Adopting the Grid for Business Purposes: The Main Objectives and the Associated Economic Issues

George A. Thanos[1], Costas Courcoubetis[1] and George D. Stamoulis[1]

[1]Network Economics and Services Laboratory, Department of Informatics
Athens University of Economics and Business, Patision 76, Athens 104 34, Greece
{gthanos, courcou, gstamoul}@aueb.gr

Abstract. Grid technology offers numerous opportunities for the players involved. Despite the fact that the academic community has already exploited many of them, there is an evident reluctance from the business community to act likewise. Recent analysis reveals that the problem lies in overcoming certain business barriers rather than technological ones. At this stage understanding the real-life economic issues from a business perspective is deemed as more important than gaining understanding of complex theoretical economical problems, such as those related to accounting or resource sharing mechanisms especially in cases where the players do not exhibit the required technological expertise. This paper is stimulated from interaction with players from the industry and aims to fill this gap. In particular, we identify and evaluate a number of economic issues that should be taken into consideration by industrial players so that their trust and confidence in the adoption of this promising technology be increased.[1]

Keywords: Grid Technology, economics, resource sharing, virtual organisations, market, economies of scale, network externalities etc

1 Introduction

Grid technology promises a new way of delivering services across IP-based infrastructures. These range from common ones, such as existing mass multimedia services, to more complex and demanding customised industrial applications. Over the last years Grid technology has proven its merits through enabling the execution of highly resource demanding applications for the scientific community some of which were previously only realised over expensive high-performance computing (HPC) centres.

However, in order for Grid technology to fulfil the aforementioned promise, it has first to be adopted by the diverse business community thus being provided and consequently validated, by a significantly larger number of providers and users. Recent studies [1] and European initiatives [2] have indicated a reluctance and slow take-off of Grid technology and market by the industry, something attributed mainly to economic and market barriers rather than to technological ones.

[1] This project has been partly supported by FP6 EU-funded IST projects BEinGRID (IST5-034702) and GridEcon (IST5-033634)

So far there has being a lot of work around theoretical economical analysis examining issues like accounting and resource sharing mechanisms for Grid architectures etc. However, our experience from interacting with industry players and discussing their concerns has shown that prior to solving complex architectural issues there is an evident need for analysing the Grid phenomenon and its economic side effects from a business perspective. Thus, in this paper we identify and analyse those criteria and economic issues that a new player should take into consideration prior to making his decision whether to adopt Grid technology for his business or not and how these will affect his Grid business afterwards. Such a decision can be made by means of a relevant model, which will take the factors identified in the present paper as inputs. Our overall aim is to increase the confidence of the industry towards Grid adoption by exposing the business issues, both positive and negative ones, that once taken into careful consideration by the value chain players will enable them to realise the numerous opportunities that Grid technology has to offer and at the same time construct feasible business plans to fully exploit them.

Our identification and analysis has been performed with support by the Integrated Project Business Experiments in Grid – BEinGRID [3], European Union's largest integrated project funded by the Information Society Technologies (IST) research, part of EU's Framework Programme 6 [4]. The communication with 18 real-life Business Experiments from various industries provided the practical framework to validate our theoretical analysis.

The paper is structured as follows: a brief introduction to Grid economics is presented in Section 2 followed by a discussion on the main economic objectives for adopting the Grid and an initial identification of associated economic issues in Section 3. Section 4 identifies and analyses a number of economic issues related to Grid adoption from the industry whereas Section 5 provides a case study and evaluation of how these issues affect real-life scenarios. Section 6 provides some concluding remarks.

2 A Brief Introduction to Grid Economics and Related Work

Firstly, it is imperative to review some basic definitions related to Grid Technology and the current work in Grid Economics. To start with, we define a Grid service as a Web Service that provides some well-defined interfaces and follows specific conventions [5]. The interfaces address issues such as address discovery, dynamic service creation, lifetime management, notification, and manageability. The conventions regulate naming and upgradeability of services. Each service described in the Open Grid Services Architecture (OGSA) [6] is a single Grid service or a composition of Grid services. A Grid middleware is typically composed of several Grid services with different functionality. Usually, at least the following functionalities are covered: resource management, Job management, Service discovery, scheduling, accounting and security.

Nowadays, a single business process and value chain of a company can be performed by several business partners. The company involved in this process is then a virtual company or organization (VO), as it is only a temporary aggregation of partners in order to perform a specific process. The corresponding concept from economics is called the coalition. VOs can be seen one of the most important drives for Grid technology adoption as it allows these organisations to efficiently share and utilise their geographically distributed computing, storage and data resources over a common infrastructure.

Among the first to raise a number of true economic issues focused on the commercialization of Grid resources (i.e. computing) were Kenyon and Cheliotis. Specifically, in their work they argue that Grid commodity is rather a stochastic one rather than as a deterministic one (such as oil, electricity, etc). Since Grid resources are non-storable, the authors claim that future contracts will be the basic building blocks in Grid environments instead of spot markets. Market uncertainty and decision support are the most important issues that need to be addressed in this context.

The authors identify a set of requirements for commercialization of Grid resources such as product construction and reservation, contract management, clearing, accounting and billing, trading support, price formation and decision support. Also, in [7], Cheliotis et al. set a number of important questions on the successful creation of a Grid market. They argue that the most important part for a successful Grid market creation is to fully understand and foster user requirements and demands. Overall, [8], [9], [7] mostly define the most important issues for Grid commercialization and they do not propose any specific solutions for them.

Gray on the other hand in [10] discusses the economic tradeoffs of doing Grid-scale distributed computing (WAN rather than LAN clusters). Specifically, Gray analyzes the economics of outsourcing. Using simple commercial examples, he calculates the corresponding value of 1$ for bandwidth over the WAN, for number of CPU instructions, for CPU time, for disk space, for database accesses and for disk bandwidth. Identifying communication cost as a bottleneck, Gray concludes on a rule of thumb regarding outsourcing, according to which computations must be nearly stateless and have more than 10 hours of CPU time per GB of network traffic before outsourcing the computation makes economic sense. Otherwise, LAN cluster provide a more economically viable alternative.

Probably the most extensive work on Grid Economics up-to-date has been performed by the GRIDS (Grid Computing and Distributed Systems) laboratory, headed by Buyya. Their most significant research work related to our work is the Economy Grid project where it is clearly identified that a major challenge for next-generation Grid computing is the creation of an “Economy Grid”, meaning a competitive realistic Grid Marketplace that regulates supply and demand, and offers the right incentives to players (suppliers and consumers) for improving the utilization of resources. The next step was the Gridbus [11] project, aiming at producing a set of Grid middleware technologies to support e-science and e-business applications. In some of the designed and developed components for this technology one will find incorporated features relevant to “Grid Economics”, such as a broker agent software for job scheduling, a market directory for publishing and searching for available services, and a centralized infrastructure that provides accounting and payment services. The “Economy Grid” project, the GRACE architecture and an overview of related work on price setting, market-based resource allocation and scheduling systems are presented in [12].

Other works in the Grid Economics include a centralized strategy-proof architecture for Grid Computing by Egg [13] and the Mojo Economy [14], the Weng

Price-setting mechanisms [15], the price prediction mechanisms by [16], and work driven from European funded IST projects.

As already mentioned the aforementioned work is more focused in the theoretical analysis of economic mechanisms and fails to analyse specific economic issues from a business perspective such as the economies of scale/scope, network externalities, free-riding problems, information asymmetry, and impacts to other markets etc which we will address in the subsequent sections.

3 Economic Objectives for Adopting the Grid and Initial Identification of the Associated Economic Issues

The aim of this section is to discuss the main economic objectives for adopting the Grid for Business and identify the underlying economic issues/concerns. We propose at this stage the main three alternative economic reasons for Grid to be used in commercial applications. By keeping the number of alternatives small and hence abstracting to a significant level the implementation context, we can understand the economics better. These are discussed in the subsequent sections.

3.1 Optimization of Processing Power in a Single Organization

A single organization may require processing power that cannot be provided by means of stand-alone machines. By interconnecting these machines in a Grid, high processing power can be used even by a single application. Thus, the organization achieves both a high peak processing capacity and a high average utilization of the processing power available, since this can be flexibly allocated to multiple Grid-enabled applications. These features also lead to increased cost-efficiency for the infrastructure deployed. This is particularly important for a large organization with several departments scattered around the world, each possessing its own local infrastructure. Interconnecting these in a Grid attains the aforementioned performance enhancement, high exploitation of resources, and cost-efficiency and economies of scale, due to the fact that interconnection of all machines improves utilization of each individual one. Moreover, the whole approach is scalable, due to the fact that the Grid middleware provides automatic load balancing and transparent usage of the hardware. Besides these, if the various departments possess complementary infrastructure, then the organization also attains economies of scope.

Regarding management, since the Grid belongs to single organization, a centralized approach is always an option. On the other hand, particularly if there are multiple departments in the organization, with some notion of autonomy (e.g. own infrastructure contributed to Grid and IT budget), then self-management of the Grid by means of economic/market mechanisms is possible and probably preferable. Indeed, the centralized approach requires complete information, which is not always straightforward to gather in a highly distributed single-domain system. On the other hand, a market mechanism defining prices for accessing and using the Grid resources by the various departments provides the right incentives for rational usage and results in shaping of demand according to the actual needs, which in fact may be thus discovered; prices may either be really monetary, or virtual ones with each department being allocated a Grid virtual budget. This approach also requires accounting functionality, e.g. for monitoring the usage of resources by the various departments and assigning the relevant charges, as well as specification of the right SLAs and appropriate tariffs for them.

3.2 Sharing of Complementary Resources in Multi-provider Environments

Consider a group of organizations, each of which possesses its own resources, which are complementary to each other. For example, organization A possesses a powerful database server, while B has a huge amount of data and C possesses an application running over its server that requires data such as that of B. Clearly, when collaborating in the form of Grid, all organizations can bring together a powerful outcome, while each of them exploits very highly its own resources at a cost-efficient way, without needing to invest to the missing resources that are now contributed by others. In this case, the collaborating organizations enjoy economies of scope, since bringing all resources together by means of Grid broadens their scope of applicability. Apart from serving their own needs by forming a Grid, organizations with complementary resources may also form a Virtual Organization serving third parties. The formation of VOs has a considerable impact to the market; see item 3 below. If the group forming the Grid is not closed, then network externalities and economies of scale may arise in the case where new organizations can join the group, thus enhancing the associated gains per participant.

Regarding self-management, the collaboration of the participants in the Grid should be regulated by means of market mechanisms that provide them with the right incentives to both contribute to the Grid the resources promised and not to free-ride those of the others. For example, a global agreement can prescribe that all contribute as necessary. Similarly to peer-to-peer systems such agreements can be based either on rules prescribing a fixed minimum contribution for all participants or on rules regulating the consumption levels of each participant (quantitatively or qualitatively) in accordance/relation with his contribution over time. These rules should be complemented by accounting functionality that certifies conformance with them. Also, an internal market mechanism, based on SLA and monetary prices for these SLAs can also be employed as an effective approach for self-management, particularly in cases where the level of contribution of the various participants is not symmetric, and a global agreement is hard to be reached. These ideas apply to the case where the Grid is formed in order to serve the participants' own needs, including the case of a single organization with multiple departments (see item 1). If the participants also serve third parties, then the relations between the former and the latter should also be managed by means of market mechanisms.

3.3 Offering Utility Computing Services

This amounts to offering applications (software) and computing services (hardware) on a pay-per-use basis rather than by means of licensing or long term static agreements (leasing, etc.). In this model, applications are sold as components according to the SOA architectural concepts; customers can design their full solution by combining components from different providers and run these on their own premises or again using some Application Service Provider (ASP) computing services. Essentially, this application level Grid allows for a new version of the application based on components to be accessed by the customers. This version is more affordable to infrequent users of the application, who now have a benefit compared to investing on the corresponding software license and/or computational infrastructure. Therefore, both these users and the service provider gain, since this version increases the demand for the service by making it affordable at lower costs. At the lower layers an ASP may benefit from Grid computing services using his own infrastructure complemented with utility computing services offered form third parties. The issues discussed in the previous items regarding high performance, economies of scale and scope etc. are still applicable here.

Nevertheless, other interesting economic issues arise too in the present case. In particular, we now have a new market (that of the pay-per use application), in which: a) the proper SLAs should be offered to customers, and b) resources should be self-managed and the revenue should be properly distributed to the players involved, while c) this market also has significant impact on other markets!

In case where this provider is a single organization, the self-management of its resources is attained through its incentives for optimizing its profits obtained from the market; for example, the predictions for market demand and the revenues foreseen accordingly can serve as an input of a capacity expansion policy. In case where the Grid provider is a virtual organization (or a single one yet with multiple participating departments), then additional self-management mechanisms are needed in order to pass the revenues to the various participants according to their level of contribution.

As already mentioned, the new market created in the present case may have a significant impact to other markets too. In particular, a Small and Medium Enterprise (SME) that cannot afford investing on a license or on infrastructure obtains new capabilities by outsourcing its missing application to the Grid provider on a pay-per-view basis. Thus, such an SME can now serve as a provider in another market, in which this application is a necessary capability for each provider. Therefore, the Grid version of the application leads to a reduction of the barriers of entry in the other market, which is now more competitive. This in turn may have a positive effect to the Grid provider itself, since the SMEs penetration in this new market generates additional demand for the Grid application. If beneficial for the Grid to expand, which is particularly the case if economies of scale and scope apply, then the customer SMEs will benefit even more by the expansion of Grid. Network externalities also apply here.

A summary of how the aforementioned issues impact the Grid adoption decision process is presented in the next table:

Table 1. The impact of the economic issues in the Grid adoption decision process
(1: Strong Influence, 2: Medium Influence, 3: Weak influence)

Categories/ Adoption Decision Influence	Econ. of Scale	Econ. of Scope	Network Externalities	Self-management	New markets	Impact to other markets	Free-riding	Info. Asymmetry	Perform. Differentiation
Optimisation of processing power	**1**	2	3	**1**	2	2	3	3	**1**
Sharing of complementary resources	**1**	**1**	**1**	**1**	2	2	2	2	2
Utility Computing	**1**	2	2	**1**	**1**	**1**	2	3	2

4 Analysing the Economic Issues Associated with Grid Business Scenarios

In the previous section we have briefly identified a number of economic issues that should be taken into account for Grid technology adoption in the business context. Consequently, these identified issues are listed below with a brief explanation of their meaning, their relevance in the context of Grid business scenarios and their significance. Following this analysis in subsequent sections we aim to evaluate them and further discuss their impact in terms of real-life Grid Business scenarios in Section 5. As will be seen there, these issues together with the objectives determine the decision of whether to adopt Grid or not; see Figure 1.

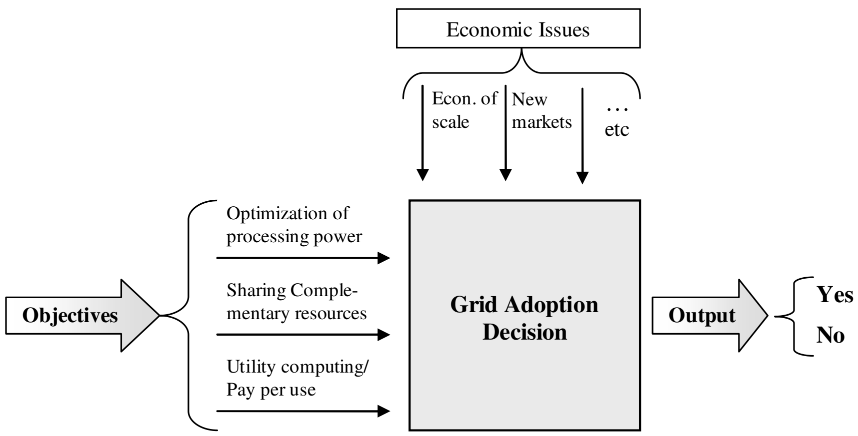

Fig. 1. Grid adoption decision process

Economies of scale and scope (complementarities)

As a definition it can be said that there are economies of scale in production if the cost per unit of production declines with the number of units produced. (Thus, "economies of scale" is a descriptive, quantitative term). Due to economies of scale, larger companies have greater access to markets in terms of selecting media to access those markets, and can operate with larger geographic reach whereas for traditional companies, size does have its limits, where additional size actually increases costs to companies (impacts communications costs etc., diminishing returns).

Economies of scope are conceptually similar to economies of scale. Whereas economies of scale apply to efficiencies associated with increasing the scale of production, economies of scope refer to efficiencies associated with broadening the scope of the service(s) offered, of marketing and distribution thereof etc. That is, while economies of scale refer primarily to supply-side changes (such as level of production), economies of scope also refer to demand-side changes (such as marketing and distribution).

The economic concepts of "economies of scope" and "economies of scale" similarly apply to the Grid market, where the integration of Grid technologies from a value chain actor and the consequent infrastructure and application improvements (e.g. in terms of performance) can lead to a production scale of the company's end-user products. Furthermore, sharing complementary resources among organizations could lead to the specification and the market entrance of new market products, thus to a realization of the "economies of scope" theory.

Network externalities

Network externalities are the effects on a user of a product or service of others using the same or compatible products or services. Positive network externalities exist if the benefits are an increasing function of the number of other users. Negative network externalities exist if the benefits are a decreasing function of the number of other users. For example a positive network externality arises in telephony, when the network expands; thus, each new user has more opportunities to communicate with others, and thus may be the amount that he is willing to pay for subscribing to the network depends on who or how many other parties are connected to it. Such an externality also applies to Internet, together with a negative externality that the more users the higher the congestion.

In a similar fashion, network externalities strongly apply to the Grid case, where for example an organization wishes to participate in a Virtual Organisation (VO) structure whose participants share complementary resources and the final outcome and thus "Grid" benefit for the new member strongly depends proportionally to the amount of resources available at that time to be shared by the other VO participants, i.e., the number of total members.

Self-management issues

Grid environments usually depict strong-collaboration principles especially where many players are involved e.g. different departments in an intra-organizational Grid structure or a VO. These players have a great deal of control on the Grid infrastructure and any change or management decision will produce an important effect for all of them. For this reason self-management of the Grid infrastructures and services should apply in terms of how resources will be shared and on what charge so that the participant's incentives remain sound and solid. For example, an internal market mechanism such as a pricing unit ("Grid dollar") should essentially be defined as for the Grid resources to be shared according to well-defined principles and priorities.

New markets

By this criterion we refer to the possibility of the creation of new markets due to the use of Grid technology in existing or in new products, not foreseen before. For example, a company that was selling a software product or service to a customer based on specific commercial licenses (e.g. per machine installation), now can provide another version of the same service over a Grid infrastructure, without the customer having to install the software in his workstation, on a pay-per-use basis where the customer will pay for the times he uses the service only and depending on his requirements such as the QoS needed, the availability of the service, the completion time. The provider will make available different version of his service to accommodate the different requirements of his clients.

Furthermore, and due to the realization and wider adoption of the Grid technology a service provider could offer his product as a number of different stand-alone services (components) which the end-user can utilize together with services from other providers towards a new highly-customized and personalized scalable product or service. All players in this scenario take advantage of the new market foreseen by the realization of Service Oriented Architectures (SOA).

New entry and impact to other markets

As already mentioned, the new market created by the Grid adoption may have a significant impact to other markets too. The fact that applications are now offered on a pay-per-use basis provides new capabilities to SMEs, which can serve as providers to other markets, the barriers of entry to which are thus lower. Indeed, the SME can now develop applications and offer services over virtualised Grid environments (with fewer components, less actual development time and expensive infrastructure owned) and use the computing power of a Grid utility provider in order to offer them to a new market (not achieved before) thus directly impacting and increasing competition of this already established market.

Free-riding

In economics, collective bargaining, and political science, free riders are actors who consume more than their fair share of a resource, or shoulder less than a fair share of the costs of its production. The free rider problem is the question of how to prevent free riding from taking place, or at least limit its negative effects. Because the notion of 'fairness' is controversial, free riding is usually only considered to be an economic "problem" when it leads to the non-production or under-production of a public good or when it leads to the excessive use of a common property resource.

The problem and effects of free-riding are really evident in the context of a Grid virtual organization where resources are shared among and for the common benefit of their participants. A free-rider highly consuming participant limits the common benefit and participates on the expense of other participants. Hence, it is really imperative for internal agreements e.g. SLAs to be implemented among VO-forming participants, the right incentives to be given to prevent free-riding, and penalties to be applied in cases where this is detected.

Information asymmetry, risk and unpredictability-related issues
Information asymmetry arises when one party to a transaction has more or better information than the other party. Typically it is the seller that knows more about the product than the buyer, however, it is possible for the reverse to be true: for the buyer to know more than the seller. Information asymmetry leads to market inefficiency, since not all the market participants do have access to the information they need for their decision-making processes.

In the context of Grid, information asymmetry and issues related to risk and unpredictability arise when participants of a Grid environment (either inter- intra-organizational) have incomplete information about the incentives and repudiation of other participants, such as VO members or internal company departments. This has a negative effect on their willingness to participate in the formation of Grid as well as on their reluctance in sharing their resources and data over the infrastructure. In all cases there is an associated risk and unpredictability of other partners' future behaviour and the origin of their incentives. Apart from the impact of information asymmetry on the sharing of resources by the Grid participants, security issues also impact their willingness to share data especially when sensitive information is to be distributed. This risk also applies to clients. Finally there is an always evident risk of adopting and investing on a new technology especially if this hasn't been fully adopted or if it is based on proprietary implementations.

Performance differentiation and QoS
The objective of performance improvement for application and services constitutes one of the foremost reasons for a company or organization in adopting/moving towards the Grid technology. Thus, it becomes apparent in such cases that the amount of money someone is willing to pay for a service provided over Grid or for such an implementation is strongly dependent on the magnitude of the advantage that this will offer to him in the market. The requirements from the clients/end-users may differ in terms of QoS parameters such as the time of completion, the availability and in this sense it is required to have different and adaptable (but secured by SLA-type agreements) level of services offered by the provider.

5 A Case Study: Analysing and Evaluating The BEinGRID Business Scenarios in Terms of the Identified Economic Issues

Following the identification of the main drives for Grid adoption and having elaborated on the economic issues around them, our next step is to classify the large number of possible Grid Business Scenarios in specific categories to enable us to discuss them further and investigate their impact in real-life scenarios.

In order to accommodate for business examples from different industries we have chosen to analyse the 18 business scenarios from the BEinGRID project (called Business Experiments –BEs in the context of the project). A high-level description of these business cases can be found in [3]. The reasons behind our selection were the following:

- The BEinGRID business cases constitute real-life scenarios in the respect that are implemented by companies that their intention is to enter the Grid market immediately upon the successful completion of the project. Most of these companies did not have any previous experience with Grid Technologies and are currently in the phase of considering Grid adoption by evaluating all the relevant factors both business and technology oriented with emphasis on the former.
- The scenarios cover a range of industries from automotive and film industry to financial and ship building ones and including companies from the whole Grid services provisioning value chain: resource providers, integrators, service providers, end-users etc.
- As members of the BEinGRID consortium we had access to detailed (and sensitive) economic information such as their business models and business plans something that would not be available to us in any other case.

5.1 Classification of Grid Business Scenarios

Firstly, to ease the process of our analysis, the Business Scenarios were classified in three distinct categories, corresponding to the main economic objectives presented and discussed in the previous section. These categories are the following:

- *Category 1: "Grid Business Scenarios with a clear performance-associated benefit"*. This category of scenarios represents those cases that their implementations primarily aim at addressing one of the following limitations: a) additional CPU power needed for executing a demanding application (typical HPC scenario) b) huge amount of data storage/memory is required c) access to heterogeneous, geographically distributed data resources is required.
- *Category 2: "Grid Business Scenarios with a highly collaborative benefit"* i.e. benefit arising from sharing complementary resources among participating organizations. In this case the resulting benefit from Grid adoption comes from sharing data, power and resources utilized for a common scope. Typical examples of this category are intra-organisational Grids and Virtual Organisations and the expected economic benefit in this case could be shared among all participants in contrast to the first category where the main economic benefit is anticipated from the end-user where the service or application will be provided. Also, the services of this category cannot be provided by a single provider since data or other resources are necessary to be obtained from other providers.
- *Category 3: "Grid Business Scenarios exploiting the component-based software paradigm"*. This category comprises those business scenarios involving a service provider that offers applications on a pay-per-use basis rather than by means of licensing or long term static agreements and thus exploiting to the most the concepts of the next generation Service Oriented Architectures (SOA).

The classification of each of the BE's was based on analysing the technical context, business motivation and detailed work planned for the BE, as this was described in the relevant BEinGRID technical documents. In cases where a BE belonged to more than one categories, the decision was based on the prioritisation of the BE objectives as this was presented in the internal BE description and in some cases based on the feedback provided by us after contacting and interviewing the BE leading partner.

Our preliminary analysis with regard to the business scenarios and by examining their initial business plans provided to us in the context of the project, indicated that approximately 70% of the cases belonged to Category 1, 25% in Category 2 and only 5% in Category 1.

5.2 Impact of the Economic Issues in the Business Scenarios

Following the identification of the most important economic issues applicable to the Grid computing adoption in Section 4, the business scenarios were analysed in terms of these issues in order to investigate their relevance to the specific cases, the extent that these apply and therefore the importance that should be given to those by the partners involved in these experiments.

The BEs were evaluated using 3 different grades based on the applicability of each economic issue. The three grades were the following:

Grade A – Strong Impact: Economic issues of this kind exist in this business case; their impact is very strong and should be carefully addressed

Grade B – Average Impact: Economic issues of this kind may exist depending on the scenario configuration, or may exist in the future, their impact is and therefore should be analysed.

Grade C – Weak Impact: Economic issues of this kind do not exist or exist but their impact is considered weak and thus it is not vital to be considered at this point

Inputs for our evaluation were provided by the partners of the business experiments in terms of their business models and plans, technical descriptions of their scenarios and by personal interviews. The results of the evaluation for the experiments are presented in a tabled form in Appendix A.

5.3 Discussion on the Impact of Specific Economic Issues in the Business Scenarios

Our evaluation of the economic issues identified earlier with respect to the specific business scenarios resulted in a number of observations per economic issue examined. Due to space constraints only two of them are listed below as examples.

Network externalities

Network externalities are very evident in many of the experiments that involve the forming of a virtual organization to serve a common scope such as the execution of a complex simulation. The gained benefit for each organization is proportional to the number of organizations participating and offering their resources for the common purpose. For example in “BE02: Business workflow decision making” in order for the risk simulations for the film production industry to be as comprehensive and sound as possible, information must be collected from many of the involved actors: film editors, special effects producers, animators etc – the more obviously the better. If the information is limited then the benefit for the end-user, i.e. the quality of risk-related results given to the producer, becomes questionable, thus decreasing the willingness of the producer in participating in such a virtual organization. The same characteristics can be found in BE10: Collaborative environment in the supply chain management where the number of participants increases the total benefit and vice versa, thus influencing the amount a potential customer is willing to pay for the same service. These observations are in line with our Category 2: “Grid Business Scenarios with a high collaboration benefit” economic characteristics discussed previously.

Information asymmetry, risk and unpredictability-related issues

As discussed in the previous section, information asymmetry and issues related to risk and unpredictability arise when participants of a Grid environment possess incomplete information about the incentives and repudiation of other participants, such as VO members or internal company departments. This has a negative effect in their willingness to participate in the Grid environment and in their reluctance for sharing their resources and data over the infrastructure. In these cases there is also an associated risk and unpredictability of the new partners' behaviour. These issues are more evident in the studied Grid scenarios where the Grid participants are not well-known before and depending on their numbers i.e. in the more “open/loose to participation” cases of Grid structures. On the other hand, more “closed” type of Grids, such the virtual organisations formed by a company's departments (enterprise Grids), are obviously less susceptible to such issues. Examples of the former are “BE10: Collaborative environment in the supply chain management” and “BE14: New product and process development” whereas of the later is “BE12: Sales management system”.

For example, in BE14 let's consider a small firm that intends to run a complex CAD simulation for a potential new product. They have tried to run this simulation on their few workstations but couldn't complete it due to the insufficient power available from their machines. Using Grid technology i.e. “renting” infrastructure from a provider seems as an attractive option to them instead of buying new PCs or a new better CAD tool. However, their lack of expertise in computing and the fact that this is a new product does not enable them to estimate exactly the amount of CPU power and memory that will be needed from their CAD tool in order to perform these simulations. On the other hand, the computer experts from the Grid provider side, having used CAD tools extensively in the past and having rented their infrastructure to other companies for the same purpose in the past are in a better estimate the power needed for their simulation. If this information is not disclosed to the buyer (the small firm) could create a situation where they will pay to utilise more resources (to be on the safe side) than those actually needed for their product thus causing a market inefficiency.

6 Conclusion and Further Work

Grid technology has the potential to revolutionise the way services are distributed and executed over heterogeneous dispersed infrastructures in the future. Lessons learnt from recent past have taught us that technological maturity stand-alone cannot drive a new technology forward. Business and economical drivers should be considered as equally important. Along that direction, in this paper we have tried to identify and analyse a number of dominant economic issues that could act as both acceptance drivers as well as impediments and therefore should taken into account by industrial actors considering the adoption of the Grid for their business. These issues include the associated economies of scale/scope, information asymmetry, self-management issues, network externalities, free-riding, impact to new markets etc. We examined these in the context of a case study with real-life scenarios. Furthermore, we evaluated them in terms of their impact/influence in the decision process of whether a company should adopt the grid or not in the scenarios under consideration. Further work and analysis will include specific proposals on tackling these issues to be applied in an array of different industries. Finally, further work will include the definition of a decision model and associated methodology to be utilised by both Grid experts and business people for deciding towards the Grid adoption, based on the factors presented in Section 4.

Acknowledgements

The authors wish to thank T. Papaioannou and S. Routzounis for their contribution to the material of Section 2.

References

1. Forge S., Blackman C,.: Commercial Exploitation of Grid Technologies and Services, Drivers and Bariers, Business Models and Impacts of Using Free and open Source Licensing Schemes", SCF Accosiates for DG Information Society and Media (2006)
2. http://cordis.europa.eu/ist/grids/index.html
3. http://www.beinGrid.eu
4. http://cordis.europa.eu/fp6/
5. Foster I., Kesselman C., Nick J.M., Tuecke S.: The Physiology of the Grid. An Open Grid Services Architecture for Distributed Systems Integration. Open Grid Service Infrastructure WG, Global Grid Forum (2002)
6. http://www.globus.org/ogsa/
7. G. Cheliotis, S. Miller, J. Woodward, and D. OH.: Questions for Getting Smarter on Creating a Grid Market Hub, Grid MarketPlace RoundTable. GECON’06, Singapore, May 2006
8. C. Kenyon, and G. Cheliotis: Grid Resource Commercialization, International Series in Operations Research and Management Science, Netherlands (2003), ISSU 64, 465-478
9. G. Cheliotis, and C. Kenyon: Autonomic Economics: Why Self-Managed e-Business Systems Will Talk Money, IEEE Conference on E-Commerce ’03, (2003)
10. J. Gray: Distributed Computing Economics. Microsoft Research Technical Report: MSR-TR-2003-24 (also presented in Microsoft VC Summit 2004, Silicon Valey, April 2004), March 2003.
11. http:// www.Gridbus.org/

12. R. Buyya, D. Abramson, and S. Venugopal: The Grid economy, In Special Issue of the Proceedings of the IEEE on Grid Computing. IEEE Press, 2005.
13. J. Brunelle, P.Hurst, J.Huth, L.Kang, C.Ng, D.C.Parkes, M.Seltzer, J.Shank S.Youssef: Egg: an extensible and economics-inspired Open Grid computing platform, GECON 2006.
14. http://mnetproject.org/
15. Chuliang Weng, Minglu Li, Xinda Lu,Qianni Deng, Economic Based Resource Management Framework. CCGrid'05, 2005
16. J. K. MacKie-Mason, A. Osepayshvili, D. M. Reeves, and M. P. Wellman: Price Prediction Strategies for Market-Based Scheduling. In Proc. of ICAPS' 2004

Appendix A: Evaluation of the Impact of the Economic Issues in the BEs

Application	Economies of Scale	Economies of Scope	Externalities	Self-management	New markets	Impact to other markets	Free-riding	Info. Asymmetry	Perform. Differentiation
Computational Fluid Dynamics & Computer Aid Design	A	B	C	A	A	B	A	B	B
Business workflow decision making	A	C	A	A	A	B	B	B	A
Visualization & virtual reality	A	B	C	A	A	B	B	C	B
Financial Portfolio Management	A	A	C	A	A	A	B	A	A
Retail Management	A	C	C	A	B	B	A	B	A
Groundwater modelling	A	C	C	A	A	C	B	A	B
Earth Observation	A	A	B	A	A	B	A	B	B
Engineering and business processes in metal forming	A	A	A	A	A	B	A	B	A
Distributed online gaming	B	A	A	B	A	A	A	B	A
Collaborative environment in the supply chain management	A	B	A	A	B	B	A	A	B
Risk management	A	C	B	A	A	B	B	A	A
Sales management system	A	C	B	A	B	C	B	C	A
Textile Grid portal	A	A	A	A	A	A	A	A	B
New product & process development	A	B	B	A	A	B	A	A	A
Virtual engineering workplace for financial e-services	A	A	B	A	A	B	A	B	B
Ship building	A	C	C	A	B	B	A	B	A
Logistics & Distribution	A	C	B	A	A	C	B	C	A
Seismic imaging & reservoir simulation	B	A	A	A	A	B	A	A	B