of them is lower than or equal to those proposed by the Seeker.

- To selected question will respond only agents that will be able to perform the knowledge assets within the required date end.
- If an Expert possesses required by different Seekers knowledge assets, it will be added in one response list because it can reply only to one knowledge asset/agent.

The Seeker answer choice is made by the Expert on the basis of the "productivity value", the relationship between the price posted and the number of iterations needed to complete the knowledge assets -man (in the case of more knowledge assets you will add up their prices and will divide them by the sum of the man - iterations associated with each knowledge assets). The Expert will choose to reply to the Seeker associated with higher productivity. The Seeker who posted the demand for knowledge assets receives more offers from different Experts. It will select the agent who has the most updated knowledge asset (delta _ t lower, then associated with a knowledge asset used internally or exchanged recently) considering the received offer types.

Seekers which is sent to an empty list for the required knowledge asset (if no agents have been able to answer) will be the same as "outstanding", namely, repost.

The answers lack may be due to many reasons:

- Posted price is too low;
- Nobody can perform knowledge assets by end date;
- No expert befitted to respond because of too low productivity.

If the Seeker does not receive a response, it will have to repost the same knowledge asset at a higher price to the next iteration, more precisely:

$$P_t = P_{t-1} + \mathcal{E}_p P_{t-1}$$

Where: $P_{t-1}$is equivalent to the price which had been requested the same previous iteration knowledge asset, Ɛ_p (EPSILON _ PENDANT) corresponds to the new increase price percentage.

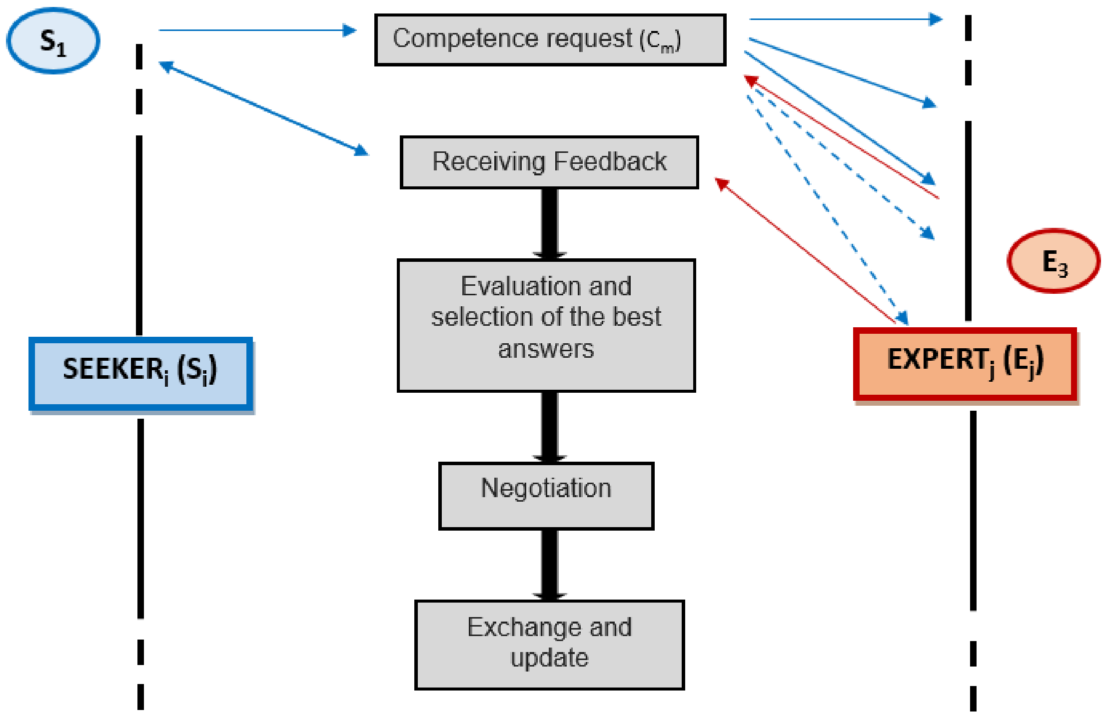

Figure 22 Market Dynamics

In addition, it will postpone the one-day task end date.

This process will continue as long as at least one Expert will be prepared to reply to the request to reach conditions.

The end task date will increase the fee indicator NUMERO _TASK_ END. The case will undergo a change at the checkout end work, positive or negative, it will depend on the accuracy level of calculated estimate in the generation task time.

Worker beginning activation has made a cost estimate, adding up the prices of possessed knowledge assets by those calculated when received historians, all increased by a percentage (Markup); this calculation was included in the "ESTIMATED" variable.

Once it has been purchased all the necessary knowledge assets, reached the end, it runs the difference between the estimate and total paid knowledge assets ("PAID").

If this difference is positive, it will get a cash increase as a reward for task completing, contrariwise it should be negative, the prediction will be wrong and it will get a cash decrease.

The goal is to reward the finished works with a monetary award, it also allows for feedback to the system (control).

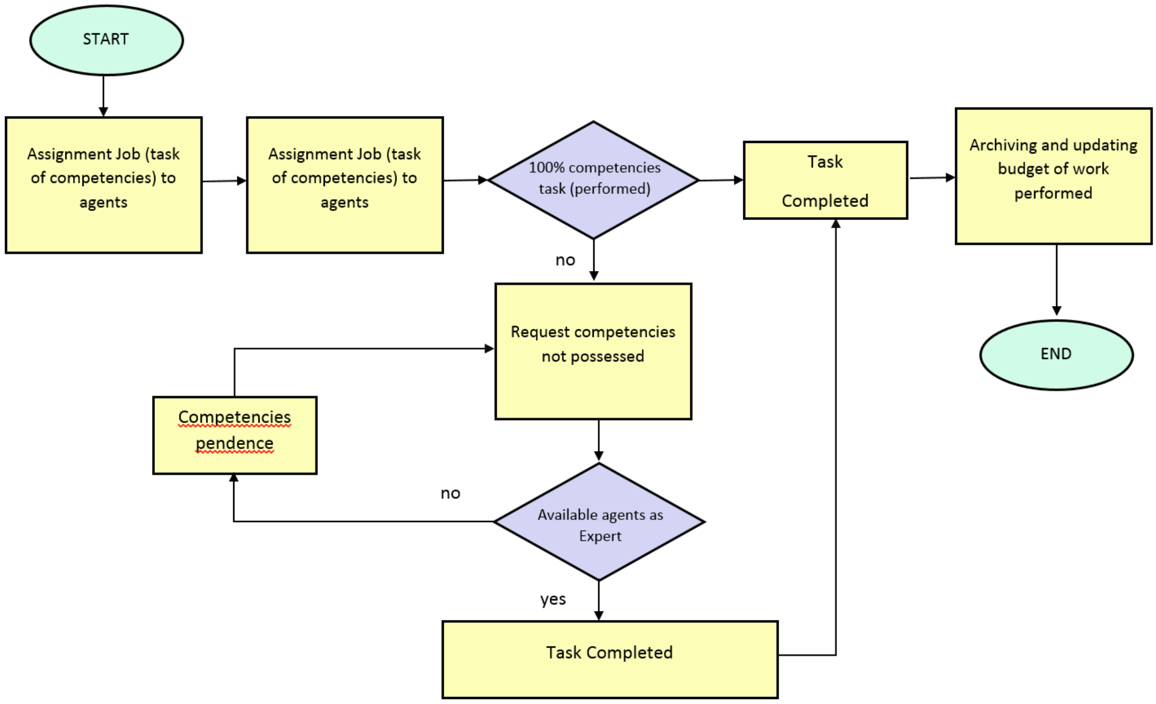

Figure 23 Model's block diagram

4.6. Market Dynamics

All transactions have been preserved, in order to guide the knowledge assets pricing operations Seekers (price history allows to establish from what value to require a knowledge asset).

The Market system will record the transfer of expertise from the Expert to the Seeker after the transaction, it marks the exchange time and it will update the knowledge assets price in agreement with if it has been used inside (it will return at the last recorded price) or sold (it will update at the exchange price).

Each knowledge asset is subject to a depreciation of its value proportional to " TAX_DECREASE ". This calculation allows taking into account the concept of knowledge assets obsolescence. The knowledge assets lost their value with the passage of time it will be recovered only using or exchanging it. The devaluation process has been described by the following formula:

Price = Price*(1-TAX_DECREASE)

4.7. System Initialization

The system generates a universe of different knowledge assets from each other, from which the workers will draw later for portfolio decisions and tasks. Any agent registered in the system, start filling his portfolio with the knowledge assets who has taken from the universe. The trade numbers in the Market are zero. The times are set for each knowledge asset, while the values are the same for all because they are not different and separated in sectors or thematic fields and there are not preferential or priority relationships between them. The better chance has been to an associate whole at the same price. The opening time and virtual currency budget were set during the simulator testing and straightened on obtained results.

4.8. Model Implementation

The Model is populated by the following agents' type: Seeker and Expert. The Model implementation occurs using the Data Types, the Memory Variables, the Functions, the Messages reported in the following tables for agents included in the Model.

Tables summarize the memory variables, functions and messages for all the agents presented in the model.

4.8.1. Agents

Players interact in performing task system exchanging knowledge assets according to market logic.

Seeker is a worker agent with a task to perform, who placed one or more requests for not owned knowledge assets, setting a price and an expiration date; he afterwards will select the best offer that agrees with his needs.

An expert is an agent potentially capable of responding to the knowledge assets required by Seekers.

Knowledge assets that are written on the Model.xml, are the main elements of the system and the product exchanged between different agents. They are coded as a set of variables. These variables are under the data type Competence. It has professional qualifications held by workers:

Data Type(Competence)	**Description**
id_competence	Identifier of each competence
price	Price/Value of competence
iterations	Needed to build and run a given knowledge asset
price_start	Price of the competence during initialization
indicator_expired	Alert that a knowledge asset is going to fall both for the Individual worker for the entire universe
instant_utilization	Latest iteration or knowledge asset exchange
validation_comp	Binary value if task knowledge asset is in the agent's portfolio

Table 10 Data Types (Competence)

Data Type agents_portfolio contains information about a single agent.

Data Type (agents_portfolio)	**Description**
id_agent	id of agent
array_competencies	array of competencies
timeAvailable	number of available operators, the capacity of running competencies in parallel on the same day by the individual "worker" (in the past to be used for running the competencies

Table 11 Data Types (Portfolio)

4.8.1.1. Worker Agent

It is the agent that contains all potential seekers and experts, divided them according to the availability of budget and models the exchange of expertise negotiations.

Memory Variable	Description
id_agent	id of agent
portafoglio_of_competencies	arr vector structure containing knowledge assets
timeAvailable	number of available operators, iterations / Man, daily capacity slot available by a single agent
XY	variable to available time generated in initialization
first_day_free	worker or skilled end date (day, iteration)
rest	iterations/man "advanced" number to detract from a day to time Available of the following days until it is exhausted
activation	Binary indicator, if the agent is one, it produces a task in the "Task activation and generation" function
cash	money cash for each agent, it will be used to buy not owned knowledge assets
task_competencies	the structural vector containing the set of knowledge assets that make up a task
task_expired	iteration (days) number within which all task knowledge assets must be completed
timeAvaliable_rest	the day when the worker finishes a job
competences_of_buying	the vector containing the task knowledge assets to buy and the posted price
choice	knowledge assets vector structure bought with ID agent
credit_expert	the vector in which each agent employed stores, the Expert voice from which buys, the knowledge assets bought and the price to be credited and scale
Pendence_agents	the structure includes for each iteration the outstanding knowledge assets of each agent
pendence	binary indicator, 1 means the agent has outstanding and it can not be activated as a function "enabling and task generation."

number_task_conluded	incrementing counter at each reporting date of a task (task_expired= 0)
counter_exchange	means knowledge assets exchanges occurred in each iteration for each Seeker
estimate	task estimated value with mark-up addition
paid	sum knowledge assets owned and bought
task_duration	task duration
difference_estimate_paid	difference between estimate and task true value; it is added to or subtracted from the Seeker fund according to its final value

Table 12 Memory Variables of Worker Agent

Functions	**Description**
initialization	performed only once start the simulation
receive_updated	every worker receives the agent database from the system
sending_info_agents	Update for each agent, "prices" values of competencies (using obsolete function), then check the budget of time and money of each agent. Sending two messages: the first containing the portfolio competencies of each agent and the second containing info on the previously calculated budget
activation_task_generation	selection of agents to be activated and self-generation, for these active agents of a new competences task
historical_request	with this function, we separate the agents who must request the historical prices for new and old skills, from those that did not require it
receive_calculated_post_price_history	Received the required historical, each agent determines what price to post.
receive_selected_Negotiation_Info	Every seeker receives the lists with experts able to supply the competencies required to the posted price. Competences of the experts are ordered according to their Delta T (degree of competence update).
Send_inside_time	for each agent, the function calculates and updates the busy time for the job done inside

updated_budget	for each agent that is receiving the remaining time budget and the updated budget of money, both relating to the next iteration

Table 13 Functions of Worker Agent

4.8.1.2. System Agent

It is the macro-agent receiving updated information for each agent employed; process and sends the information requested by seekers; updates and stores information relating to the occurred exchanges and budgets.

Knowledge assets exchange environment. Inside it meet supply and demand of the different agents, are drawn exchanges, mark the moments at which these transactions take place and update the variables associated with each knowledge asset. The agent system receives updated information for each agent employed, it processes and sends the requested information to Seekers, it receives and stores data regarding the occurred exchanges and the updated budgets.

It too is characterized by a series of variables:

Memory Variable	**Description**
timeAvailable	An integer variable avaiable time
competence_total	structure vector containing the entire universe of knowledge assets
agents_database	the database containing all the information regarding the agents (cash, tempoDisponibile, portafoglio_agenti, etc..), overwritten at each iteration
historical_database	vector structure that stores the portfolios knowledge assets of workers agents with updated prices, for a number of iterations equal to the size of the array itself. It is taken into account to calculate the price for posting the knowledge asset to buy.
databaseDT	database created by the system and it organizes, for each Seeker, all Expert available to sell the necessary expertise in order delta_t
Pendence_agents_s	the structure that stores, agent for an agent, the tasks for which you have not received a reply, will, therefore, remain outstanding and subject to repost the next iteration

Table 14 Memory variables of System Agent

Functions	Description
system_initialization	initialization of system agent
sending_updated	sending the database_agents updated at the end of the previous iteration
Receiving_Competencies	receiving and classification of the portfolios of competencies
Receiving_Budget	receiving information about the updated budget after attribution of a new task
calculating_price_history	receives the message containing the required competencies to buy and for these skills creates price history (string value)
organize_experts_deltaT_list	send a message containing the posted price
storage	the function receives information of occurred exchanges, stores this information and updates prices of traded competences at the new exchange price. Calculates the new economic budget for each agent involved in the negotiations
update_budget	It receives information on the inside job's times and calculates the time budget for each agent to the next iteration. Finally, send the new time and money budgets of the agents available to the next iteration

Table 15 Functions of System Agent

Messages

Interaction messages between agents.

Message	Description
message_updated	update system with universe competencies from system to workers.
message_time	the values of the memory variables of the various agents useful for updating the agent database in the System
message_universe_competencies	sending universe competencies from system to workers
message_universe_competencies1	sending universe competencies from system to workers
message_portfoliocompetencies	agents id which is sending portfolio of competencies
message_budget	sending to the system, agent by agent, the budget of available time and id

message_price_history	Agent id, task competencies which are sending by price history
message_price_history_return	Price return
message_post_price	Posted price random number
message_deltaT_list	Send random number
message_negotiation_info	Send random number
message_inside_time	Send random number
message_final_budgets	Send random number

Table 16 Messages

4.8.2. Development processes on FLAME

The first step on the FLAME is 'xparser'. It is an analysis program. It allows us to analyze the model in XML and to transform it into the source code of the simulation program and compiling it with the functions' (implementation) code of the agents and template files.

This is called a 'parsing' process and it will be shown in Figure.

This procedure generates the following documentation:

- stategraph.dot - an acyclic graph of states, functions, and messages among agents in the model.
- stategraph_colour.dot - as above (Functions are coloured.)
- process_order_graph.dot - as above, but message synchronization is shown.
- latex.dot - the description of the model written in a LaTeX document.

It also generates the following files related to the source code of the simulation program:

- Makefile - a compilation script used by the "make" program.
- xml.c - the source code that manages the simulation inputs and outputs.
- main.c - the source code that contains the loop of the main program.
- header.h - a header file in C language that contains the global variables and the declarations of all functions in source code.
- memory.c - the source code that manages the memory requirements of the simulation.
- low_primes.h - contains data used for partitioning agents.
- messageboards.c - the source code that manages the functions related to the messages, it means message functionality.
- partitioning.c - the source code file that manages the partitioning of agents between nodes in parallel.

- timing.c - the source code that provides temporal routines.
- Doxyfile - a configuration file to generate documentation using the "Doxygen" program.
- rules.c - the code contains the rules generated for the conditions of the functions and the filters for input messages.

For each type of agent an associated header file is also created:

• <agent_name> _agent_header.h - the header file that has the macro codes inside and it is necessary to access the variables in the agent's memory.

To do this, the GXParser software is used on Windows 8.1 and Windows 10.

In the model, the software package is used that includes;

- Xparser GUI: Parser for FLAME models;
- GNU GCC compiler: C compiler for model + framework code;
- Flame Editor: Generate model.xml file, XML description of the model;
- Population GUI: Generates initialization files, population description. (to create an initial state as an input of a simulation);
- Simulation GUI: Settings for simulation experiments and data analysis.

It is worth saying that the GCC compiler, XParser (Model description-XML)and LIBMBOARD (Agent communication and behaviour implementations-C functions) are required software components.

Furthermore, there are also Optional software components. They are PopGUI, ExpGUI as Initialization and experiment setup, VisGUI as Data Visualiser.

GXParser

XParser GUI is used to generate a simulation of FLAME.

Set of compilation files that compile the files with the developers'files to produce a simulation package for the simulations. Xparser needs the files below on running;

- Model.xml – It is worth saying it is a series of XML files that contain all structure of the model such as agents' descriptions, memory variables, agents' functions and messages.
- Functions.c – they are multiple '.c' files that include the implementations of the agent functions. These are specified in the XML files.
- 0.xml - The initial states of the memory variables of the agents are represented in this file such as all parameters are initialized here. The number of the resulting XML files depends on the number of iterations specified to run a model (through Main.exe) [58].

The processes of the Xparser;

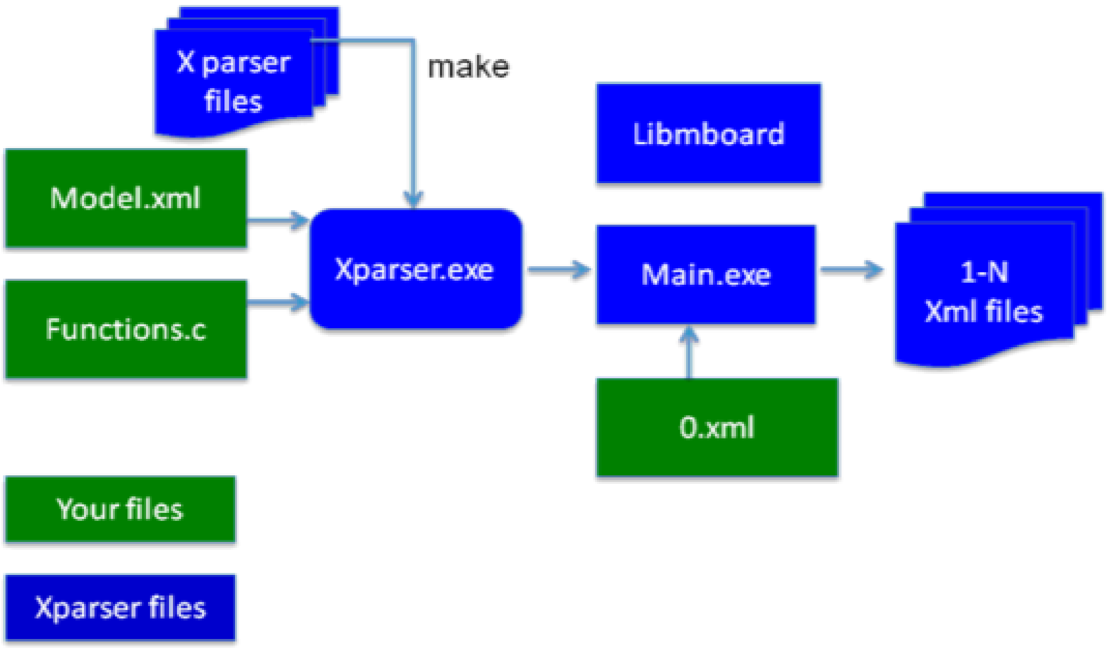

Figure 24 Block diagram of Xparser

It is the simulation program of the FLAME. Blocks in blue are the files automatically generated. The green blocks are modeller files.

XML model is needed as input on GXParser. It is located inside the folder that contains the other models and the C codes of the functions: Firstly, Xparser will be launched. It will check the model and produce the files automatically. If no error message is seen on the program interface, the GNU Make function starts to launch. It means the compiler of the C code generated by Xparser. If the syntax or compile errors do not occur in the functions of the agents, the executable file will be created, i.e. the file "main.exe".

It can be seen as an image of the application window in Figure 25. On the left side of the screen, the Errors of the model.xml files occurred on the structure could be seen and there is also an output section that includes the name of the model, agents as nested models, function files, etc. On the right side, it is a directory layout that has all the files about the model that is created.

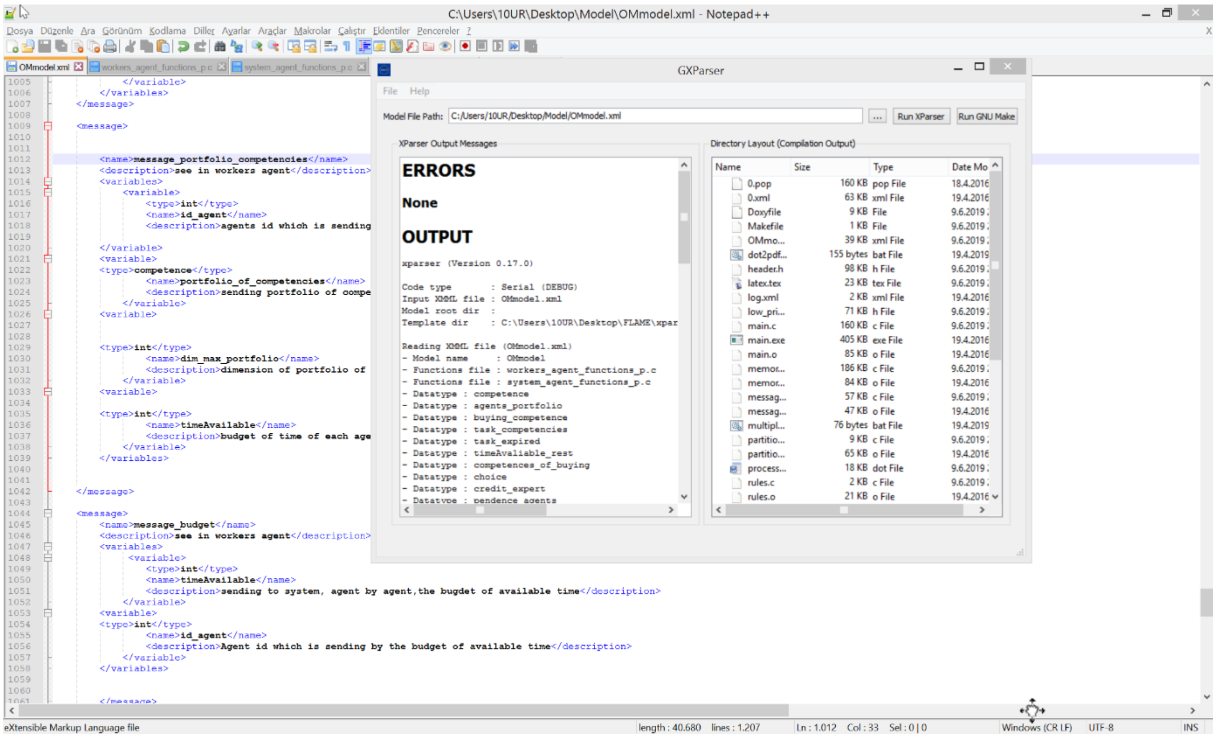

Figure 25 Screen of the GXParser program with the output of the XParser function

4.9. Stategraph

The stategraph explains the model in-depth and it is created through the GXParser program. Stategraph is a flowchart of the model that contains states, functions, and messages.

As it is seen in Figure, the beginning of Worker and System agent diagrams. Ovals are the states with the name inside them (as it is seen the first one is always defined as "start_agentename" while the following have some abbreviations in numerical order), the coloured rectangles are the functions with the name inside (a different colour for each agent), the black arrows indicate the flow of the agent's behavior from state to function and vice versa (and in case of duplication of the path, the single arrow will have indicated the condition) while the green arrows indicate the messages, which start from the sender function and arrive at the recipient function and have the close tag indicating that the name of the message (in the image, for example, it is seen the message universe_competencies).

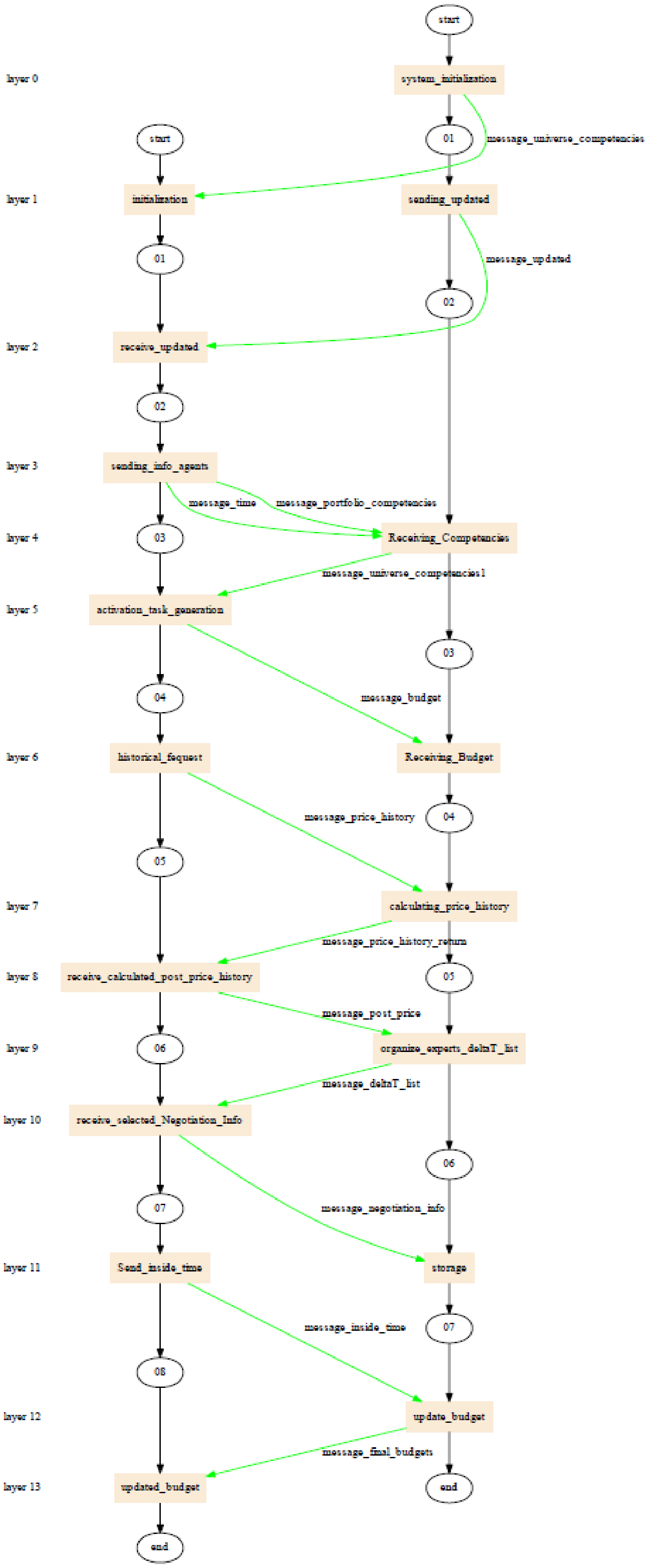

Figure 26 Stategraph of the Model

4.10. Launching Simulations and Read Results

The executed executable code is explained.

At this point, the simulations process and executed executable code are explained.

The file .bat has been produced in which the path of the test folder and its' name, the name of the initialization file (init.xml file is used that is created by default but it can be changed), the number of iteration wanted and the frequency of output creation (which are structured XML files equal to the initialization file but that are generated in the simulation with the values).

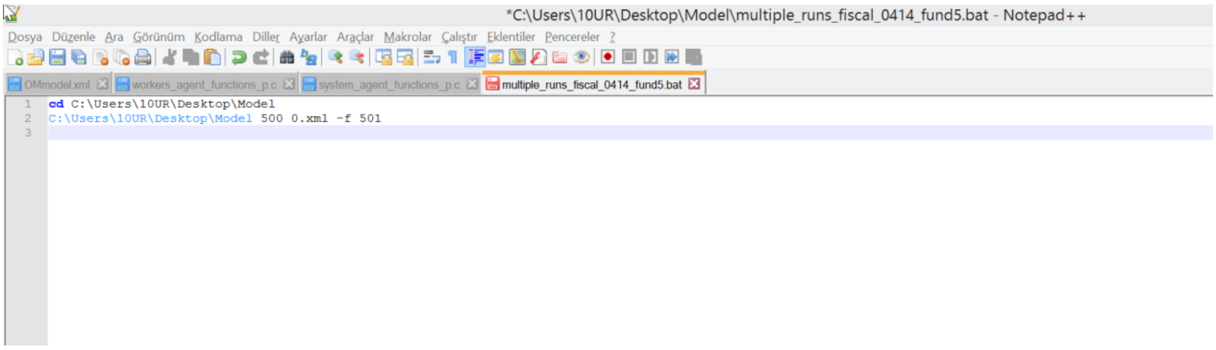

Figure 27 Simulation parameters – Launch.bat

The figure shows the launch .bat file and the code inside. Chosen iteration 500 and frequency 1.

4.10.1. Data Analysis

The first test performed on the extracted data from the simulator regards the conservation of the total cash. In the absence of remuneration by tasks that run the test consists of the sum of cases of agents at each iteration, making sure that the sum will remain unchanged throughout the simulated period (500 iterations). If this not happen would be to search the cause of creation from nothing or cash dispersion. In the presence of the remuneration of the task, the feedback tool, the verification on the cash has been addressed differently. At each iteration, it has been stolen remuneration value of the task that the agent is accredited work is finished and compared this with the case of the previous day.

In both cases, the results obtained showed conservation of the case, without the emergence of abnormal sources of distortion of the parameter.

4.10.2. Lack of Market Analysis

The first analysis performed on the data returned by the simulator was verification of the utility and convenience market. It was investigated, in the absence of market conditions, the level reached by the parameters of interest: the average price of knowledge assets, the number of tasks completed in the simulation period and the average daily number of tasks completed, the total number of trades and average daily. To achieve this scenario has changed the code implemented in the C simulator so that the interactions between the agents and the exchange of expertise were prohibited.

The initial set-up, which was chosen as a model for subsequent analysis, foresees among other data 13 "worker agents" each with timeAvailable values of 12, 300 cash, knowledge assets wallet size 15.

```
#include "header.h"
#include "workers_agent_agent_header.h"
#define AGENTS 13
#define DIMENSION_HISTORIC 20
#define DATABASE_DIM 16
#define TASK_DIM 5
#define DIMENSION_PORTFOLIO 15
#define DIMENSION_PORTFOLIO_1 8
#define DIM_DATABASE_AGENTS 30
#define EPSILON_MIN 0.02
#define EPSILON_MAX 0.03
#define EPSILON_PENDANT 0.03
#define UNIVERSE_COMPETENCE_FOR_TASK 30
#define PERCENTUALE_MARK_UP 0.10
#define PERCENTUALE_NOT_ACTIVATE 0.90
```

Figure 28 Initial Settings

With this initial setting, the following trend of prices and average price value are obtained:

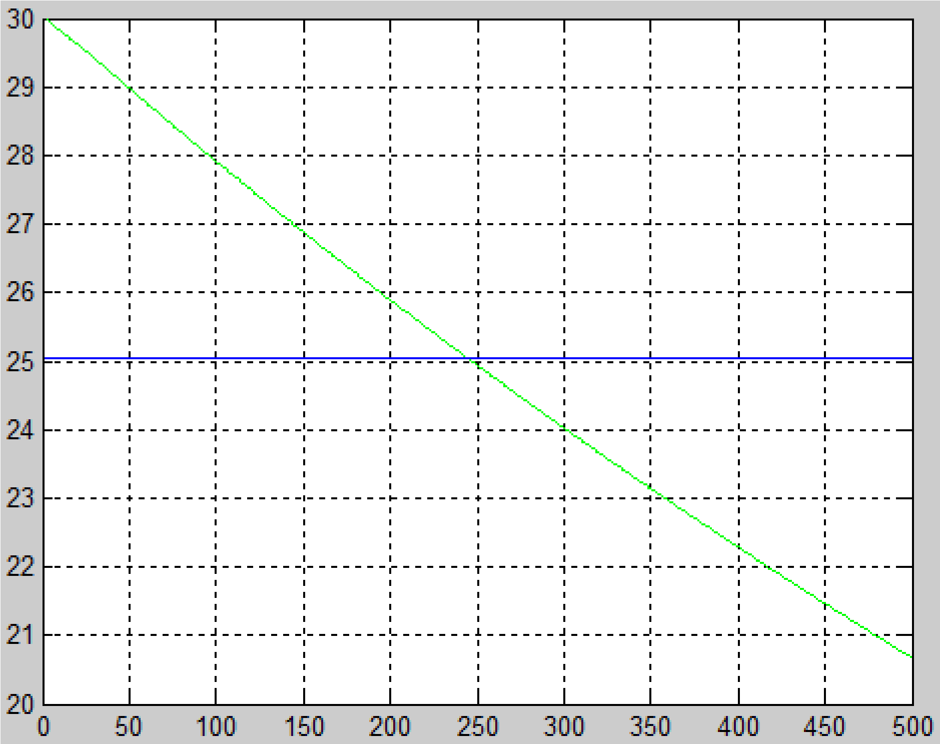

Figure 29 Price trend (green line) and average price (blue line) in the absence of a market, 500 iterations

With this setting the parameter's values considered are as follows:

- average price knowledge assets = 25.049
- the number of tasks completed = 1,047
- number of exchanges made = 0

As it was forecasted, in the absence of trading the price of knowledge assets collapses. Since the number of completed tasks is very little, the only relevant phenomenon that influences the price trend turns out to be the devaluation due to obsolescence.

4.10.3. What-if Analysis

It helps us to calculate the sensitivity to changes in certain variables of the model.

The objective of the what-if analyses was to test the sensitivity of the system towards some of the parameters included in the starting settings. To perform these analyses some parameters, one by one, have been settled and then the consequent changes to the variables of interest (i.e. average price of knowledge assets, number of tasks completed in the simulation period and the average daily number of completed tasks (volume work performed), total number of exchanged expertise and average daily number (trading volume)) have been verified.

Where necessary, after the graphical representation of the results, the "Wilcoxon rank-sum test" was used. This non-parametric statistical test allows verifying if the statistical samples, in the presence of ordinal values from a continuous distribution, considered in pairs, originate or less from the same population.

The initial setting data, taken as reference for the analysis of the subsequent scenarios, is identical to that described previously in the analysis in the absence of the market, with the only difference given by the activation of the same market. The simulation period set for this, as for the other analyzes, is equal to 500 iterations.

```
#include "header.h"
#include "workers_agent_agent_header.h"
#define AGENTS 13
#define DIMENSION_HISTORIC 20
#define DATABASE_DIM 16
#define TASK_DIM 5
#define DIMENSION_PORTFOLIO 15
#define DIMENSION_PORTFOLIO_1 8
#define DIM_DATABASE_AGENTS 30
#define EPSILON_MIN 0.02
#define EPSILON_MAX 0.03
#define EPSILON_PENDANT 0.02
#define UNIVERSE_COMPETENCE_FOR_TASK 30
#define PERCENTUALE_MARK_UP 0.10
#define PERCENTUALE_NOT_ACTIVATE 0.87
#define DIMENSION_UNIVERSE_COMP 51
```

Figure 30 Initial Settings

Please note that, in all performed data analysis, were considered 500 iterations over 550 total. The reasons for the rejection of the first 50 days simulated is linked to instability due to the initial conditions of the system, different from those in the scheme. For example, at the beginning of the simulation, all agents will have positive cash flow and no one will be already occupied. For this reason, after estimating a duration of this phase of instability around the 50 iterations, we have been considered valid for analysis only the 500 subsequent iterations.

With the initial scenario described above the considered variables assume the following values:

- Average price knowledge assets = 30,06
- Total number of tasks completed = 483.13
- The daily average number of task completed = 0.97
- Amount of exchanges of knowledge assets = 1213.88
- The daily average amount of exchanges of knowledge assets = 2.43

At this point the simulations were carried out, each one imprinted on a different scenario. In some scenarios a single parameter was changed, leaving all the others as basis settings, in order to observe which one impacts more on the model. For each scenario, 10 simulations were performed varying the "random seed", the guide value for the randomness in the random drawing functions. This operation was performed to give more strength to the output of the simulations in statistical terms.

Simulations were performed increasing the number of random seeds to 30 to verify the possible attainment of a greater solidity of the outputs. Since no significant variation was observed in the results obtained (fluctuations of the average values lower than 0.5%), we decided to use 10 random seeds in order to reduce the simulation duration without significant consequences on the results.

The first parameter to be modified was the percentage of agents "activated" at each iteration, that is the percentage of agents, including those selected because they possess the necessary characteristics (cash greater than zero, no open tasks to be completed, etc ..), which is assigned a task to perform. The percentage of activated agents was, respectively, equal to 5%, 10%, 15%, and 20%, for the first 4 scenarios.

The data obtained from the simulations were compared using box plots, a Matlab tool that allows you to plot the variation of a variable chosen the trend of a parameter on all the "random seed" tested. This way to plot the results allows detecting the distribution of the sample by analyzing the dispersion and positioning of the values. The upper and lower limits of the rectangle represent first and third quartiles, while the centre line represents the median; trunks to the rectangle depicting the further dispersion of the points; the symbols in the form of plus indicate outliers.

Later, using the "Wilcoxon rank-sum test", it was possible to analyze whether the samples, taken in pairs or not, come from the same population.

Here are box plots resulting from the first analysis:

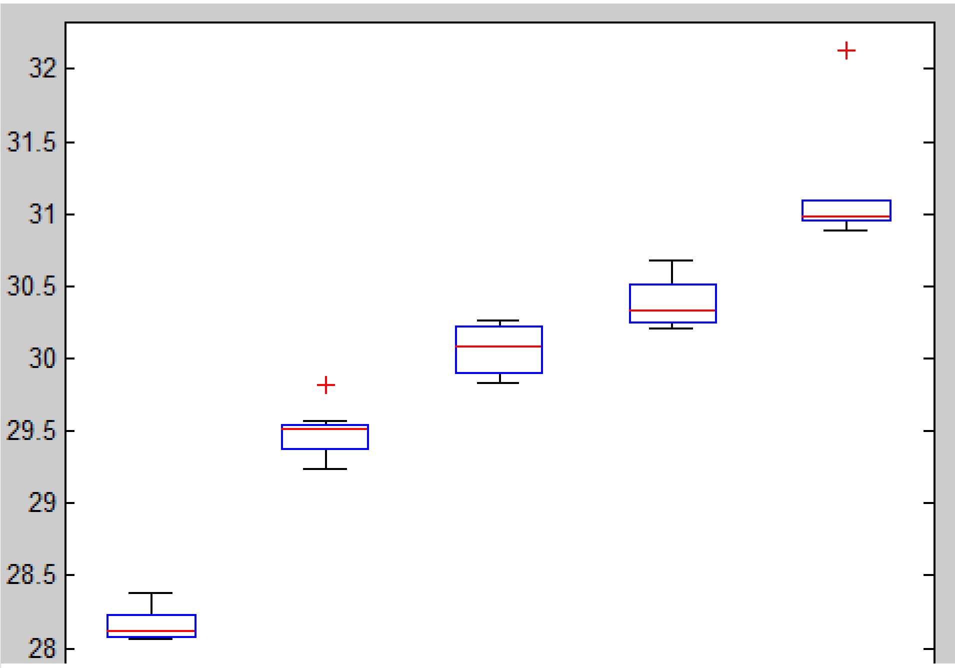

Figure 31 Average prices of knowledge assets / % of active agents

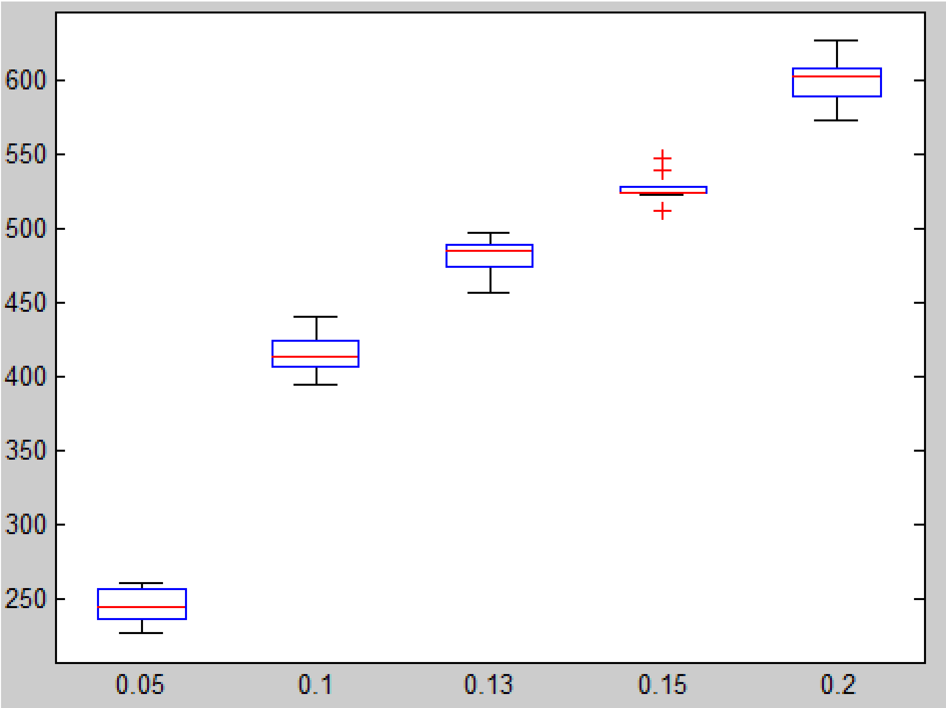

Figure 32 Total number of completed tasks/ % of active agents

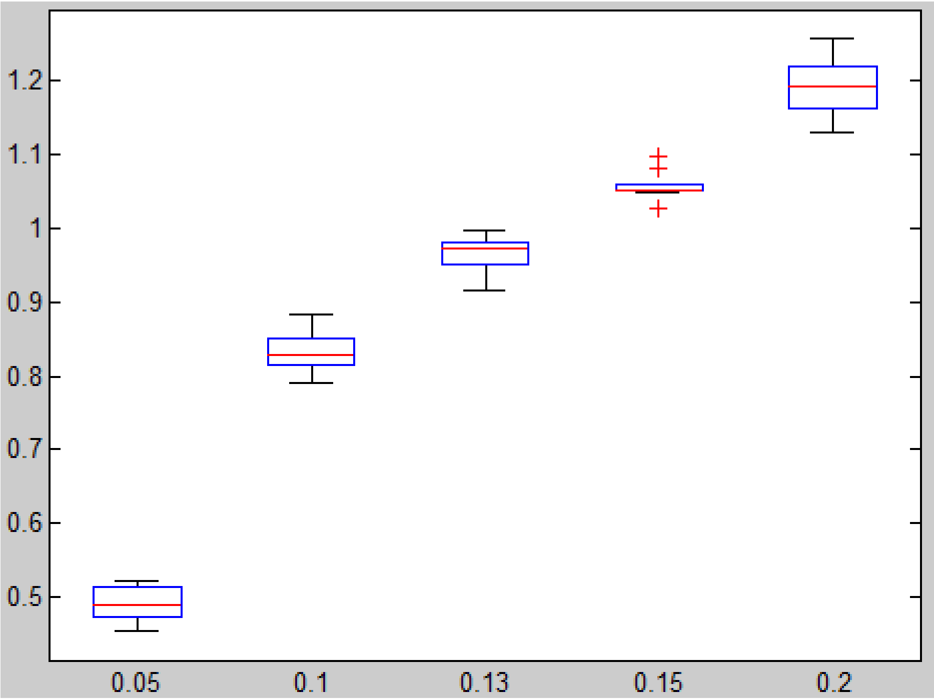

Figure 33 Daily average number of completed tasks / % of active agents

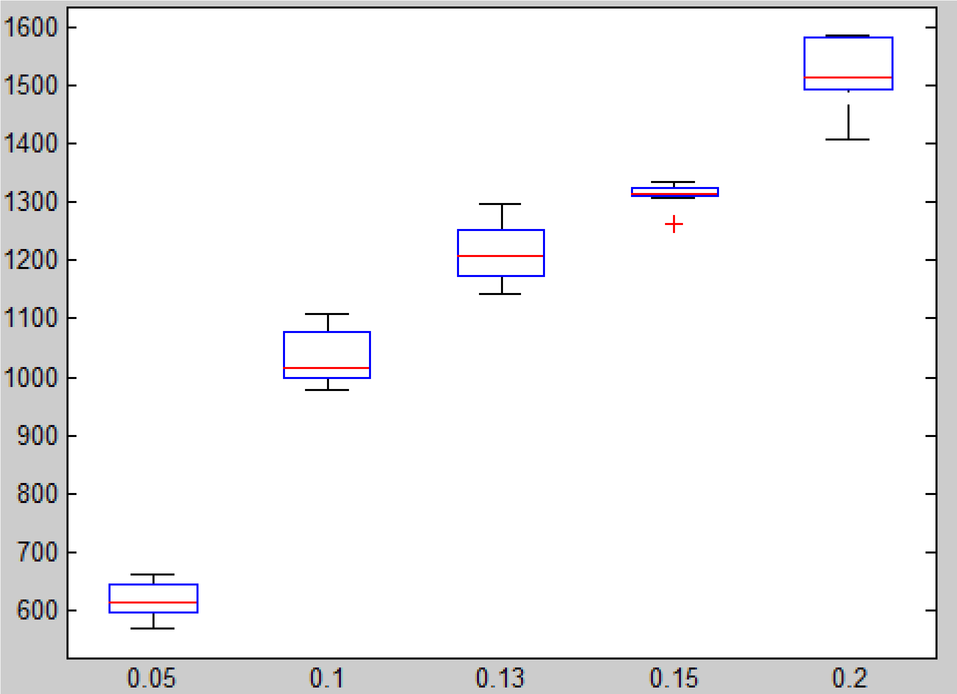

Figure 34 Amount of exchanges of knowledge assets / % active agents

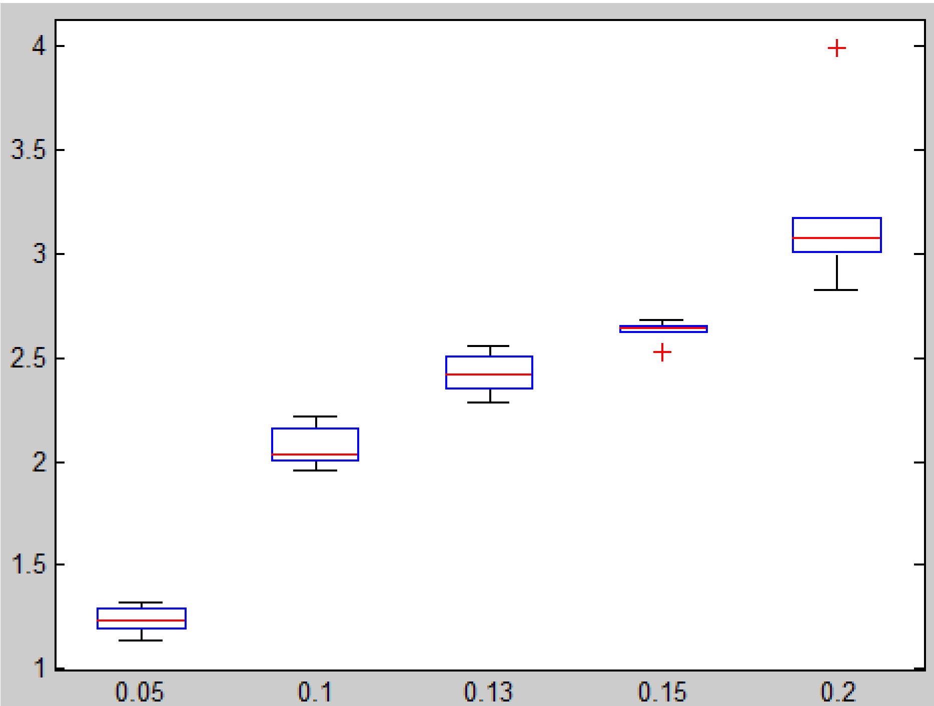

Figure 35 Daily average amount of knowledge asset exchanges / % active agents

The graphs highlight looks like this, with the increase of agents that can be activated at each iteration all the considered parameters increase. The greater the increase may be logged in the transition from the activated percentage of 5% to 10%, where the average, evaluated on medians, price increases of 4,73% (compared to the other cases in which the growth is estimated to average around 1,35 %), the number of tasks completed by 41% (compared to other cases where on average there was an increase of 11,7%) and the number of registered trade by 65% (in comparison to a 12,42% middle for the other cases).

Finally has been tested a scenario with a value equal to 100% of activated agents, the data reported show an almost linear and continuous growth in all analyzed parameters, without highlighting trends to some asymptotic values.

In the second set of simulations, the percentage of mark up has been varied that every agent is attributed during to esteem the value of a task to perform. The hypothesized sceneries respectively foresee values of mark up equal to 5%, 10% (value of the simulation of departure), 15% and 20%. The gotten data have always been analyzed through a graphic comparison using the boxplots.

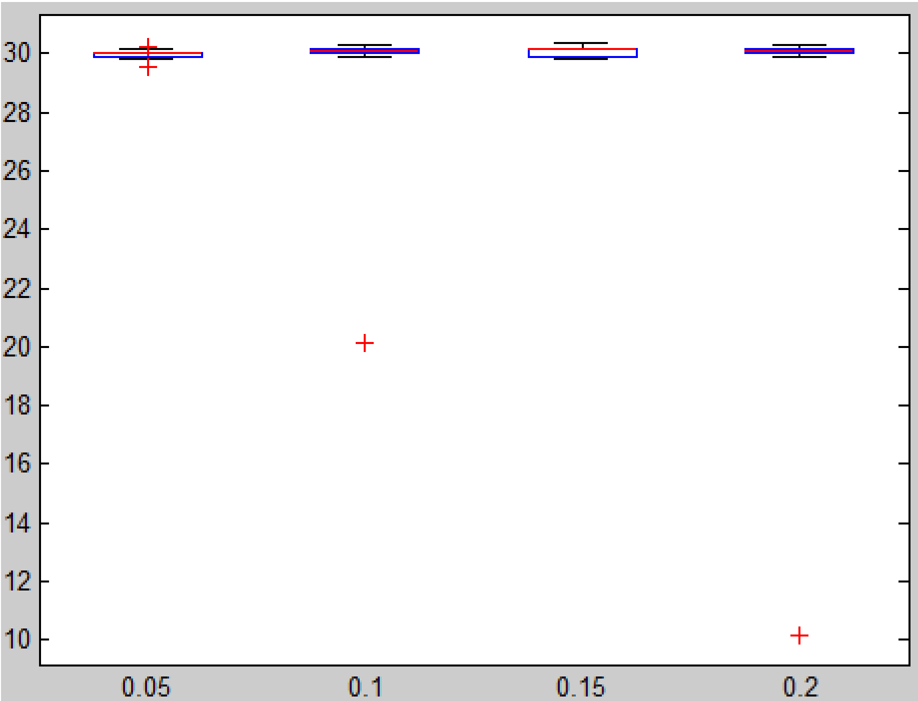

Figure 36 Average prices of knowledge assets / % mark up

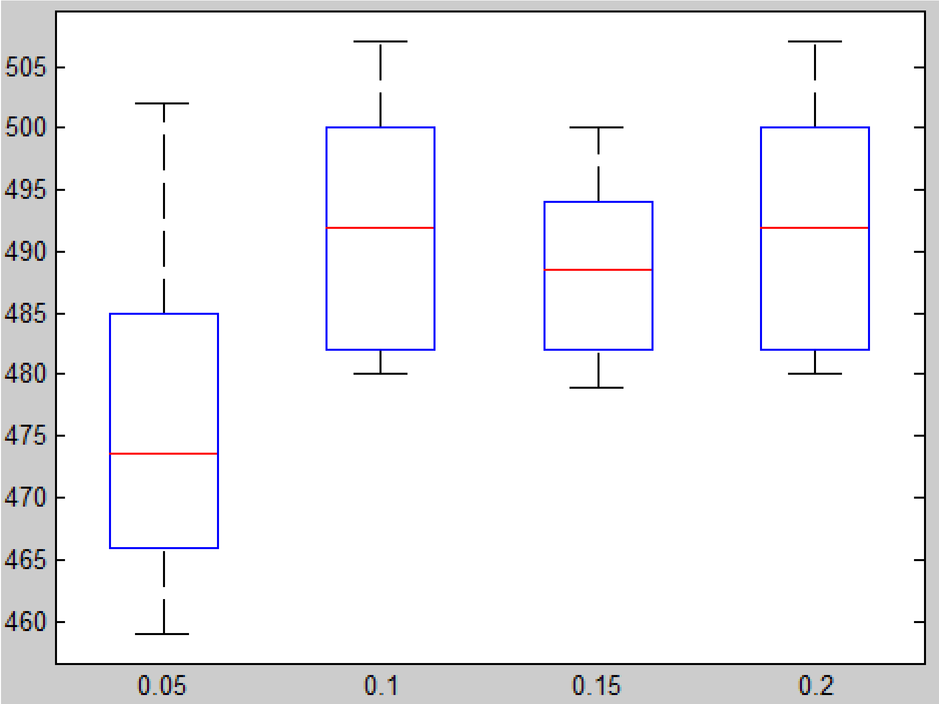

Figure 37 Total number of tasks completed / % mark up

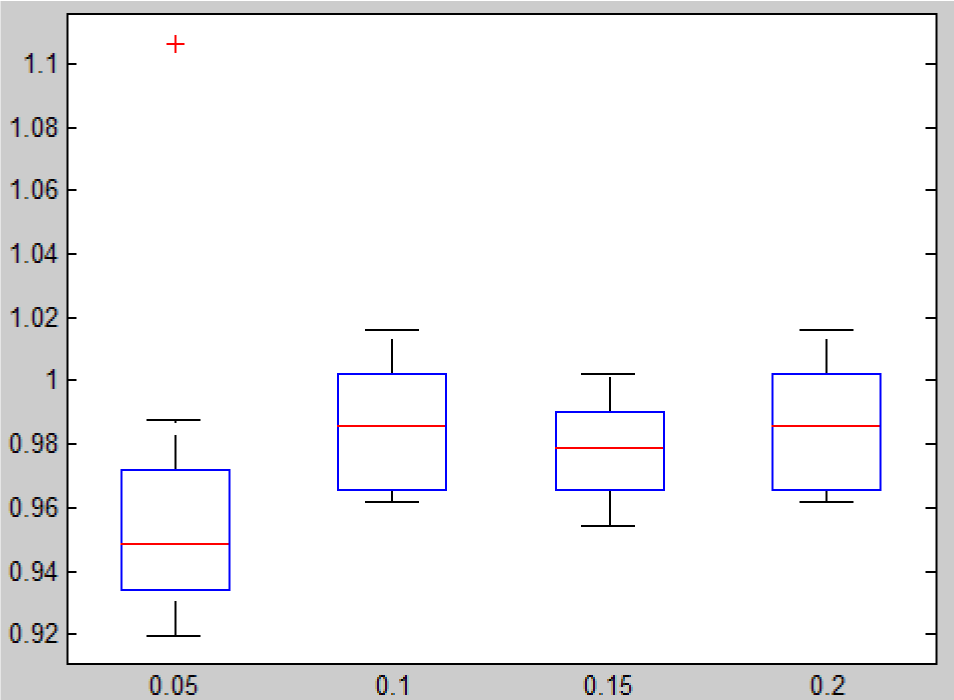

Figure 38 Average daily number of tasks completed / % mark up

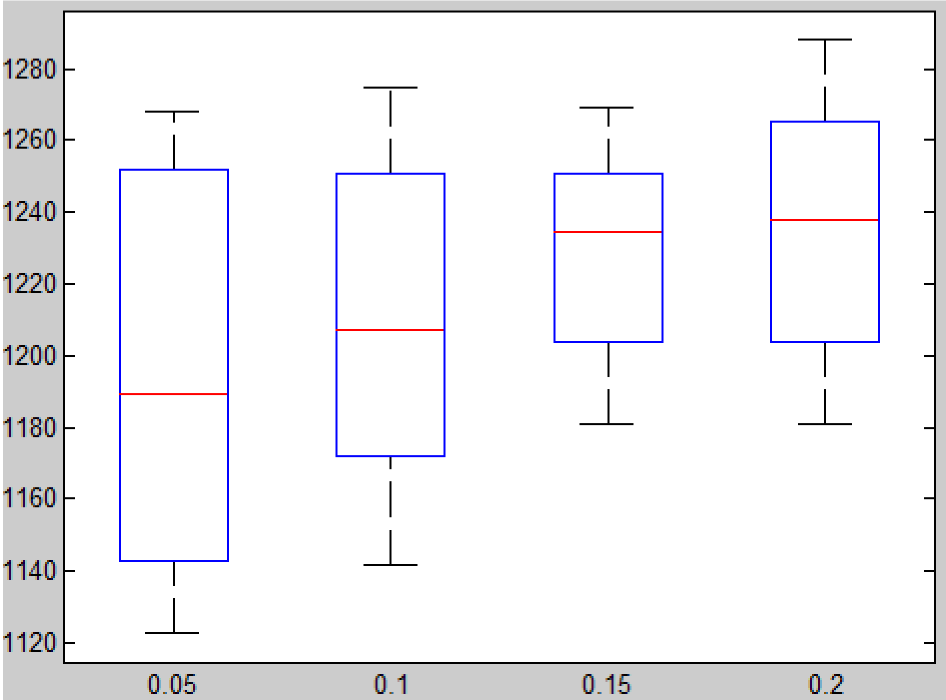

Figure 39 Amount of exchanges of knowledge assets exchange / % mark up

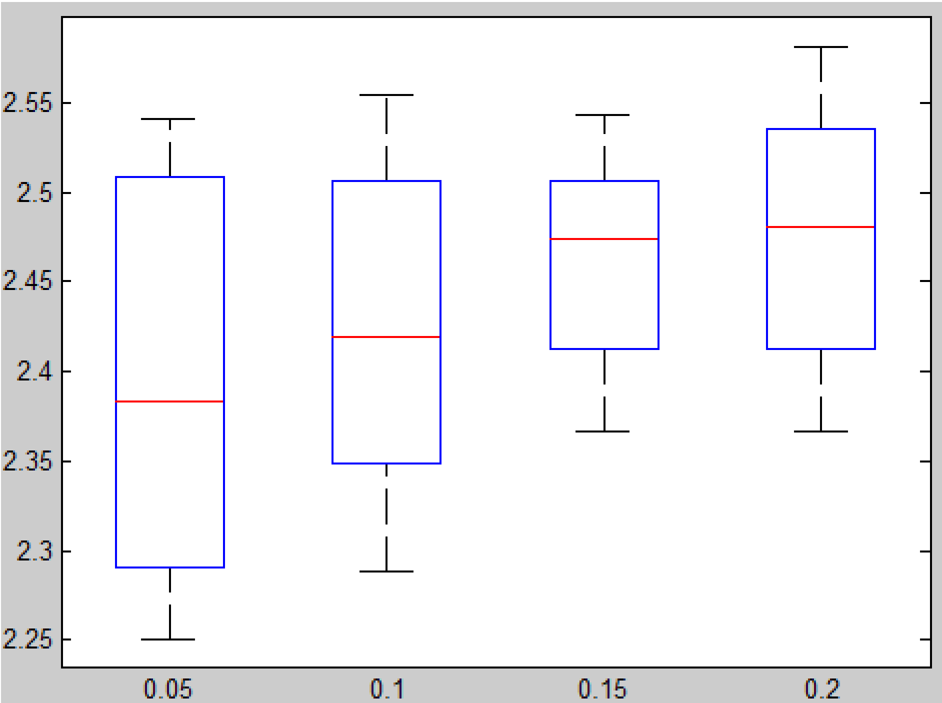

Figure 40 Daily average amount of exchanges of knowledge assets e / % mark up

From this analysis, we observe the poor sensitivity of the system to changes in the mark-up set percentage. Despite the percentage you get tested quadrupled, deviations on the average prices of the knowledge assets are almost null (approximately 0.2%), while for the total and an average number of both tasks completed both exchanges made variations of the medians remain very low (around 1.7%).

View deployment of focus points highlighted by the box plot is further analysis is considered necessary by the "Wilcoxon rank-sum test." From the matrix of p-values resulting from the tests, characterized by the presence of all values above the chosen threshold of 0.05 it can be concluded that the hypothesis H0 is not to be rejected, meaning that the average of the measurements remain substantially unchanged and the parameter markup is no significant impact.

0	1.8267e-04	1.8267e-04	1.8267e-04
0	0	1.8267e-04	1.8267e-04
0	0	0	0.0017

Table 17 p-value matrix

In the third set of simulations, it was made to vary the relationship between the size of the knowledge asset set of each agent and the size of the universe total knowledge assets. To make a more complete analysis possible, considering the impossibility to increase at will the dimensions of the wallet due to inherent limitations of the simulation software, have been made before the portfolios vary with size 5 (corresponding to approximately 17% of the competencies Total), 10 (33%) and 15 (50% and starting setting) and subsequently reducing the universe from 30 to 25 (thus bringing the relationship between size of the portfolio and that of the universe to 60%) and finally to 20 (75%). For this reason, the data were analyzed separately, before those relating to the condition of the universe fixed size to 30 and the variable size of the wallet, then the inverse.

Subsequently shows the box plots for the two analyses.

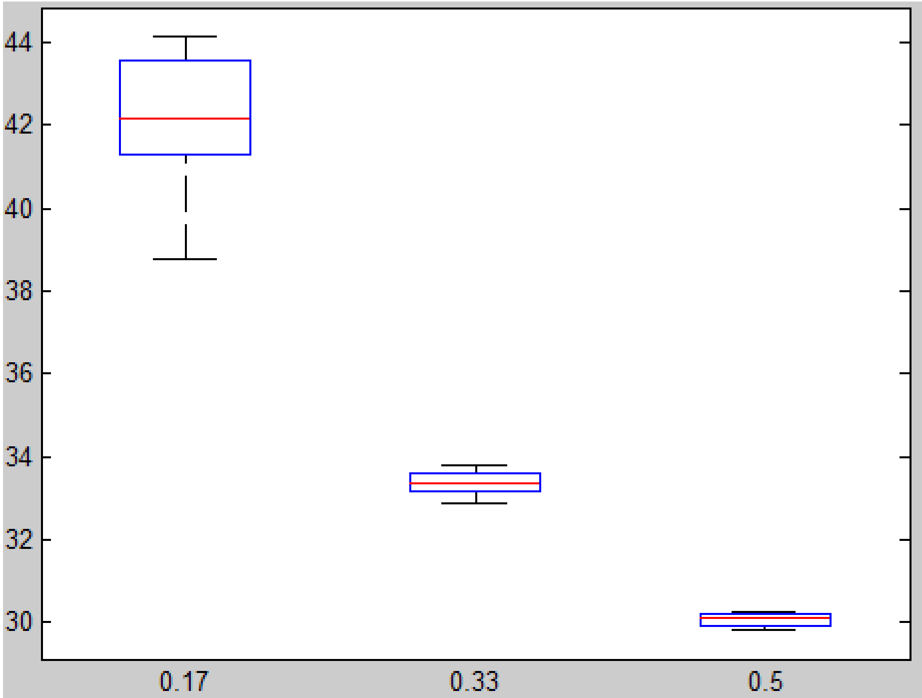

Figure 41 Average prices of knowledge assets/ratio between portfolio size and universe size

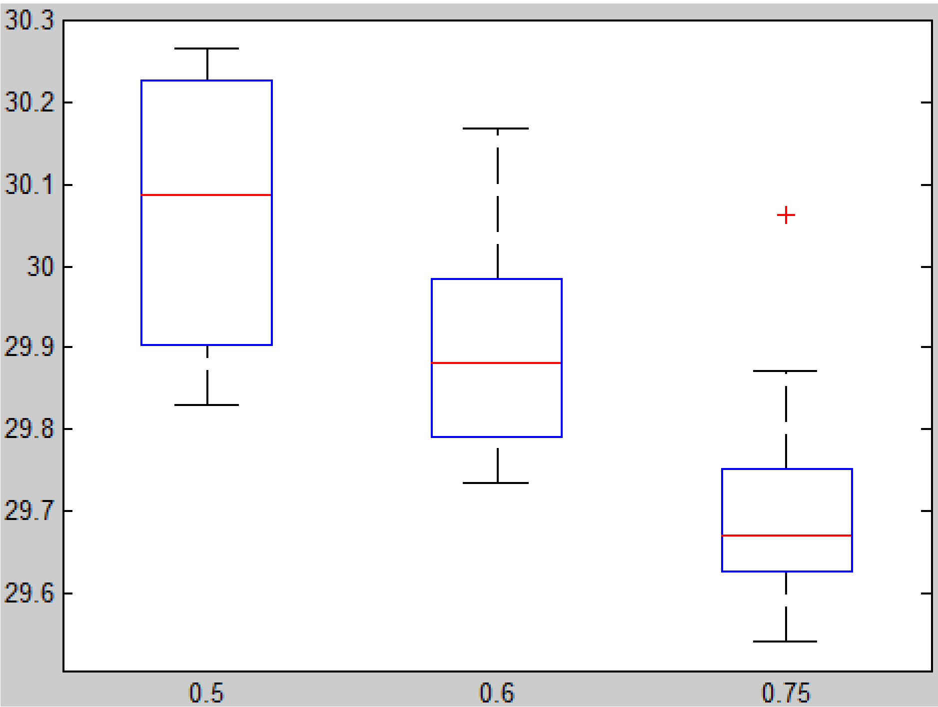

Figure 42 Average prices of the knowledge assets/ ratio between portfolio size and universe size

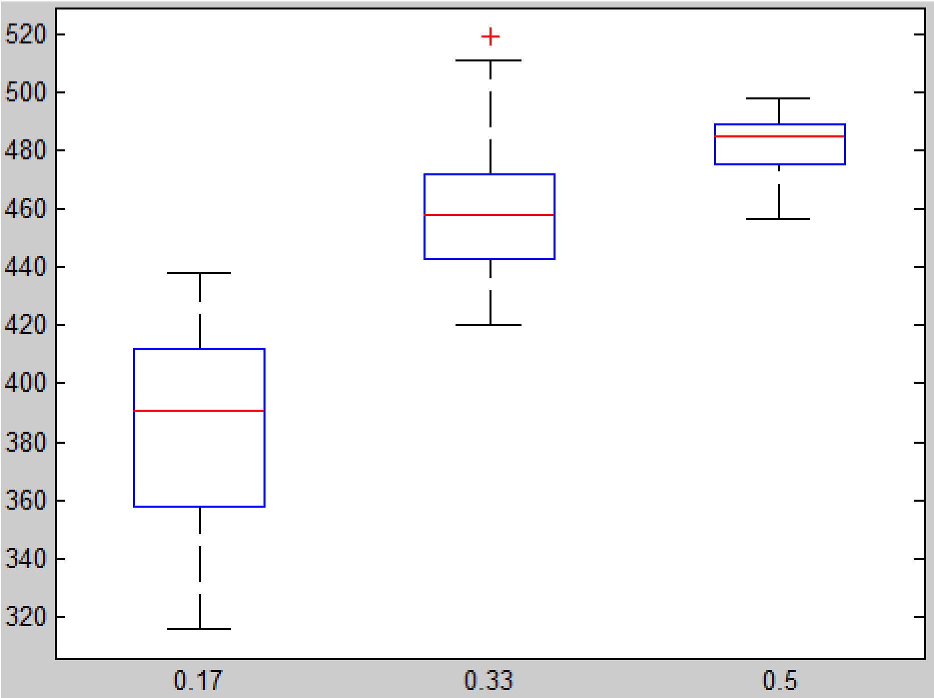

Figure 43 Total number of completed tasks/ ratio between portfolio size and universe size

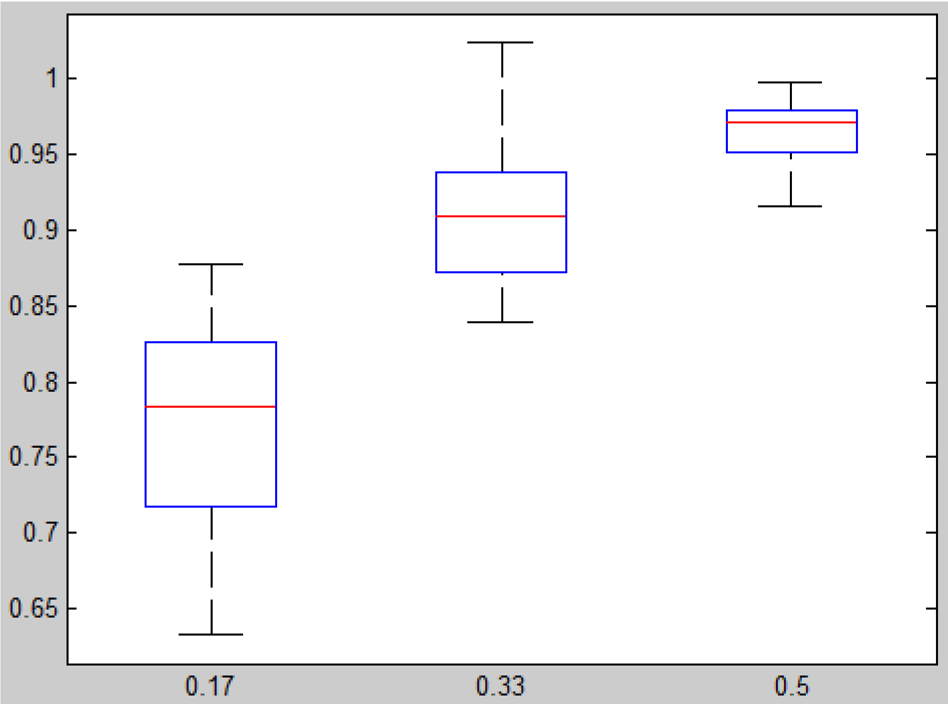

Figure 44 Average daily number of completed tasks/ ratio between portfolio size and universe size

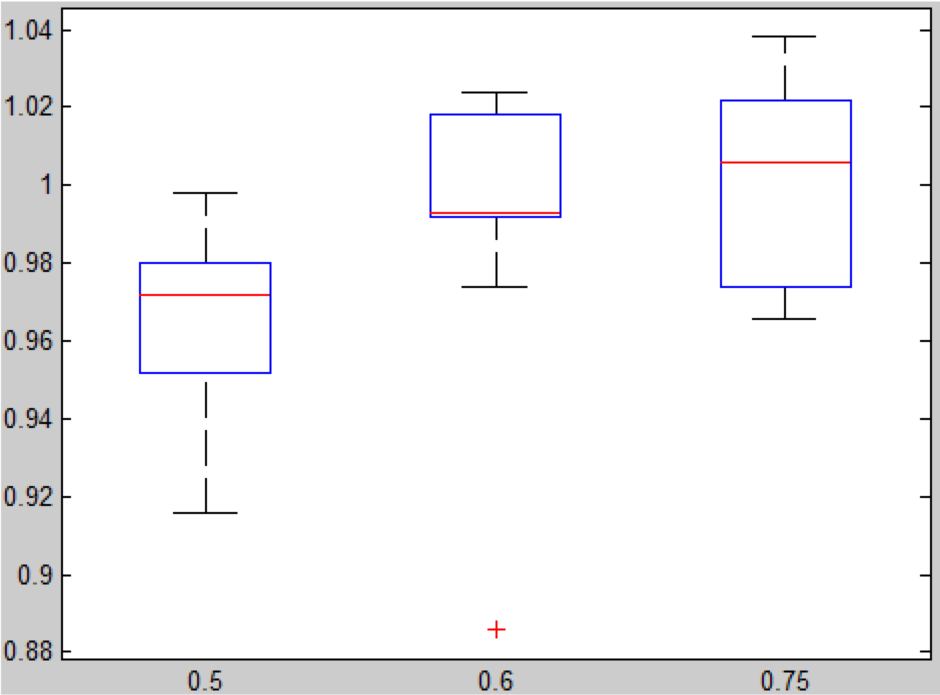

Figure 45 Average daily number of completed tasks/ratio between portfolio size and universe size

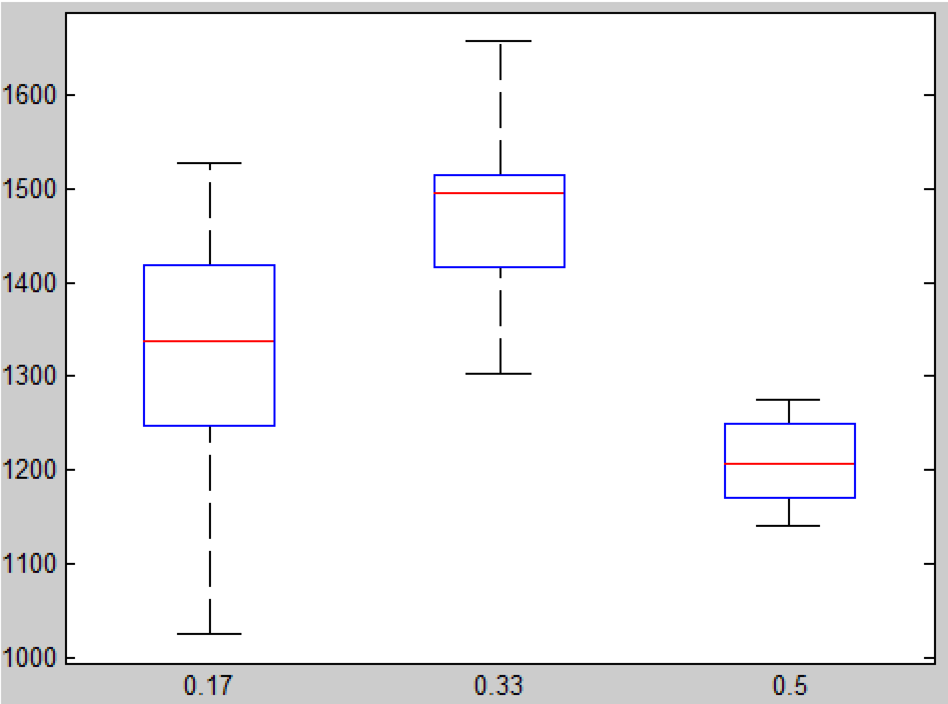

Figure 46 Amount of exchanges of knowledge assets/ ratio between portfolio size and universe size

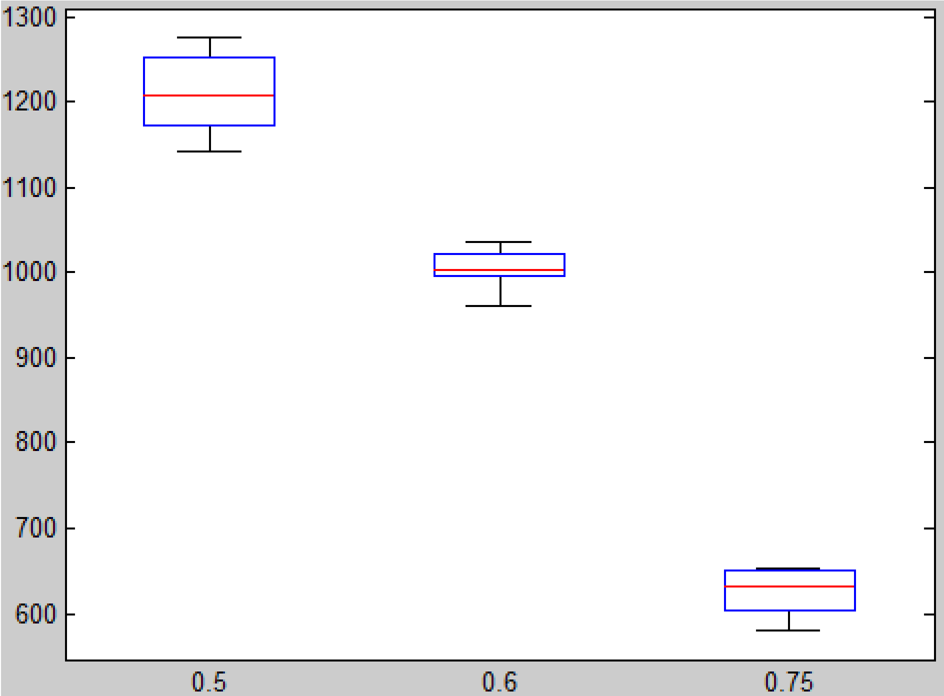

Figure 47 Amount of exchanges of knowledge assets/ ratio between portfolio size and universe size

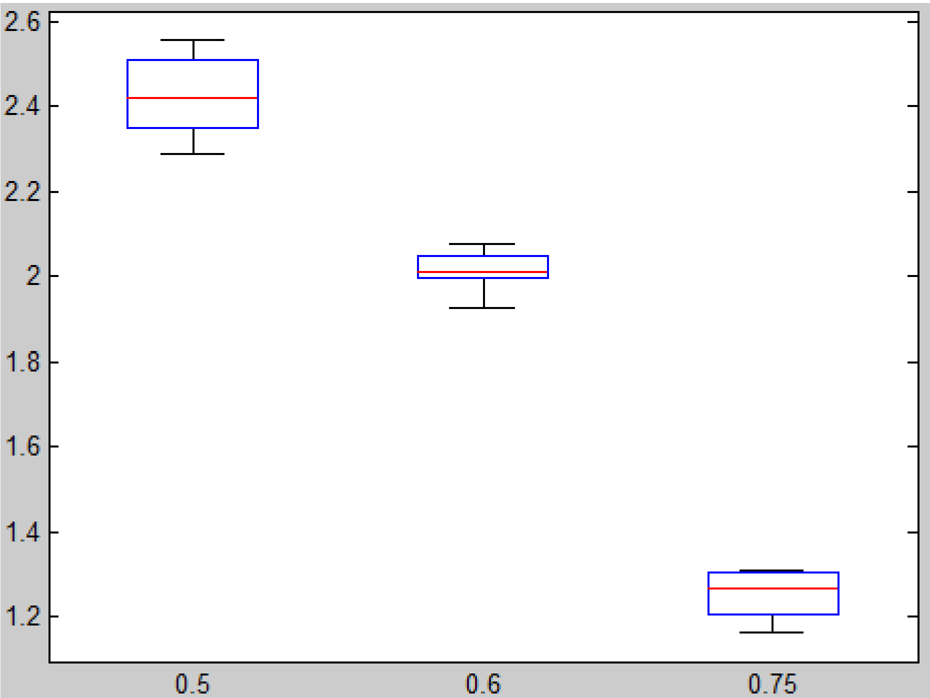

Figure 48 Average daily amount of exchanges of knowledge assets, / ratio between portfolio size and universe size

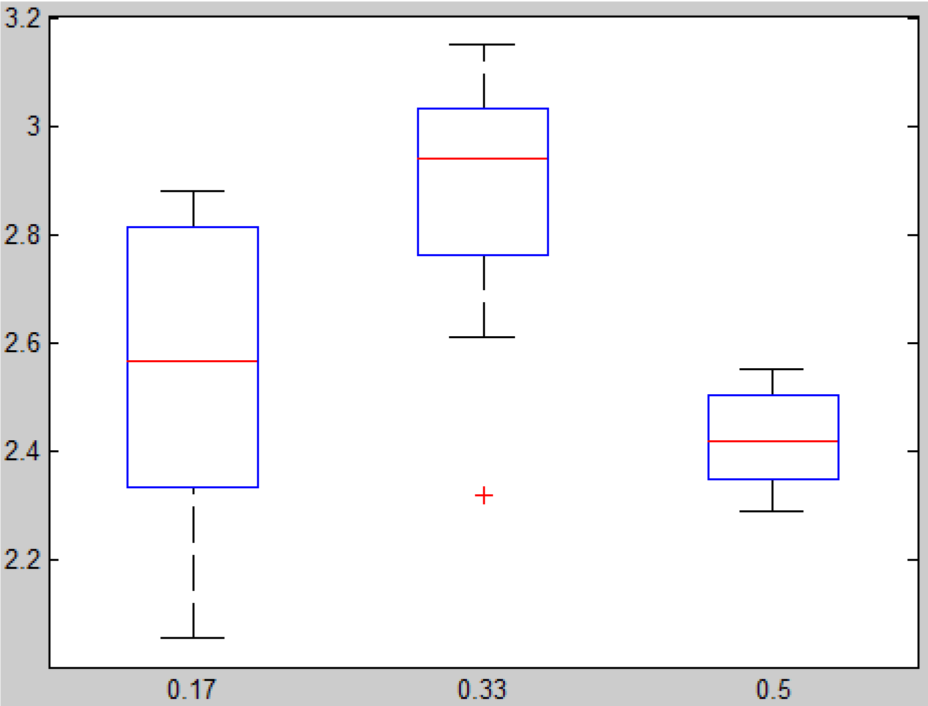

Figure 49 Average daily amount of exchanges of knowledge assets/ ratio between portfolio size and universe size

Looking at price developments can be noticed as a significant decrease in the average price of knowledge assets. With a competencies portfolio small equal to 5 competencies of a universe of 30 (17%), or with a wallet size equal to that of the task, the probability of not possess some of the knowledge assets required in the task is high. Therefore, the agents have to interact much to find the knowledge assets they need, this fact creates a bottleneck, in turn, causing delays in the negotiation mechanisms, it generates a lot of "pending" and lengthens the average time required to complete a task (equal to 7.8 iterations for the ratio 17% portfolio-universe, equal to 6.9 iterations for the ratio 33% and equal to 6.4 iterations for the ratio 50%). A large number of exchanges and the presence of many competencies "pending" gives precedence to the price revaluation of mechanisms to devaluation (obsolescence function). In the condition of the portfolio variable appears immediately significant variation of the size of the portfolio, in the case instead of the universe variable competencies had the sense to use the Wilcoxon test to verify whether, also, in this case, the variation of the parameters significantly impact or not. The comparison between portfolio variables and universe variables. It means, does the portfolio variables affect more significantly to the variation of the size of the portfolio than the universe variable? And is it statistically meaningful?

0	0.0376	0.0010
0	0	0.0091

Table 18 P-value matrix

The number of completed tasks increases with the percentage ratio wallet-size - universe dimension. However, the growth slows down when it exceeds 50%. The growth of the work done passing from 17% to 50% is equal to about 19.38% (changing from 391 tasks completed on 500 iterations up to a maximum of 485). The growth in the transition from 50% to 7% is more modest and is between 485 works completed up to 502 (about 3,39% more). In this second case, it was helpful to use the Wilcoxon test again, which showed that statistically affects, considerably, the only variation from 0.5 to 0.75. The comparison of the parameters 0.5 and 0.6 are of borderline statistical significance, while it is not to reject the hypothesis H0 in comparing the parameters 0.6 and 0.75.

0	0.0050	0.0099
0	0	0.9093

Table 19 P-value matrix

Finally, it is an interesting analysis of the registered trade volume. In fact, from the graphs, it is observed a maximum point, close to the ratio wallet-size - universe equal to 0.33, for trade-in total and average knowledge assets over a period of simulation. This fact shows that the number of exchanges that take place in the system reaches a maximum value of 1494, beyond which you can not go for two reasons: if it still reduces the portfolio (and consequently the relationship with the universe of knowledge assets and with the size of the task, which remains fixed) the market becomes "too crowded" because too many agents have to buy a large number of competencies, all leads to an increase of the time necessary to the closing of a task (almost 8 iterations) and the reduction in the volume of trade; on the contrary, increasing the size of portfolios increases the ratio wallet-size - task size, and consequently increases the probability of having more competencies than those required in the task. All this leads to a reduction in the number of competencies equal to 19.2% from having to search the market and thus an overall drop in trade (up to 1207).

Even in this case, it was performed the Wilcoxon tests to vary the size of portfolios, which showed the acceptance of the hypothesis H0 showing a non-significant variation of the values analyzed at varying ratios tested (0,17 and 0,33 0,55).

0	0.0155	0.0376
0	0	1.8267e-04

Table 20 P-value matrix

The last set of simulations was characterized by changes to the "size of the task" parameter or changed the number of constituent competencies the task to be performed assigned to agents. In the scenarios simulated the size of task tested were as follows: 3, 4, 5 (value set in the reference scenario), 6 and 7 respectively the relationship between the size of the task and the size of each agent's competencies portfolio (equal to 15) it is made to vary from 20% up to a little less than 50%. Below are the graphs obtained from the comparison of the data with varying size of the task.

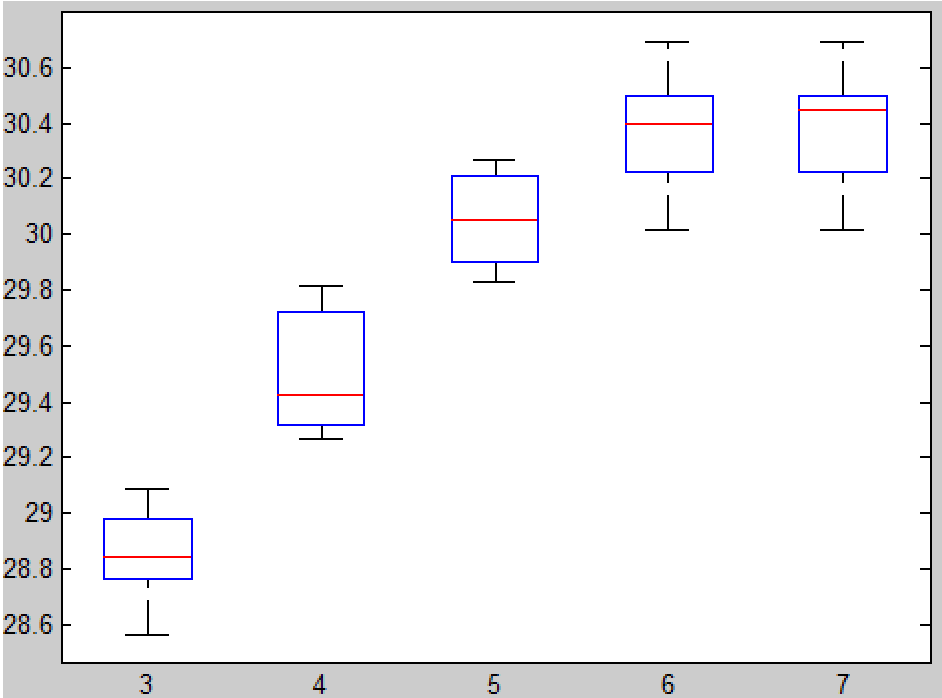

Figure 50 Average prices of knowledge assets/dimension task

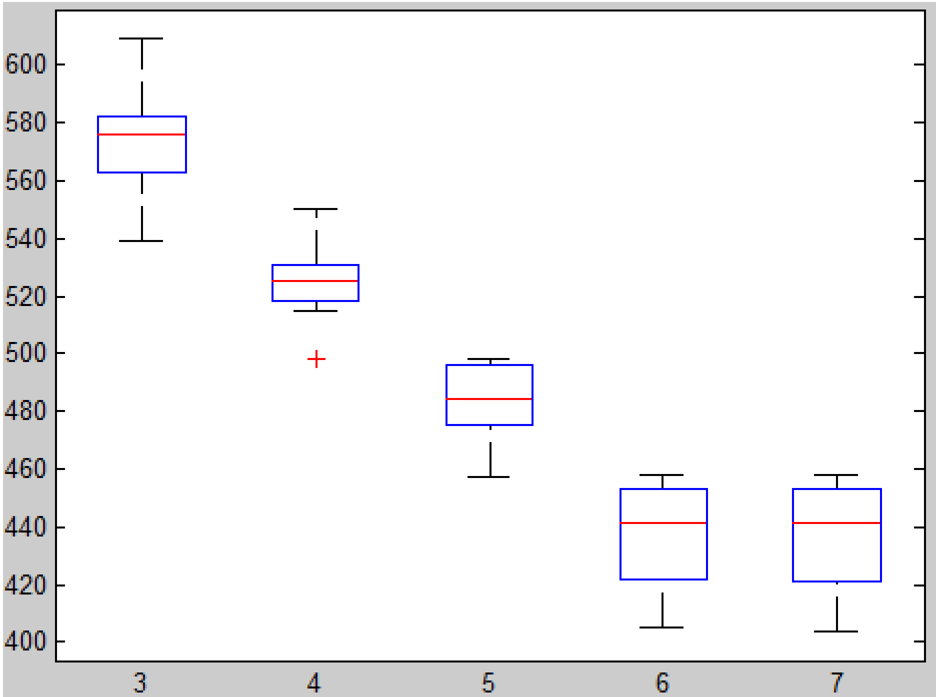

Figure 51 Total number of completed tasks/dimension task

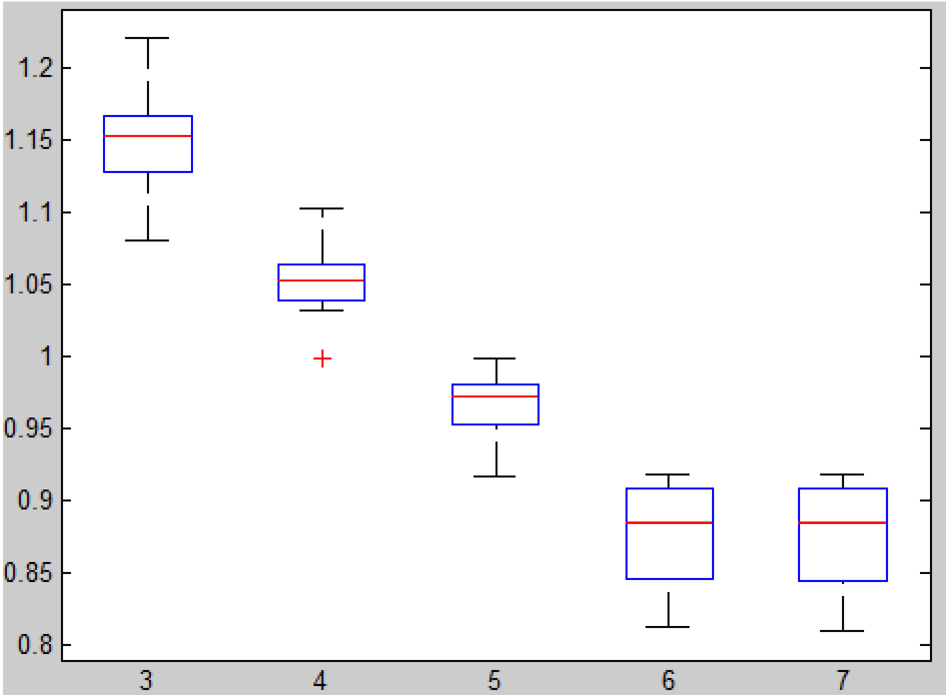

Figure 52 Average daily number of completed tasks/dimension task

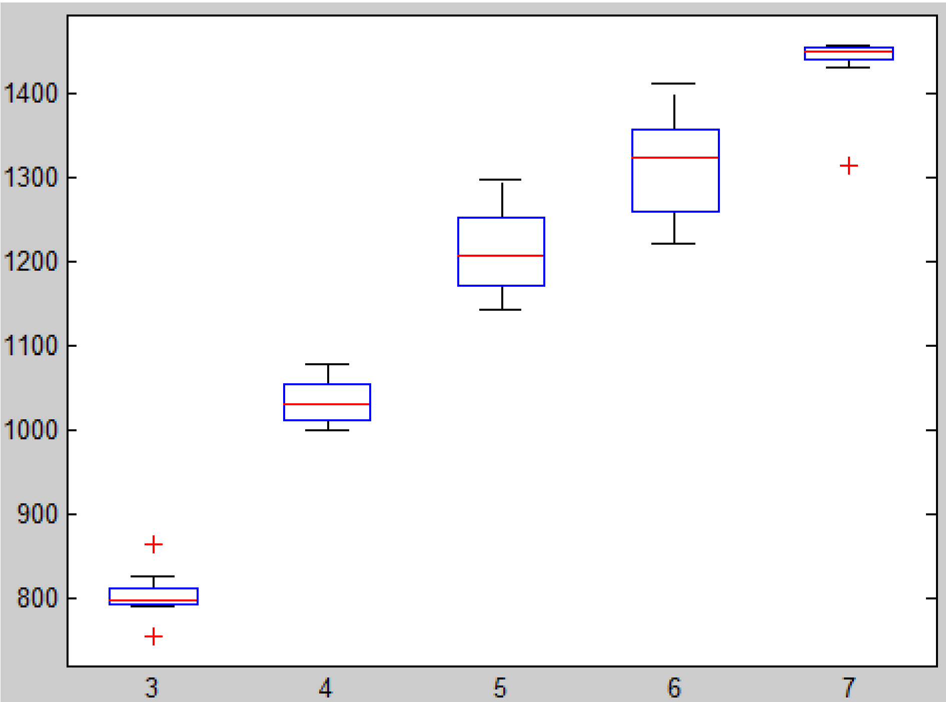

Figure 53 Amount of exchanges of knowledge assets/dimension task

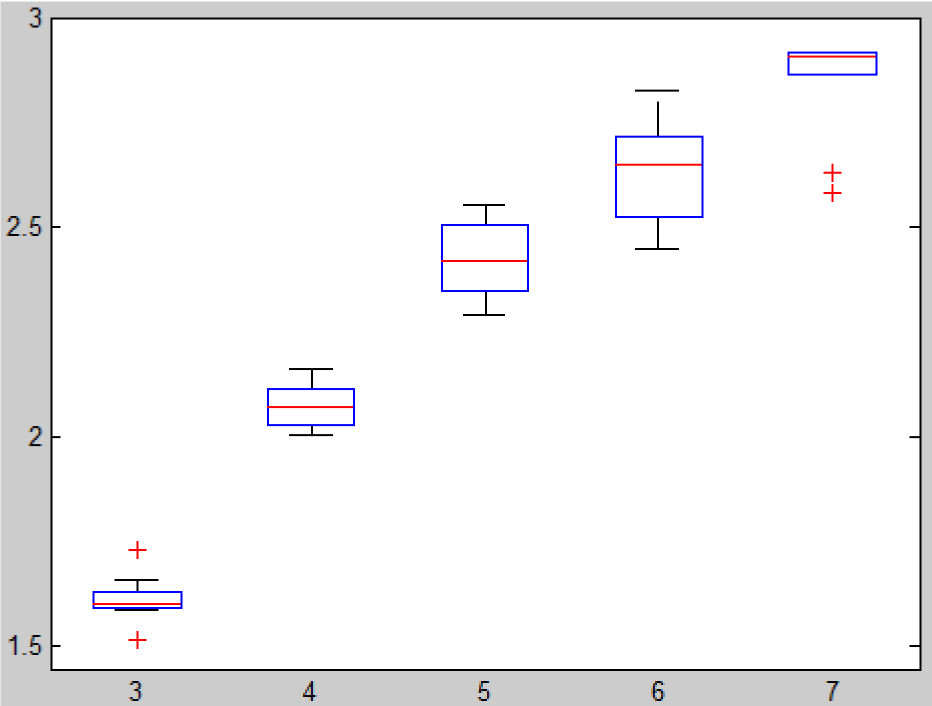

Figure 54 Average daily amount of exchanges of knowledge assets/dimension task

Looking at the trend in average prices of the knowledge assets is observed an increase of the median and the distribution of points until 6. The average price grew from 28.85 up to a value of 30.4 for a total increase of 5.01%. This increase is motivated by the increasing probability of finding, in the task, not knowledge assets possessed in his wallet. For this reason, the prevalence of price revaluation mechanisms on the write-down due to obsolescence. The size 6 onwards appears less significant, if any, the change in average prices. This is due to the fact that, by increasing the ratio between the size of the task and size of the portfolio (with a task size it is 7 has a value of about 48%), increases the population of knowledge assets of the task that will run internally while it is reducing that of knowledge assets to purchase. This means that to prevail, among the knowledge assets of the revaluation mechanisms, both the recovery of the initial price at the expense of the increase of the price, own of the market mechanism. This fact is confirmed by an index that represents the average number of knowledge assets acquired to completed tasks (calculated as the ratio of the number of exchanges made in the simulation period divided by the number of tasks completed). This index is valid: 1.4 for task dimension equal to 3; 1.98 for tasks size 4; 2.5 for task size 5; 2.98 for tasks size 6; 3.4 task size 7.

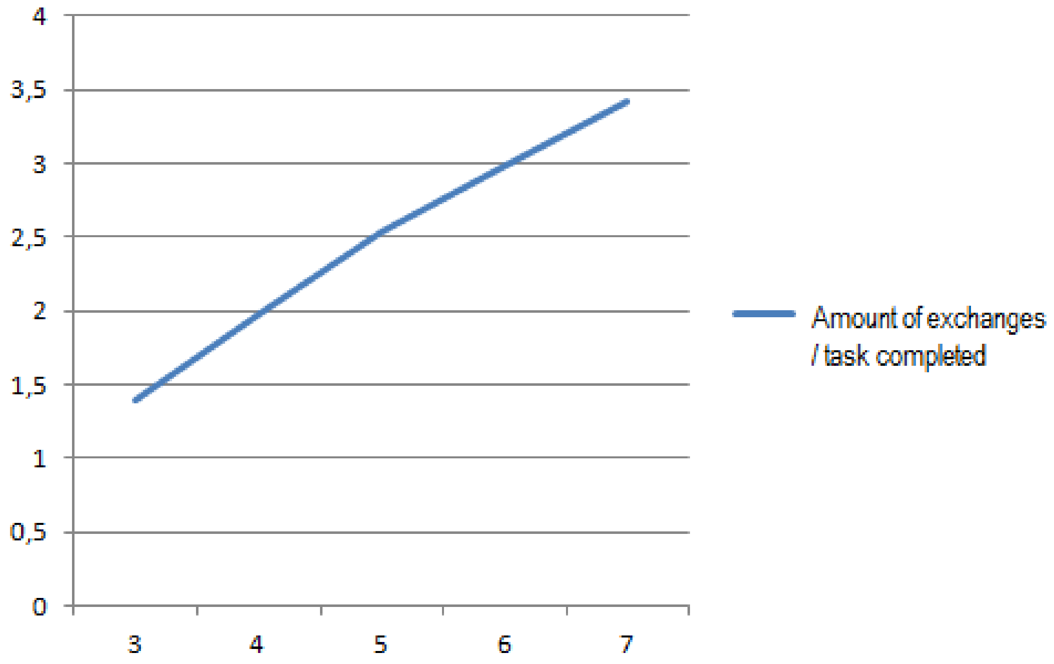

Figure 55 Exchanges/task completed

It's clear that the curve does not grow with the linear trend, like the dimensioning task.

Increasing the size of the task the average number of acquired knowledge assets does not grow in the same way, but more slowly, thus decreasing the greatest impact of the revaluation of the knowledge assets prices.

To test the apparent non-significant change in prices between values 6 and 7 was used usual Wilcoxon test. This test has returned the following matrix, which confirmed what appeared graphically.

0	1.8267e-04	1.8267e-04	1.8267e-04	1.8267e-04
0	0	1.8267e-04	1.8267e-04	1.8267e-04
0	0	0	0.0036	0.0036
0	0	0	0	0.8794

Table 21 P-value matrix

In fact, it is evident no significant change in average prices also moves from size 6 to size 7 of the task.

Instead of price, the trend of the total number of tasks concluded (and the average per day) is significantly reduced by increasing the size of the task. It passes from a total number of tasks concluded with 576 (1,15 task concluded on average for each iteration) in the time of simulation, up to a minimum of 441 (0.89 average for iteration) in the vicinity of the value set to 6. As observed with the prices also the number of tasks concluded varies in a minimal to vary the size of the task from 6 to 7. This reduction in the volume of work completed during the simulated period is caused by the increase in the average time required for the execution and completion of a task. It passes from an average time required for the execution of all the knowledge assets required to 4,13 iterations (in the dimension of matching task 3) up to a mean time of 8.6 iterations for the tasks of the greater size tested. It can then be observed, compared to a growth of the average time needed to completion of a task of about 52%, a decrease in the number of completed tasks on the simulated period of 23,44%.

Finally, using the Wilcoxon test was found what appeared graphically, ie: the change of the parameter tested from 6 to 7 leaves the medium substantially unchanged. The trading volume instead follows an upward trend. It passes from a minimum of 799 total in the simulated period (1.6 knowledge assets exchanged on average for iteration) for the task dimension equal to 3, up to a maximum of 1450 (2.9 powers exchanged on average for iteration) in correspondence of the tasks of larger size. Given therefore growth of 57% of the size of the task is an increase of 44.9% in the number of exchanged knowledge assets.

This growth in trade volumes is explained by an intrinsic aspect of the system. For as has been modelled, the system means that at least one of the task knowledge assets is already held by the agent to whom the task is requested. In doing so, it is observed as the ratio indicating the minimum number of already possessed knowledge assets in a task steps from 1/3 (33%) up to 1/7 (14.3%). With bigger task then, with the same size of the knowledge assets portfolios of the agents, it increases the likelihood of having to buy not possessed knowledge assets to complete the task. This causes an increase in trade volume.

4.10.4. Market Effectiveness

Finished the analysis on the sensitivity of the system, the analysis was performed starting from a curiosity that arose spontaneously during the phase of the definition of the key parameters of the model. The doubt raised concerns the definition of the setting that leads to the greater volume of work done, completed tasks, acting solely on two variables number of agents and size of their portfolios. The selected settings for the two scenarios to be compared were decided as follows: a first case with few agents (5) characterized by large portfolios (10 knowledge assets on a universe of 20), and a second mirror with so many agents (10) each of which provided with few knowledge assets (5 of 20 total).

Other setup and data remained unchanged in the two scenarios are, respectively: the dimension of the universe of the overall knowledge assets set at 20, so as to vary the relationship knowledge assets portfolio size / knowledge assets universe size from 0.25 to 0.5; the size of the task flow to 3 for both the scenarios, so as to avoid the case of higher dimensional task or equal to the minor dimension of portfolios.

Along with the parameter of interest for this analysis, the total number of simulation time of completed tasks, the figures for the total number of exchanged knowledge assets and reported the average price of knowledge assets were also plotted.

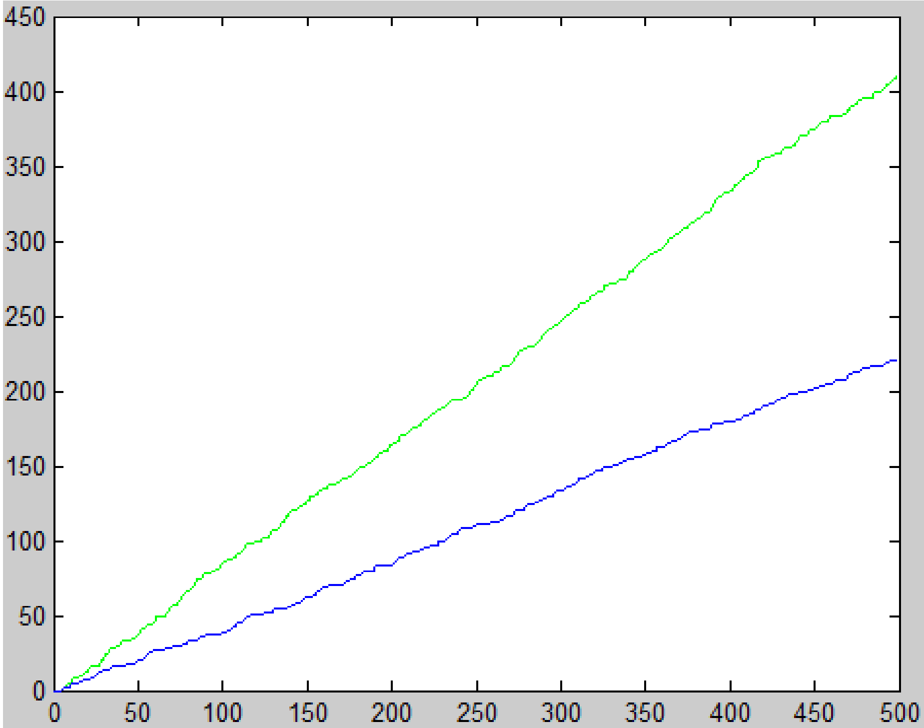

Figure 56 Task completed (green: 10 agents 5 knowledge assets; blue: 5 agents 10 knowledge assets)

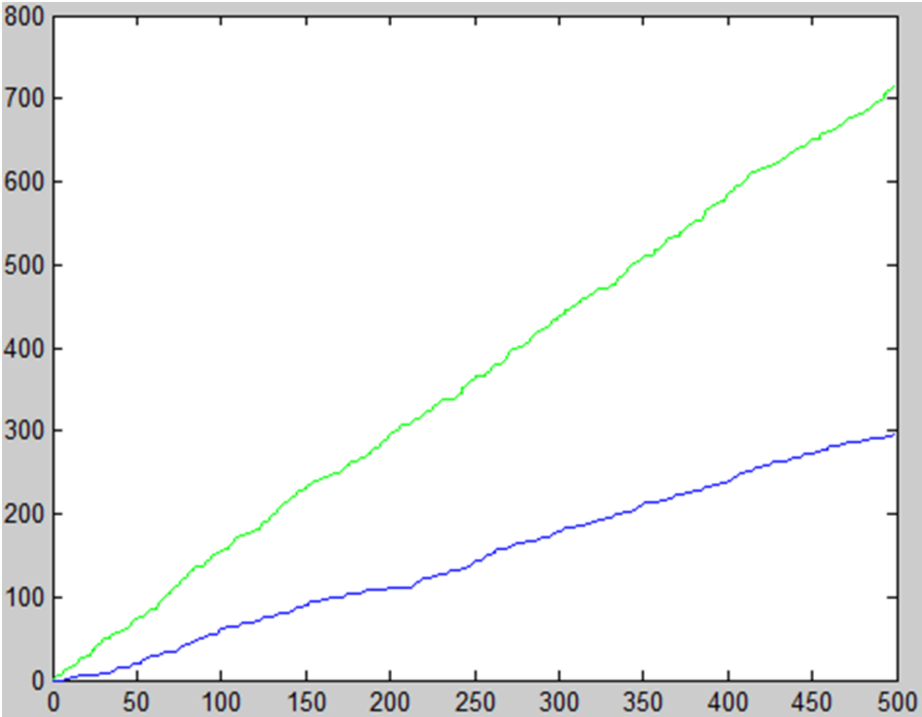

Figure 57 Amount exchanges (green: 10 agents 5 knowledge assets; blue: 5 agents 10 knowledge assets)

As it is evident from the graphs, the configuration with a higher number of agents characterized by a minor dimension portfolio has proved capable of realizing a higher task number, as well as to produce a greater volume of trade. The average number of completed tasks, passing the configuration few agents and many knowledge assets that many agents with few knowledge assets, increases by 45.91% (from a mean value of the 10 tested seeds of 222.3 with fewer agents up to a value of 411 with more agents). As for the exchanges, a 58,14% growth was recorded passing from one scenario, with the average number of exchanges that rises from a value of about 300 up to about 715. Finally, connected to the larger number of exchanges made, even the average price undergoes a rise passing from one configuration to another.

The increase in prices is around 15.6% with values that go from an average of 29.96 to 35.5.

The data obtained from this analysis, therefore, show an obvious consequent advantage in settings characterized by a high number of agents, even if provided of a few knowledge assets. In fact in this case not only it is able to conclude more tasks and then to complete more work, but the knowledge assets are moving more into the system and are maintained up to date due to their frequent use. Possibly in a system characterized by the ability to learn new knowledge assets from the interactions between different agents, increased circulation of expertise combined with a lower average rate of obsolescence can be of great interest in the evolution of the system itself.

4.10.5. Pareto Distribution of Resources (Sensibility Analysis)

This ultimately has been inspired, for the initial setup of variables and parameters of the system, as a real fact, the Pareto distribution of resources. More detail has been defined a scenario in which about 20% of the agents (3 of 13) possesses about 80% of knowledge assets' system (knowledge assets portfolios of size 16 with a size of universe 20) and the remaining 80% of agents It owns 20% of the total knowledge assets.

Each scenario was also made to change the initial settings of the cash, analyzing some significant parameters to vary the amount of cash at the start (same for everyone).

Finished simulations for different scenarios, with the usual random 10 seeds, it was observed the following average distribution of the crates.

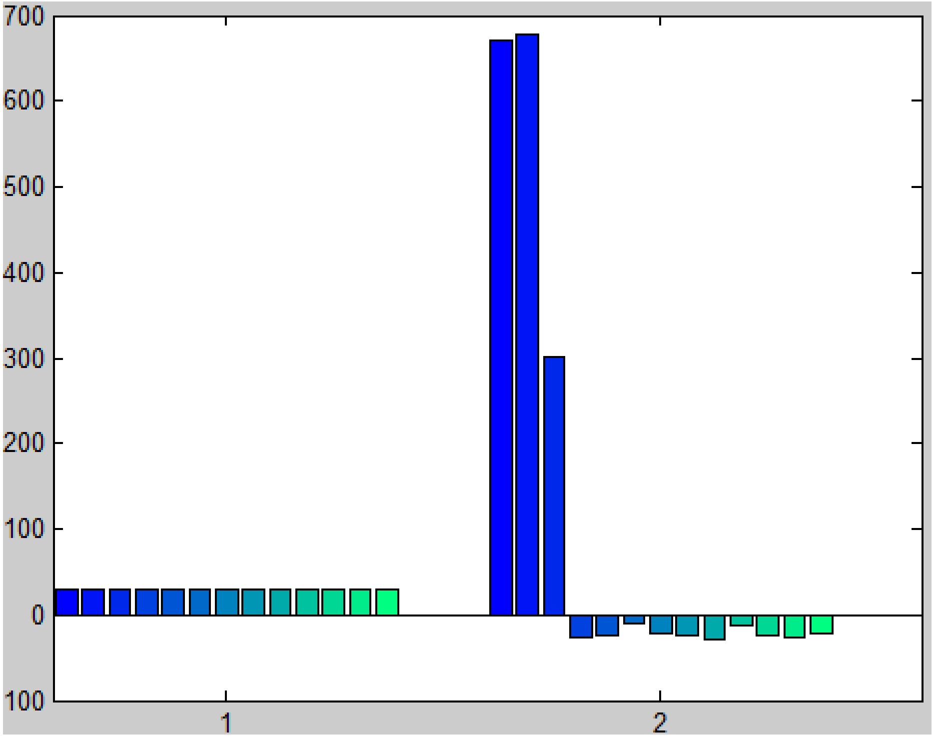

Figure 58 Average cash for each agent at the initial time (1), cash 30, and at the final time (2)

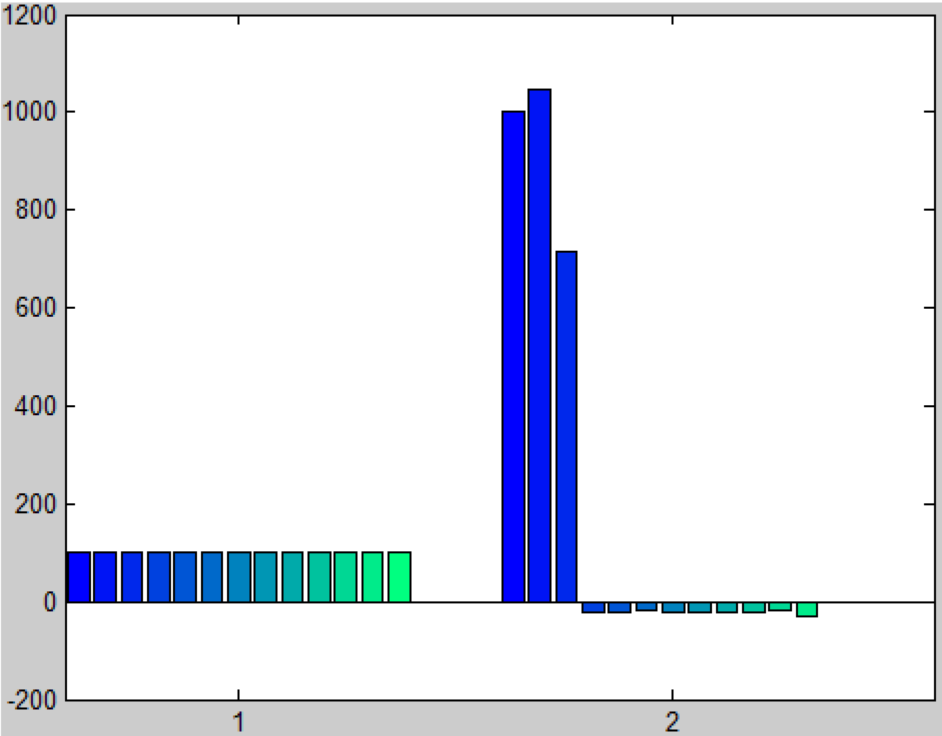

Figure 59 Average cash for each agent at the initial time (1), cash 100, and at the final time (2)

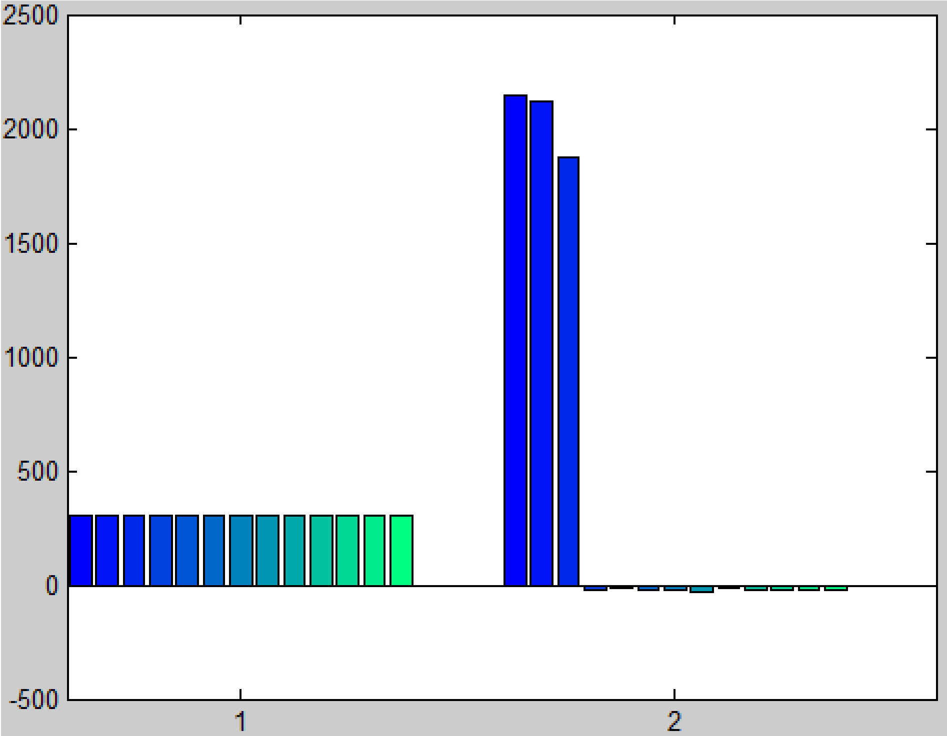

Figure 60 Average cash for each agent at the initial time (1), cash 300, and at the final time (2)

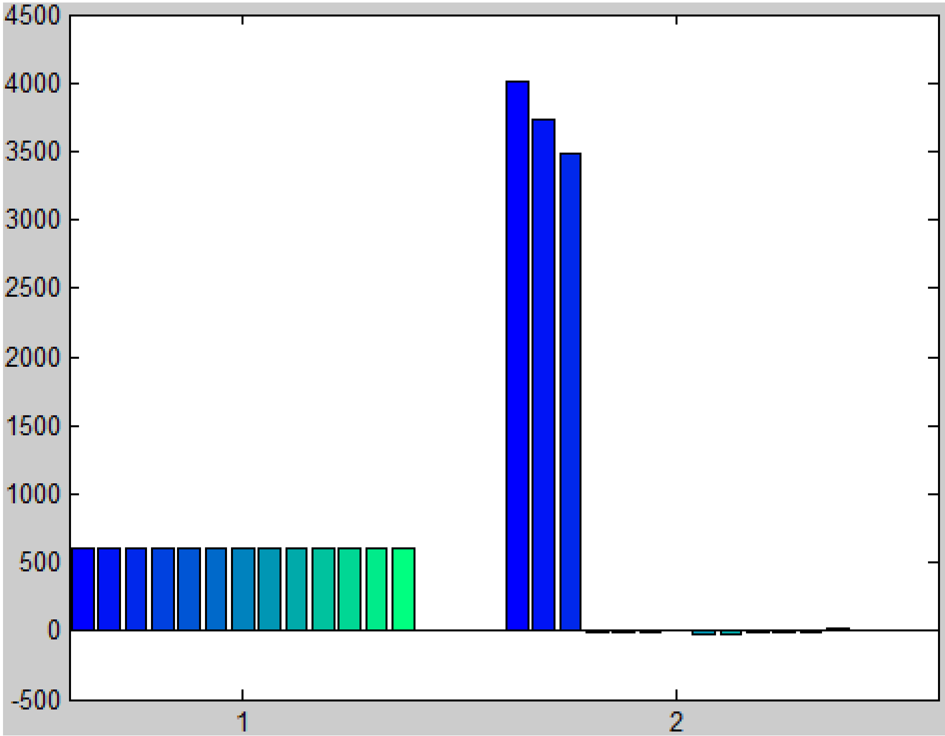

Figure 61 Average cash for each agent at the initial time (1), cash 600, and at the final time (2)

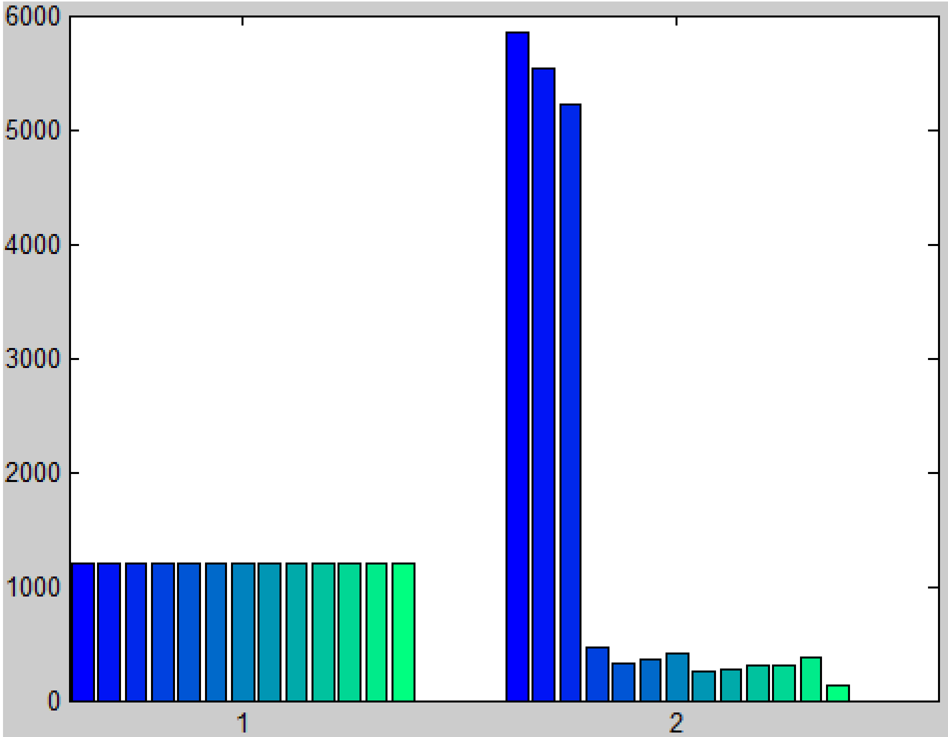

Figure 62 Average cash for each agent at the initial time (1), cash 1200, and at the final time (2)

It is observed from the graphs obtained a common trend in all scenarios. The agents that departing possesses more resources (a greater number of knowledge assets) in order simulation possess most of the cash resources. In cases with initial cash equal to 30, 100, 300 and 600 20% of agents with more knowledge assets end with their own values very close to 100% of the total cash. The setting with initial cash equal to 1200, however, the door 20% of agents to possess about 84% of the total cash. Observed this change has wanted to test with even greater initial cash if the proportion of cash in the possession of these agents tends to 80% (trend Pareto) or continues to decrease. Until an initial cash value adjusted to 1400, there is a trend Pareto in the coffers, which increased the value of the relationship instead is changed by not respecting more the expected 80-20. To look again a Pareto trend in the cash is necessary to increase the simulation period, to increase the total volume traded and to allow cash transfers, or increase the prices of individual knowledge assets, so as to accelerate the flow of cash to agents with more knowledge assets.

For the analysis of the classical parameters of interest, the number of tasks completed in simulated time and total volume traded was used again the boxplot of Matlab tool.

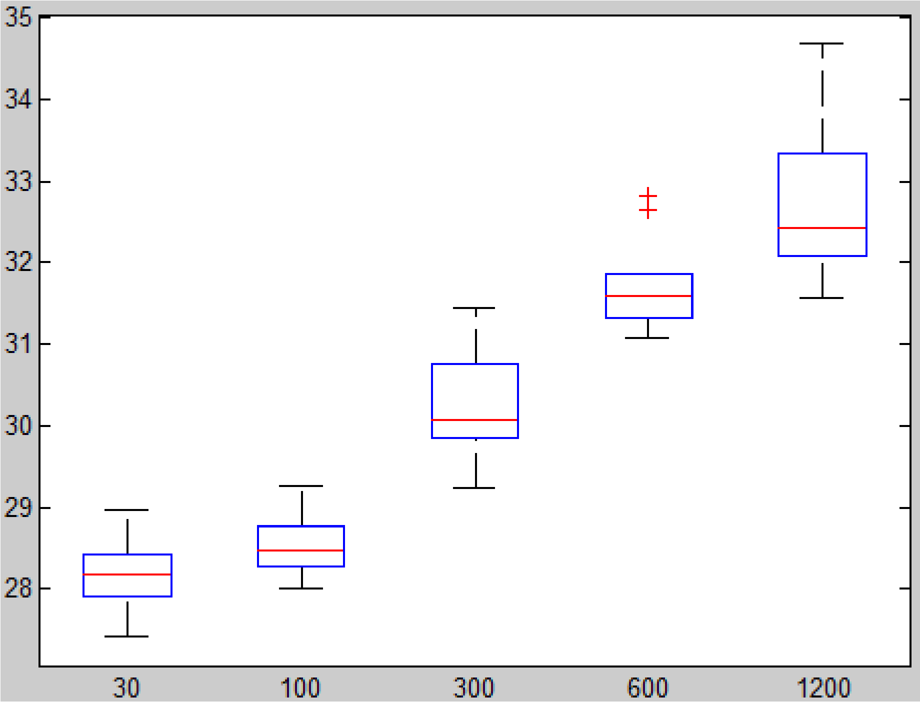

Figure 63 Average prices of knowledge assets, varying the initial cash

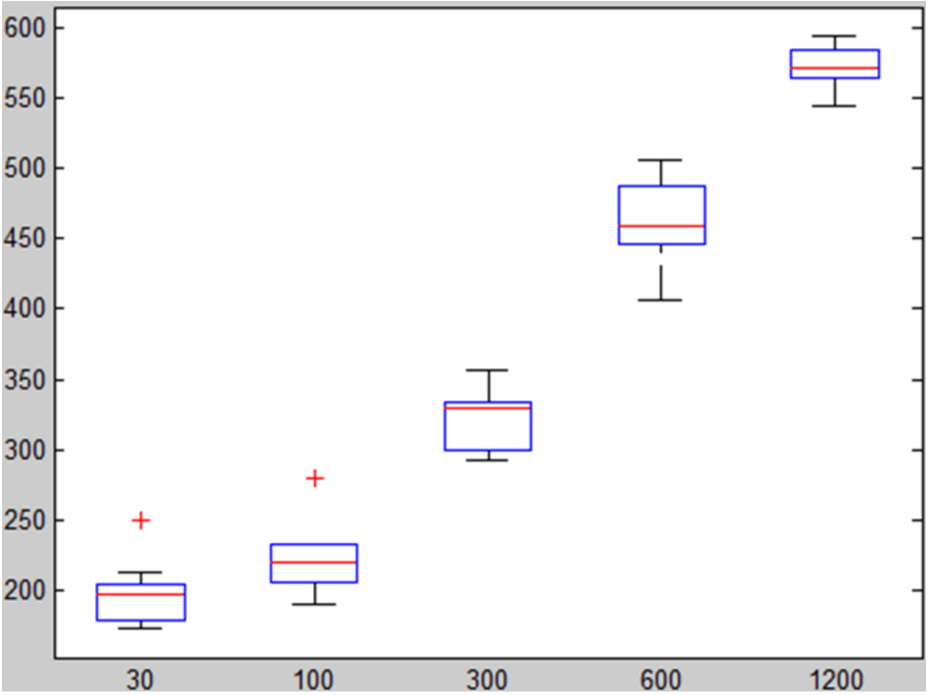

Figure 64 Total number of completed tasks, varying the initial cash

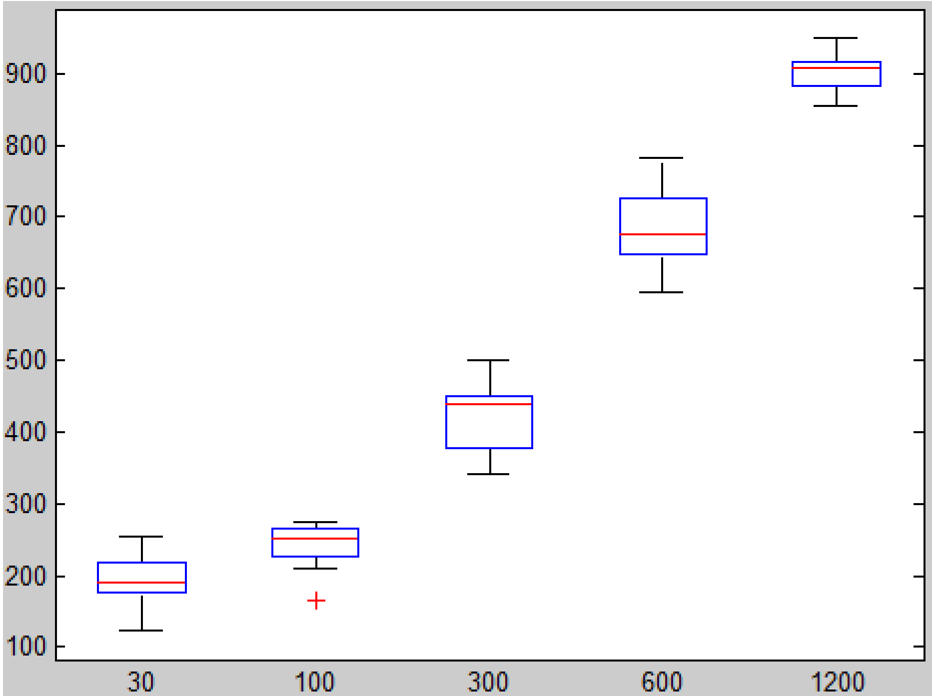

Figure 65 Amount of exchanges knowledge assets, varying the initial cash

Looking at the box plot is clear that the initial cases variable affects the results. Increasing the provision of cash to the first iteration for each agent reflects steady growth in both the average number of both completed tasks, both the volume of exchanges, both in average prices. As the trend observed for the cash is to merge almost completely into the cash of the agents with greater portfolios, providing more cash to everyone at the beginning of simulation enables agents with smaller portfolios of exchange knowledge assets and conclude tasks for a period of time longer long before you run out of all the resources for purchases. With the increase in the trading volume and concluded task, grows consequently the average price of knowledge assets as a result of a revaluation is due to the use that the exchange.

4.11. Summary of Simulation Results

Primarily it has highlighted the importance of the market, without which the ability of agents to carry out work is drastically reduced.

The what-if analysis showed that the factors with the greatest impact on the parameters considered in the analysis (average prices of knowledge assets, number of tasks performed, trading volume) are: the number of agents that can accept tasks at each iteration (% of activated agents) and all those parameters that alter the relationship between the size of the universe of total knowledge assets - portfolio of assets of each agent - tasks to perform.

Moreover, it was observed that a system characterized by the presence of numerous agents, even if equipped with a reduced number of knowledge assets, is capable of processing a greater volume of tasks compared to a system with the opposite characteristics (a few agents with large portfolios of knowledge assets). Thanks to a higher trading volume, knowledge assets result also more updated.

Finally, it was noted that starting with a Pareto distribution of knowledge assets (80% of knowledge assets possessed by 20% of agents), the long-term trend for agents owning the largest portfolios is to take possession of nearly all the cash circulating in the system. Thus the system is sensitive to the initial cash supplied to the agents (on 500 iterations). Increasing the cash initially distributed to all agents, it was noted that there is an increase in the number of tasks completed by the end of the simulation period or an increase in the volume of knowledge asset exchanges.

4.12. Limitations

The current model presents several limitations and lends itself to the possibility of further, development, integration and extension.

Some limitations are intrinsic to the model design and derive in part from the effort of creating a general model to be adapted, in future research, to represent different situations and contexts. This type of limitation is presented in this section, while suggestions for future developments are described in the following.

Finally, some limitations of the simulator are technical in nature and depend on the development tool, Flame, that constrained some choices, such as for example the length of the time-window for the price history of the knowledge assets. These technical limitations are described in a separate section.

Limitations of the model

A first limitation of the model is that knowledge assets are totally independent one from each other. They are only characterized by a number which identifies them, without actually defining whether a certain asset is connected in any way to another.

Consequently, the tasks and the portfolios are filled in with knowledge assets in a totally random way, without taking into account any correlation between them.

A second limitation of the model is that each expert can choose to answer only one seeker at a time, i.e. the one who guarantees the best productivity ratio. It would be interesting to improve this aspect by eliminating this impingement giving each expert the possibility to be available to different seekers simultaneously. Thus a more sophisticated mechanism of seeker's choice by the experts should be implemented involving management and scheduling logic.

Similarly, the choice of from which expert to buy by the seekers could be improved. In the current model, the seeker receives a list of the potentially available experts and chooses to buy from the expert with the most updated knowledge asset. This choice could be made more realistic introducing a probabilistic function to simulate the unpredictability of the preferences of the seeker at the time of choice. In fact, in conditions of limited rationality, individuals often don't make decisions solely on the maximization or minimalization of a certain parameter.

A third limitation of the model regards the monetary exchange at the transaction time. In the current model, as the agreement between the seeker and the expert is reached (demand-offer matching point) the seeker’s cash is decreased and the expert’s cash in increased of the same amount, even if the expert is unable to spend the money until the work is completed. It works like an anticipated payment that seems unrealistic.

A fourth limitation of the model regards the fact that it is closed. In fact, it could happen that, in order to complete a task, a knowledge asset is needed that no one belongs (i.e. that knowledge asset had not been inserted in any portfolio when the system was initialized). Well, that task will never be concluded as the seeker does not have the possibility to look for that knowledge asset outside the given market. This happens because the system is closed and no mechanism to increase, in some ways, the portfolio of the agents was implemented (see the future development section for some ideas to introduce learning and innovation concepts).

Technical limitations of the simulator

During the setting, before the launch of the simulations, a problem emerged with the memory of the development tool (FLAME). In fact, the model involves the use of a series of data structures but Flame severely limits the dimension of these structures resulting in rigid constraints to some elements of the model, such as the length of the time-window for the price history of the knowledge assets. It means that the seeker, in order to fix the initial price of the knowledge asset to buy, can take into consideration no more than a time window of 10 previous transactions. Beyond this value, the system crashes. Provided that this limit could be acceptable compared to the total number of iterations considered in current simulations, extending the length of simulations it should be consequently extended. A second big limitation of FLAME is that it does not allow to send messages between the agents containing dynamic vectors. This implies that each vector was set with a fixed size making it static. Moreover, also the static array size must not exceed the limits of the system itself. This results in the rigidity of the system.

CONCLUSION

We have proposed a theory of knowledge sharing in PBOs. The theory provides testable propositions about the influence of different factors on knowledge sharing. It especially gives propositions about the influence of market mechanisms.

Firstly, this work has proposed a systematic review on the topic of knowledge and competence management in the context of PBOs, which allowed providing a comprehensive framework and identify some gaps in literature from which derive a research agenda to improve the body of literature.

In relation to the research question identified, the present review aims to identify the main factors influencing positively or negatively the adoption of KM in PBOs, the main knowledge management systems adopted by PBOs and the impact of knowledge management on PBOs' performance. The descriptive analysis offers an overview of the papers included in the literature review. It has allowed providing a summary view of the papers on the topic of knowledge and competence management in PBOs. In particular, the descriptive analysis has highlighted that the trend of papers on the topic is increasing in recent years and it is a crossroad research area that involves a variety of journals that focus on different issues. The majority of contributions are based on quantitative methodologies, with few papers using qualitative, conceptual or mixed approaches (quantitative and qualitative). The content analysis of the papers included in the literature review has given us a detailed overview of the main issues covered by research on knowledge and competence management in PBOs and has allowed us to identify the main conceptual dimensions of PMC mechanisms.

Furthermore, content analysis of this area shows that the literature on the topic focuses on the topic of KM is mainly studied as a process that develops on the following steps: creation of knowledge and competences, transfer across individuals and across departments, and companywide strategies to store, improve, reproduce and reuse knowledge and apply competences. As for the level on which the studies have focused, three main levels can be distinguished: individual, collective, organizational. In addition, the articles examined in the review adopt different perspectives of analysis, among which emerge: knowledge management, human resource management, and strategy.

This last point highlights the need for a clear definition of success factors and barriers, a consequent identification of a set of factors that drive or hinder KM adoption, a contextual classification and a more comprehensive empirical investigation in PBOs context.

We have used actual transaction data from a global knowledge management system to empirically test our internal market-based idea. The field data design gives a realistic picture of the knowledge-sharing behaviour in a real system. To the best of our knowledge, a field study on the actual knowledge-sharing activities in a real knowledge management system such as this has not yet been conducted.

Case studies have two major purposes. The first purpose of this study is to explore to what extent knowledge management was used within project environments. The second purpose is to establish the relations between knowledge management and internal barriers in PBOs. Apart from the purposes, we did two rounds of interviews. For each company, an analysis of the current situation of KM was done. This was to understand the current approach to KM. The interviewees showed their diverse opinions on KM, but they all had a general concept of KM and already realized its importance.

Case studies show that among the studied organizations the use of knowledge management methodologies is not common. Different industries and complex projects have different peculiarities. We will, therefore, discuss the main points that emerged and draw up appropriate guidelines to design a knowledge management system in this type of company.

An important finding of this first round of interviews is that all the interviewees recognize difficulties in finding "who knows what" inside the organization, as well as the lack of information on projects and research followed by different departments. The need for a tool to support localizing and mobilizing of knowledge goods clearly emerged from several parts in interviews.

Based on the findings of the first round of interviews, I aimed to develop a conceptual framework of an integrated knowledge management system, in which several knowledge-management strategies are nested. I focused on possible strategies to localize and transfer different types of knowledge resources in PBOs.

The second round of interviews shows that organizations should tend to fulfil more conditions needed to successfully create, share and store knowledge in the organization and in the projects. The interviews pointed out several organizational and managerial critical issues for knowledge and competence management inside organizations, that included: Weakness of human resources departments and lack of proper human resource management policies, lack of motivational drivers, lack of time, strategic misalignment of project units due to organizational issues, lack of managerial support, lack of a proper organizational culture, lack of communication, lack of IT support, lack of training.

Furthermore, the idea of the internal knowledge market is a possible solution to manage knowledge transfer inside the organization. It helps to match the knowledge seekers (consumers) with the knowledge sources (experts/solvers). Interactions among actors (seekers and experts) and the knowledge market must be carefully analyzed. These interactions are depicted using UML (Unified Modelling Language) use case diagrams based on the transaction phases.

This work aimed to answer two main questions, “How to design appropriate structural and behavioural aspects of a knowledge market in the context of an open knowledge ecosystem?” and “Which parameters influence the dynamics of the knowledge market and in which directions?”. In order to answer these questions, an agent-based model of a knowledge market was designed and developed. The model is very general in nature and could be applied to describe both an internal corporate market and knowledge trading dynamics among firms in a knowledge ecosystem (e.g. a cluster or a district).

The structural and behavioural aspects of the knowledge market have been designed taking into account the main characteristics of the involved parties (the worker agents and the system agent) as well as of the traded goods (knowledge assets). After the design phase, the development of the simulator followed, using the software of agent simulation. By means of this tool, it was finally possible to test some settings, by changing one or more variables, and analyze the outputs returned by the simulator, in order to identify the parameters with the greatest impact as well as the most informative and interesting settings for our analysis.

In order to reach different and more realistic investigations, I use different parameters (Budget, Mark up, Dimension of the task and competences, etc.) when I simulate the model on FLAME. The model has been tested and re-stimulated several times with many different iterations.

The functions of the market which has Worker and System agents can give an opportunity to transfer (we can say, buy and sell) knowledge from expert to the seeker immediately without causing a bottleneck or subtracting time from daily work. At the same time, an agent can get information from the history of an expert, such as the expert’s competences the relative prices.

I analysed the data that is collected by the simulator. The main idea of the analysis was to verify the utility and convenience of the market. The level of the parameters of interest, the average price of knowledge assets, the number of the completed tasks, the average daily number of the completed task and the total number and the daily average of trades were investigated. Firstly, I need to test the sensitivity of the system to some of the starting set’s variations. To make this analysis, some variables have been settled differently, one by one, and then the changes to the parameters of interest have been verified: average price of knowledge assets, number of tasks completed in the simulation period and the average daily number of completed tasks (volume work performed), total number of exchanged expertise and average daily number (trading volume). After the analysis of the sensitivity of the system, market effectiveness is investigated starting from a curiosity that arose spontaneously during the phase of definition of the key parameters of the model. The doubt raised concerns to the definition of the setting that leads to the greater volume of work done, completed tasks, acting solely on two variables number of agents and size of their portfolios. Two scenarios were created. First with 5 agents characterized by 10 knowledge assets over the universe (20) and 10 agents each of which provided with few knowledge assets (5 of 20 total). And then the sensibility analysis is performed.

The project aims to facilitate knowledge transfer between seekers and experts, represented by worker agents, using market mechanisms. The system agent acts as an all-knowing agent that keeps in memory all the information about past exchanges and about the agents and provides them under the requirement. This mechanism ensures that knowledge sources are ready to trade their knowledge with the "right" price, corresponding to the matching point between demand and offer. The main goal of the project is to reach effective knowledge transfer from experts to seekers with the pricing mechanism.

Simulation results show that knowledge markets can give several advantages to organizations as significant cost-saving, time-saving, as well as it allows solving the problem of measuring knowledge value and transferring the knowledge properly. The market also gives an opportunity to reuse existing knowledge and resources and use them effectively by reducing the time for searching and exchanging.

It is worth noting that a knowledge market is a kind of platform (IT-supported) and the value of the platform is directly proportional to the number of users. More users mean a more valuable platform.

Corporate knowledge markets are flexible solutions to knowledge management issues and can address internal needs such as organizational or innovation issues.

It is easy to follow organizational changes with the internal knowledge market and continuously adapting it to evolving organizations.

Well-designed internal knowledge markets, bringing to evidence competencies and areas of expertise as well as actual or potential organizational connection/integration into a company, can provide a powerful set of tools to help large companies to improve their corporate awareness. Internal knowledge markets can support organization as-is assessment as well as play a role in the design of to-be organizational features.

The internal knowledge market's successful implementation requires strong management commitment and vision. Knowledge markets, improving corporate awareness and influencing decision-making processes and strategy, open a company to new forms of corporate governance and management.

The results, that simulation added to my research, are; the importance of the market, without which the ability of agents to carry out work is drastically reduced.

The what-if analysis shows the parameters considered such as average prices of knowledge assets, the number of tasks performed, trading volume have the greatest impact. The number of agents that can accept tasks at each iteration and all those parameters that alter the relationship between the size of the universe of total knowledge assets - a portfolio of assets of each agent - tasks to perform. Moreover, if a system characterized by numerous agents, even if equipped with a reduced number of knowledge assets, is capable of processing a greater volume of tasks compared to a system with opposite characteristics (a few agents with large portfolios of knowledge assets). Thanks to a higher trading volume, knowledge assets result also more updated. Finally, it is obtained with the Pareto distribution, increasing the cash initially distributed to all agents, it was noted that there is an increase in the number of tasks completed by the end of the simulation period or an increase in the volume of knowledge asset exchanges.

Briefly, the effort to model and simulate a knowledge and competence market introduces a market logic in knowledge exchanges among firms in a knowledge ecosystem. The model is based on the results of the literature review, which pointed out the main knowledge and competence management issues currently faced by PBOs. The model has been tested in several case studies in order to gain some insights on its applicability in real settings. The cases shed light on several critical aspects of model applicability mainly due to technical, organizational, managerial and cultural issues.

An agent-based model of a knowledge market was designed and developed. The model is very general in nature and could be applied to describe both an internal corporate market and knowledge trading dynamics among firms in a knowledge ecosystem.

Finally, limitations and possible future research directions are drawn.

The main contribution of this study is the effort to model and simulate a knowledge market, thus introducing a market logic in knowledge exchanges among firms in a knowledge ecosystem. The same model could be adapted to simulate knowledge exchanges within a large and distributed company. Both the contexts of application are worth of in-depth analyses.

If it is true that our society is becoming more and more knowledge-driven, the trading of knowledge assets will also be of even more importance. For knowledge management researchers this study offers insights for different problems concerning knowledge asset trading and paves the way for further research in the field.

APPENDIX

The first step for the realization of the simulator is the creation of ‘stategraph’ of the model. It is a scheme that is written in XML language and the aim is the translation of the defined model with the messages and functions (encoded in C) ordered in a logical and sequential manner.

The stategraph consists of three parts. The first part is characterized by functions for initializing the system. The second part describes the market mechanism through several functions, and the last one includes data storage and updating functions.

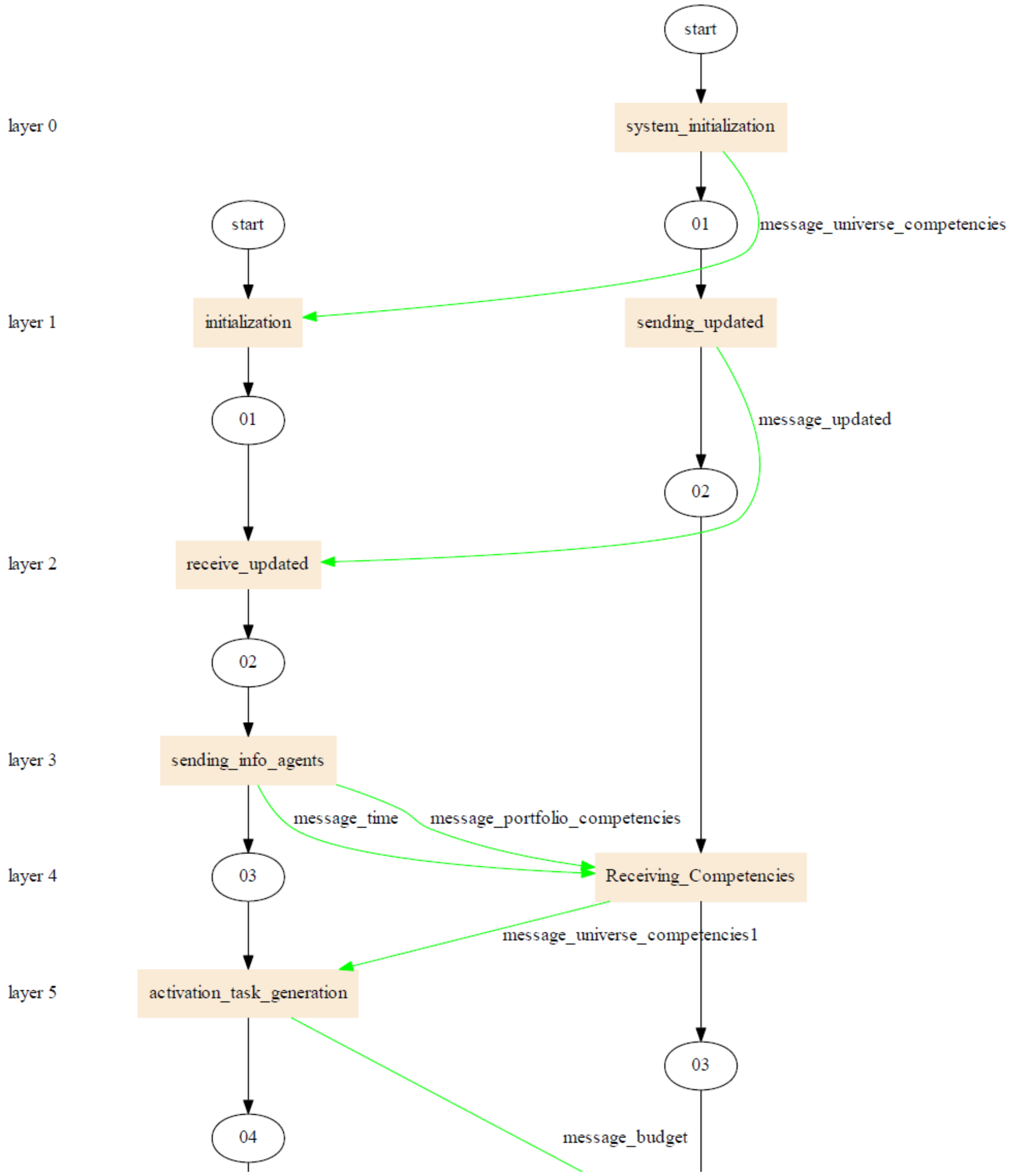

Figure 66 Stategraph

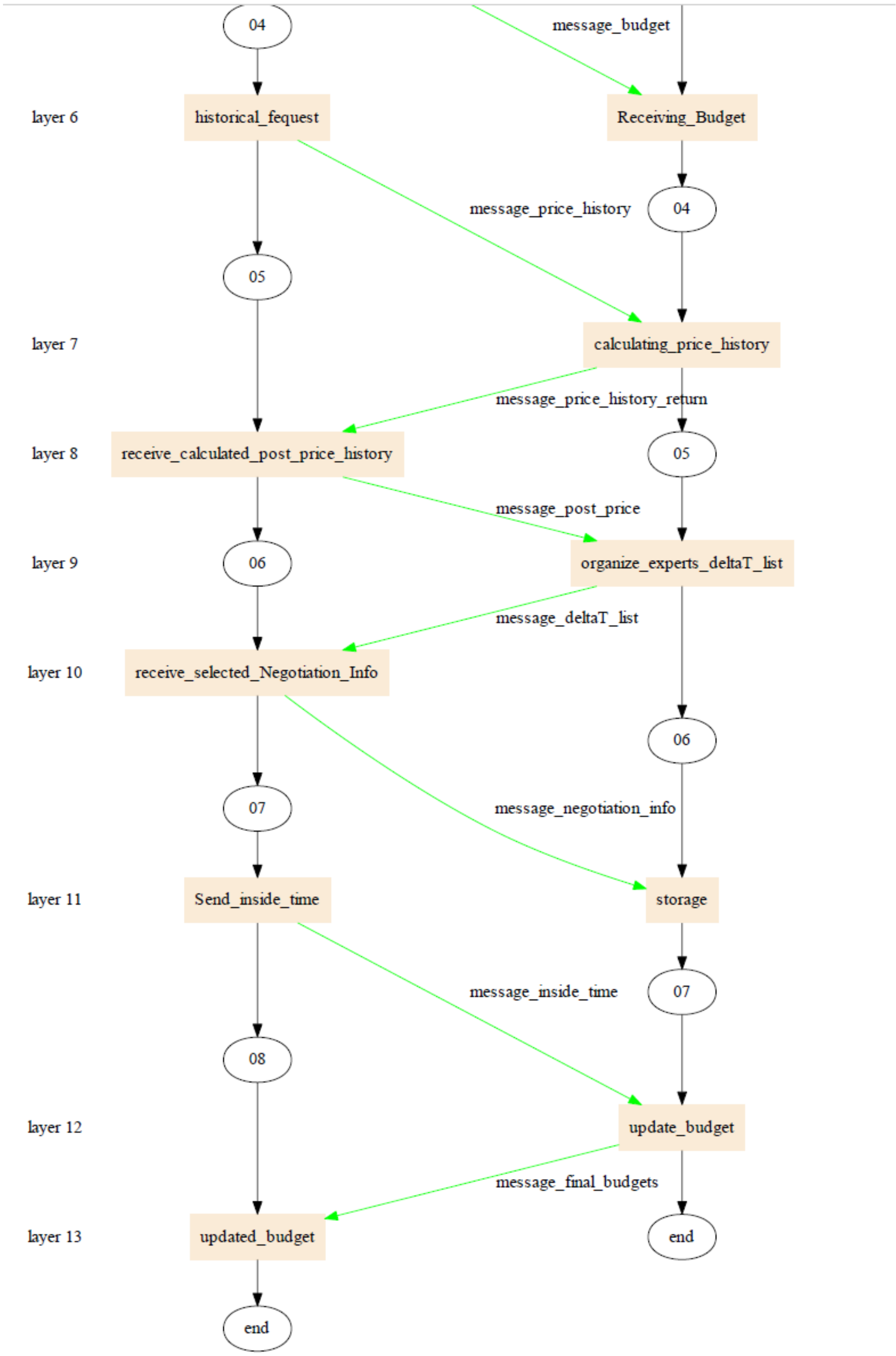

Figure 67 Stategraph 2

Once the stategraph and the definition of functions and messages in XML have been completed, I started to write every single function in C language. The Flame allows to define functions in XML language and the commands of them are created in C Programming Language and the agents will execute all functions that are specified with commands.

The first command is the activation of the function. The IF commands activate the iteration_loop variable that helps to loop between functions, both for System and also Worker. Because it has to be activated only at the beginning in the first iteration and it has to continue to activate for the following iteration from first to the end of the chosen simulation period.

This condition helps to fill the first two functions of the agents that are located in the stategraph as an ‘initialization’ for Worker Agent and ‘system_initialization’ for System Agent and their complementary commands that are created with using popGUI to implement for initializing the system.

‘system_initialization’ is the first function that is performed by the simulator and the creation of the universe of the competence and it will circulate inside the System.

In order to do this, a <dataType> or a data structure called "competence", contains a series of variables of type Int and Float, which is created in the XML file. As it can be seen in Figure 3, a series of variables includes id_competence, price, iterations, validation, the indicator for expiration. These are called variable types.

```xml
<xmodel version="2" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xsi:noNamespaceSchemaLocation='http://flame.ac.uk/schema/xmml_v2.xsd'>

<!-- Model descriptions  -->
<name>OMmodel</name>
<version>1</version>
<description>Model describing the interactions between workers agent and system agent</description>

<environment>

   <constants>
            <variable>
                <type>float</type>
                <name>decrease_rate</name>
                <description>relationship 1/k with k = the rate of obsolescence of value of competence</description>
            </variable>
   </constants>
    <functionFiles> <!-- List of C files that hold agent functions -->
        <file>workers_agent_functions_p.c</file>
        <file>system_agent_functions_p.c</file>
    </functionFiles>
    <dataTypes>
        <dataType>
           <name>competence</name>
                <description>description of professional qualifications held by workers</description>
                <variables>
                    <variable>
                        <type>int</type>
                        <name>id_competence</name>
                        <description>identifier of each competence</description>
                    </variable>
                    <variable>
                        <type>float</type>
                        <name>price</name>
                        <description>price of competence</description>
                    </variable>
                    <variable>
                        <type>int</type>
                        <name>validation_comp</name>
                        <description>string that indicate if a competence of the task possessed in the agent</description>
                    </variable>
                    <variable>
                        <type>int</type>
                        <name>iterations</name>
                        <description>number of iterations/it is needed for application of competence</description>
                    </variable>
                    <variable>
                        <type>float</type>
                        <name>price_start</name>
                        <description>price of the competence during initialization</description>
                    </variable>
                    <variable>
                        <type>int</type>
                        <name>instant_utilization</name>
                        <description>time in iterations in which the competence has been used last time</description>
                    </variable>
                    <variable>
                        <type>int</type>
                        <name>indicator_expired</name>
                        <description>the period of competence number of iteration</description>
                    </variable>
                </variables>
        </dataType>
        <dataType>
```

Figure 68 Structure of Competence Data Type (XML File)

The vector competence_total is created with the type of competences and size is 50 in the System Agent and it is filled with using for the cycle. It sends a precise value to each variable. As a last command of the function, message_universe_competence is sent with the vector ‘competence_total’ values to the Worker Agent.

```c
add_message_universe_competencies_message(COMPETENCE_TOTAL);
```

Figure 69 Example of the message sent

The dimension of the universe of the competencies is coded in the Worker Agent side. The variables that are created in XML and coded inside the C file of the functions.

```
for (int i = 1; i < DIMENSION_UNIVERSE_COMP ; i++)
 {


   int r = 30;
   int z = random_number(10000,20000);

    COMPETENCE_TOTAL[i].id_competence = i;
    COMPETENCE_TOTAL[i].price = r;
    COMPETENCE_TOTAL[i].iterations = 6 ;
    COMPETENCE_TOTAL[i].price_start = r;
    COMPETENCE_TOTAL[i].indicator_expired = 0;
    COMPETENCE_TOTAL[i].instant_use = 0;
    COMPETENCE_TOTAL[i].date_expired = z;


 }
```

Figure 70 Initialization of the universe of the competencies

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