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IMPACT OF GRID ASSIMILATION ON OPERATIONAL AGILITY IN TURBULENT ENVIRONMENTS: AN EMPIRICAL INVESTIGATION IN THE FINANCIAL SERVICES INDUSTRY

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Abstract

Financial services providers are exposed to a highly turbulent environment that is characterized by an intense competition for the development of new financial products and the attraction of customers. Against this background, Grid technology assimilation can be assumed to be a potential strategic response to address fast changing market demands and to enhance the operational agility of business processes. This article presents the results of a quantitative field study conducted to analyze to what extent Grid assimilation impacts on the agility of business processes, as well as the role of environmental turbulence in the Grid assimilation process. The research model was validated based on 178 responses from senior IT decision makers of financial services providers in the U.S. that have already adopted Grid technology. The results from partial least squares analyses suggest that environmental turbulence significantly strengthens the relationship between Grid assimilation and operational agility.

Keywords: Technology Assimilation, Operational Agility, Environmental Turbulence, Grid Computing, Quantitative Field Study.

1 Introduction

Enterprises increasingly adopt value chain improving technologies to retain a competitive position in a rapidly changing, uncertain, and demanding environment. Due to its hyper-competitive market, especially the financial services industry is exposed to a high level of environmental turbulence and resulting uncertainty (Ang and Cummings 1997). The ongoing need to realize and adapt to these environmental changes is reflected by the concept of agility which describes one of the key success factors for organizations striving to stay competitive, even in uncertain and turbulent markets (Dove 2001). Moreover, the financial services industry exhibits information-intensive business processes, high demand for large computing and data processing capacities, as well as fast changing customer needs (Teubner 2007). These industrial characteristics are reflected by the above-average annual IT investments (~ 8% of the annual revenues) which are more than twice as high as the average IT spending across all industries (Zhu et al. 2004). One way to address arising environmental turbulence and computational challenges is the organizational assimilation of a Grid-based IT infrastructure that provides users and applications with immediate access to a large pool of interconnected IT resources (i.e., computing and storage devices). Grid technology provides several benefits, including seamless computing power achieved by exploiting under-utilized IT resources and a more reliable, resilient, and scalable IT infrastructure with autonomic management capabilities and on-demand aggregation of resources from multiple sites to meet unforeseen demand (Foster and Kesselman 1999).

In this article, we especially focus on the assimilation of Grid technology for the purpose of facilitating two business processes that are of significant importance for financial services providers to gain and maintain sustainable competitive advantage in the highly competitive and dynamic financial market: *risk management* and *new product development*. Risk management is an essential and vital task to improve sensing capabilities and is mainly driven by (1) the pressure from regulators for a better control of financial risks, (2) the globalization of financial markets that has led to exposure to more sources of risk, and (3) technological advances which have made enterprise-wide risk management possible (Jorion 2006). The need for the continuous enhancement of the new product development process as a vital responding capability is mainly facilitated by fast changing customer needs that force financial services providers to provide highly customized financial products on-demand. Due to the importance of the risk management and new product development process for financial institutions, an effective and flexible IT infrastructure is essential to enhance the agility of a financial institution at an operational level, which is referred to as operational agility (Sambamurthy et al. 2003). In general, operational agility defines the ability of a firm to operate profitably in a rapidly changing and continuously fragmenting global market environment, which encompasses the capability of a firm to sense environmental changes and to respond to them in an efficient, effective and timely manner (Dove 2001, Overby et al. 2006). Since risk management can be seen as a means to sense changes in the market environment, whereas the development of new financial products can be regarded as a way to respond to these changes, we focus on the assimilation of Grid technology that is expected to effectively and efficiently facilitate both business processes and thereby to improve operational agility.

So far, the organizational assimilation of different technologies has been extensively analyzed in the extant literature (e.g., Iacovou et al. 1995, Zhu et al. 2006) and some studies already attempted to investigate the impact of IT capabilities on the operational agility (Lee et al. 2009, van Oosterhout et al. 2009). However, little empirical research has been conducted to understand the interplay of technology assimilation and the operational agility of business processes in conjunction with environmental turbulence (Overby et al. 2006, Sambamurthy et al. 2003). Hence, we provide and discuss the results of a survey conducted in the financial services industry in the U.S. to analyze the value-adding effects of Grid technology assimilation on the operational agility of two specific business processes, as well as the role of environmental turbulence as an important moderator in organizational science (Eisenhardt and Martin 2000). In particular, we address the knowledge gaps by answering the

following two research questions: 1) *How does Grid assimilation influence the operational agility of business processes?* 2) *How do turbulent environmental conditions affect the operational agility of business processes that are facilitated by Grid technology?*

This article is organized as follows: First, we provide a review of relevant research streams and develop the theoretical foundation for our research model. We then propose a methodology to test the hypotheses and discuss the results of our empirical analysis. Finally, we conclude this article by illustrating contributions of our analysis and highlighting further research opportunities.

2 Theoretical Background

The foundation of our theoretical framework comprises some theoretical elements that are presented in more detail in the following subsections.

2.1 IT Assimilation

The term “assimilation” is commonly used in IS literature and represents a comprehensive and complete process of implementation of IT innovations in organizations. Since widespread adoption of IT is not necessarily followed by widespread IT acceptance and routinized use, Fichman (2001) conceptualized the degree of assimilation as the extent to which a firm has progressed through the following major stages of innovation deployment: initiation, adoption, and routinization. In the *initiation* (pre-adoption) stage, firms evaluate whether a new IT innovation can add value to the organization (Rogers 1995), such as cost reduction and enhancing business processes, which vastly impacts the final adoption decision (Dong et al. 2009). The subsequent *adoption* stage encompasses the active decision to acquire the IT innovation and to allocate the required physical resources, whereas in the *routinization* (post-adoption) stage, the innovation is institutionalized and becomes an integral part of the value chain activities (Zhu et al. 2006). Hence, if the focus is on only one stage of the assimilation life cycle, such as the decision to adopt a specific innovation, researchers overlook the fact that technology assimilation is an ongoing process (Rai et al. 2009). Therefore, we deemed the more holistic conceptualization of assimilation in contrast to pure adoption analyses as appropriate to study the enhancement of operational agility through Grid technology.

For the unit of analysis for measuring the assimilation progress and the potential enhancement of operational agility, we chose a business process perspective due to the fact that IT investments are supposed to first affect the performance of specific business processes (Davamanirajan et al. 2006). In general, a firm encompasses approximately 18 key processes being vital for the overall firm performance (Davenport 1993). To identify the key business process being primarily influenced by Grid assimilation in the financial services industry, we conducted several expert interviews with IS executives. Since the risk management process as well as the new product development process turned out to be especially appropriate and vital for the financial services industry, we analyzed the Grid assimilation stages for these two processes.

2.2 Operational Agility of Business Processes

The extant literature offers several definitions of agility at various levels, such as at the enterprise level, business function level, and business process level (Ganguly et al. 2009). Overby et al. (2006) define agility as an organization’s ability to sense environmental changes (opportunities, threats, or a combination of both) in its business environment and thus to provide rapid responses to customers and stakeholders by reconfiguring its resources, processes, and strategies. In this study, we focus on agility at the operational level (Sambamurthy et al. 2003), or operational agility, that entails the ability to operate profitably in a rapidly changing, fragmented market environment by flexibly producing and offering high-quality, high-performance, customer-configured goods and services in a timely, cost-efficient manner (e.g., Dove 2001, Ren et al. 2003, Yusuf et al. 1999). In a dynamic market context, the capability to explore, exploit, and capture market opportunities and engage in relentless

innovations in a timely and cost-efficient manner is imperative for organizational success (Goldman et al. 1995). Therefore, flexible and scalable capacity adjustments as well as ad-hoc access to resources and capabilities are of central importance to gain and sustain competitive advantage in highly dynamic and competitive market environments, such as in the financial services industry. As already outlined, we focus on the operational agility of the risk management and the new product development processes and argue that these business-critical processes can be facilitated by Grid technology, which enables a firm to seize opportunities and threats, respond to internal and external changes, and sustain its operational performance.

2.3 Environmental Turbulence

Previous research has revealed that environmental characteristics considerably impact on corporate strategy and outcomes (Eisenhardt and Martin 2000). For example, the concept of environmental turbulence, which encompasses uncertainty and unpredictability due to massive and rapid changes in technological developments and market preferences (Jaworski and Kohli 1993), can characterize an environment on the basis of both its market and its technological turbulence. Market turbulence refers to heterogeneity and variability in preferences and demands in the market (Helfat et al. 2007), whereas technological turbulence refers to the rate of technological change (Lichtenthaler and Ernst 2007). Environmental turbulence also demands greater organizational sense-making and responsiveness to safeguard organizational outcomes. Thus, companies might be conceived of as sense-making units, stimulated by environmental turbulence and constantly challenged to identify contextually appropriate responses (McGill et al. 1994). Moreover, organizations often acquire external resources and the related knowledge to respond to their turbulent environments (Cassiman and Veugelers 2006). The assimilation of Grid technology can be a means for dealing with the dynamic circumstances of a turbulent environment by capacity and capability adjustments. Therefore, environmental turbulence was included in our research model to capture differences across turbulent versus relatively stable market environments.

3 Hypotheses and Research Model

To validate the impact of Grid assimilation at the organizational level, we developed the research model shown in Figure 1 and analyze the impact of Grid assimilation on the operational agility of two business processes. Moreover, the role of environmental turbulence in the context of Grid-induced changes in operational agility is analyzed.

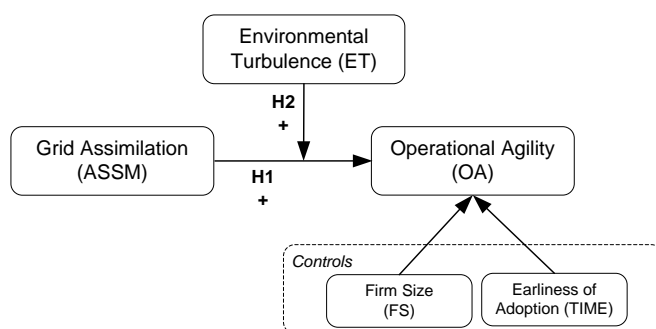


Figure 1. Research model

Prior literature has suggested that technology adoption must support companies' value-chain activities and business processes before they will have any significant business value at the operational level (e.g., Santhanam and Hartono 2003). With regard to Grid technology, Grid infrastructures offer ad-hoc access to a large number of IT resources, which provides the potential for enhanced performance of (compute-intensive) business processes and is essential for companies to gain and sustain competitive advantage in highly dynamic and competitive market environments (Pavlou and El Sawy 2006). Moreover, Grid technology allows flexible and scalable capacity adjustments, meaning that IT

resources can be rapidly provisioned (scaling up) and released (scaling down) in accordance with the resource demand, which is of crucial importance to respond more rapidly to changing business demands (Liu et al. 2008). Hence, because Grid technology is suggested to provide benefits for firms with regard to their operational agility, we anticipate a positive relationship between Grid assimilation and the operational agility of specific business processes. Hence, we propose:

Hypothesis 1: Later stages of Grid assimilation lead to greater operational agility.

Risk is manifested most strongly in volatile environmental conditions (e.g., Jaworski and Kohli 1993). In view of this, we argue that the extent to which Grid-enabled capabilities affect operational agility depends on the level of turbulence in the business environment. The capability to assess and respond appropriately to risk is especially vital in turbulent environments, as the variety of threats and uncertainties that can be present is enormous. Organizations need to lean upon their IT-enabled capabilities in environments where survival hinges on the ability to anticipate the unexpected and react accordingly in uncertain conditions (Sambamurthy et al. 2003). Hence, it is likely that an organization will manifest superior agility since it enjoys advantages arising from its strategic alignment with its environment. More precisely, a company needs to focus on the development and alignment of its resources and apply them to the changing environmental conditions to be able to produce innovations and respond to environmental changes cost-efficiently and promptly (Kohli and Jaworski 1990). The building of IT-enabled capabilities can be seen as the increase of options for response to uncertainties to match the range of possible risks and threats. This expands the repertoire of responses available and therefore increases the likelihood of the organization to perform better when faced with challenges posed by the volatility of the environment. Since Grid assimilation might support such adaptations through capacity and capability adjustments, we propose:

Hypothesis 2: In turbulent markets, compared with stable market environments, Grid assimilation leads to greater operational agility.

To account for differences among the investigated companies, we included the control variables “firm size” (Rogers 1995) and “earliness of adoption” (Fichman 2001) in the model. Rogers (1995) suggests that firm size may be positively related to innovation adoption since large firms are more likely to exhibit slack resources. In contrast to this, smaller firms are assumed to be more flexible with regard to innovative technologies (Zhu et al. 2006) due to less communication and coordination requirements. The second control variable reflects the years elapsed since the first Grid adoption and captures the fact that firms having initiated Grid implementation activities earlier than others had more time to reach later stages of assimilation, leading to different magnitudes of operational agility.

4 Study Design and Data Collection

Although there are a number of valid research approaches, we deemed a quantitative, survey-based methodology appropriate since it allows minimizing the subjectivity in the analysis of the data by employing statistical tests to examine the validity of the research hypotheses (Kealey and Protheroe 1996). Moreover, by using a survey, we can investigate the perceptions and intentions of a large number of subjects (i.e., organizations), which may not be practical with qualitative methods. Lastly, quantitative methods allow high levels of reliability and repeatability, which facilitates replication of the research (Balsley 1970). Hence, we operationalized the proposed research model as a structural equation model and used the partial least squares (PLS) method for the validation due to several reasons. First, PLS handles measurement errors in exogenous variables better than other methods, such as multiple regression analysis and, second, PLS requires fewer distributional assumptions about the data (Chin 1998). Especially in areas of newly applied research and in the early stages of measurement instrument development, little is known about the distributional characteristics of observed variables. Third, even though PLS is often used for theory confirmation, it can also suggest where relationships might exist and suggest propositions for later testing (Chin et al. 2003). Thus, the PLS approach is prediction-oriented (Chin 1998), which is regarded as an advantage since theory construction is as important as theory verification.

4.1 Measures

Whenever possible, we adapted existing measures from prior empirical studies to our research context. To ensure the content validity of these measures, we conducted several expert interviews and asked a panel of practitioners and academic judges to review the survey instrument and suggest any refinements to the wording of the indicators (measurement items). The survey items are depicted in Table A1 in the Appendix. For both constructs “Environmental Turbulence” (ET) and “Operational Agility” (OA), reflective indicators were used and measured on a fully anchored 7-point Likert scale. Whereas the measures of the ET construct are based on the operationalization used by Pavlou and El Sawy (2006) and Jaworski and Kohli (1993), we operationalized the OA construct with regard to different characteristics of an agile enterprise. Because the extant literature offers several competing definitions of agility, we reviewed various literature resources from industry and academia and discovered the major characteristics of operational agility, as we summarize in Table A2 in the Appendix. Most definitions of agility cover time and the ability to respond at the operational level (responsiveness), though Yusuf et al. (1999), Ren et al. (2003), and Dove (2001) suggest several other essential characteristics of operational agility. Following Dove (2001), we define operational agility as the *effective response ability for rapidly, efficiently, and accurately adapting to unexpected (or unpredictable) changes in both proactive and reactive business/customer needs and opportunities, without compromising the cost or the quality of the product/process*. With this definition and the results from Table A2, we decided to operationalize the OA construct as a dependent variable that could capture the agility creation momentum of Grid assimilation, attributed mainly to the operational level. Since the risk management and the new product development processes were identified as being especially appropriate and vital for the financial services industry, we analyzed these two processes in regard to changes in (1) cost-efficiency, (2) speed, (3) effectiveness, (4) quality, (5) responsiveness, and (6) flexibility.

For the “Grid assimilation” (ASSM) construct, a 7-item Guttman scale was used to capture the current Grid assimilation stage of an enterprise. This scale was grounded on prior research on the assimilation of software process innovations (Fichman 2001) and on the assimilation of electronic procurement innovations (Rai et al. 2009). The respondents were requested to identify the current stage of Grid assimilation for their risk management and new product development processes. As already outlined, these two processes were identified as being especially appropriate and vital for the financial services industry, wherefore the measurement items of the assimilation construct focused on Grid-related activities in these processes.

4.2 Data Collection and Sample Profile

To validate the research model presented in Figure 1 and the associated hypotheses proposed above, we finally conducted a questionnaire-based field study, featuring IT decision makers from financial institutions in the U.S. In general, a Grid infrastructure requires at least a certain firm size to be implemented in a reasonable manner since there have to be at least a number of IT resources (e.g., servers) which can then be interconnected and virtualized. Therefore, we administered our study among financial institutions with more than 1,000 employees. Moreover, the financial institution had to be a Grid adopter to ask the study participants for their experience with Grid technology. As already outlined in the introduction section, we deemed the financial services industry an appropriate testing field for the research model. From an empirical perspective, our focus on a single industry and a single country enabled us to control for extraneous industry- or country-specific factors that could confound the analysis, which enhances internal validity (Zhu et al. 2004).

In August 2009, we invited 2,034 potential participants of a U.S. IT business panel to respond to the survey by completing an online questionnaire and received 459 responses (response rate of 22.6%). Since the study aimed at Grid adopters, the study participants were asked at the beginning of the questionnaire to indicate whether they have already adopted Grid technology for at least one of the analyzed processes or not. In the latter case, the non-Grid adopters were directly excluded from taking

part in the survey. In total, 281 responses from non-Grid adopters or responses which exhibited missing values, that can cause bias due to systematic differences between observed and unobserved data, were removed. Consequently, this led to a final sample of 178 valid responses (from 31 CTO|COO|CIOs, 10 chief systems architects, 137 other IT decision makers), 150 of which utilize Grid technology for their risk management process and 155 of which use Grid technology for their new product development process.

5 Data Analysis and Results

As a structural equation modeling technique, PLS analyzes the measurement models and the structural model. These two models are estimated simultaneously to combine the advantages of regression analysis and multivariate measurements approaches. In our study, we obtained the results for the PLS estimation from SmartPLS (Version 2.0 M3) and a bootstrapping procedure to test the statistical significance of the estimates.

5.1 Validation of the Measurement Models

Our evaluation of both the reflective and formative models entails assessments of content validity, construct reliability, and construct validity. Because we already determined the content validity in section 4.1, we, in the following, focus on construct reliability and construct validity. Table 1 shows the validation results for the risk management and the new product development process.

Construct reliability refers to the internal consistency of the measurement model and measures the degree to which items are free from random error and yield consistent results. The reliability of the reflective constructs was assessed by using the average variance extracted (AVE), the composite reliability (CR), and the Cronbach's alpha scores. As we indicate in Table 1, the AVE of each construct is above the recommended threshold of 0.5 (Fornell and Larcker 1981), so at least 50% of measurement variance is captured by a construct. Moreover, the CR score of each construct is above the recommended threshold of 0.7 (Hair et al. 1998), which is evidence of sufficient reliability, and all Cronbach's alpha values exceed the critical value of 0.7 (Nunnally 1978), providing further support of the internal consistency among the measurement items.

Construct validity instead refers to the wider validation of measures and reveals whether indicators of the construct measure what they intend to, from the perspective of the relationships between constructs and between the constructs and their indicators. This validity can be assessed in terms of (1) convergent validity and (2) discriminant validity (Campbell and Fiske 1959). The test for *convergent validity* determines if the indicators of latent constructs that theoretically should be related are observed to be related in actuality. In general, the existence of significant inter-indicator and indicator-to-construct correlations is evidence of convergent validity of the construct. Our results clearly show that all loadings of the reflective constructs are greater than the recommended threshold of 0.707 (Chin 1998), such that there exists more shared variance between the construct and its indicators than error variance, and the measurement items used are adequate for measuring each construct. For *discriminant validity*, we tested whether indicators of latent constructs that theoretically should not be related to each other are actually observed unrelated. MacKenzie et al. (2005) propose an approach appropriate for evaluating the discriminant validity of both formative and reflective measures, which analyzes whether the inter-construct correlations are relatively low. The discriminant validity for the reflective constructs can also be assessed by analyzing the cross-loadings and the Fornell-Larcker criterion. The cross-loadings reveal that each indicator loading is much higher on its assigned construct than on any other construct, in support of sufficient discriminant validity on the indicator level (Chin 1998). The results of Table 1 show that the square roots of the AVE scores (diagonal elements) are greater than the correlations between the construct and any other construct (off-diagonal elements), which indicates that the constructs share more variance with their assigned indicators than with any other construct (Fornell and Larcker 1981). Since all constructs exhibit convergent and discriminant validity and all indicators satisfy various reliability and validity criteria, we used them to test the structural model.

	Risk Management Process (n=150)										New Product Development Process (n=155)									
	Mean	SD	AVE	CR	Alpha	ASSM ⁺	ET	OA	TIME ⁺	FS ⁺	Mean	SD	AVE	CR	Alpha	ASSM ⁺	ET	OA	TIME ⁺	FS ⁺
ASSM ⁺	5.82	1.08	n/a	n/a	n/a	n/a					5.59	1.07	n/a	n/a	n/a	n/a				
ET	5.58	0.93	0.52	0.88	0.85	0.16*	0.72				5.62	0.93	0.51	0.88	0.85	0.15	0.71			
OA	5.16	1.18	0.77	0.95	0.94	0.31*	0.49*	0.87			4.97	1.13	0.75	0.95	0.93	0.27*	0.40*	0.87		
TIME ⁺	4.06	2.98	n/a	n/a	n/a	0.19*	0.03	0.01	n/a		4.04	3.02	n/a	n/a	n/a	0.24*	-0.05	-0.02	n/a	
FS ⁺	2.88	1.11	n/a	n/a	n/a	0.04	0.08	0.06	0.09	n/a	2.93	1.09	n/a	n/a	n/a	-0.20*	0.08	-0.05	0.09	n/a

Table 1. Reliability scores, square root of AVE (diagonal elements), and correlations among constructs (off-diagonal elements), * $p < 0.05$ (two-tailed), + = 1-item measure

5.2 Validation of the Structural Model

To estimate the moderating effect of environmental turbulence (ET), we followed Chin et al. (2003). First, to reduce multicollinearity, we standardized all indicators reflecting the predictor and moderator constructs to a mean of 0 and variance of 1. This step supports an easier interpretation of the resulting regression beta for the predictor variable. The path coefficient represents the effect expected at the mean value of the moderator variable, which is set to 0. Second, using the standardized indicators of the predictor and moderator variables, we generated product indicators to reflect the latent interaction variables. Third, we applied the PLS procedure to estimate the dependent variable OA.

In Figure 2, we depict the validation results for both analyzed processes, which reveal mostly significant path coefficients above the 0.1 threshold (Sellin and Keeves 1994). Hence, for both models, the hypotheses H1 and H2 are supported by the survey data. To measure the explanatory power of the structural model, we use the squared multiple correlations (R^2) of the dependent variable OA. The R^2 values of 32.5% and 23.3%, respectively, indicate that, according to Chin (1998), the model explains a moderate amount of variance for the dependent variable. With regard to the control variables, firm size and the earliness of adoption both relate insignificantly to the OA construct.

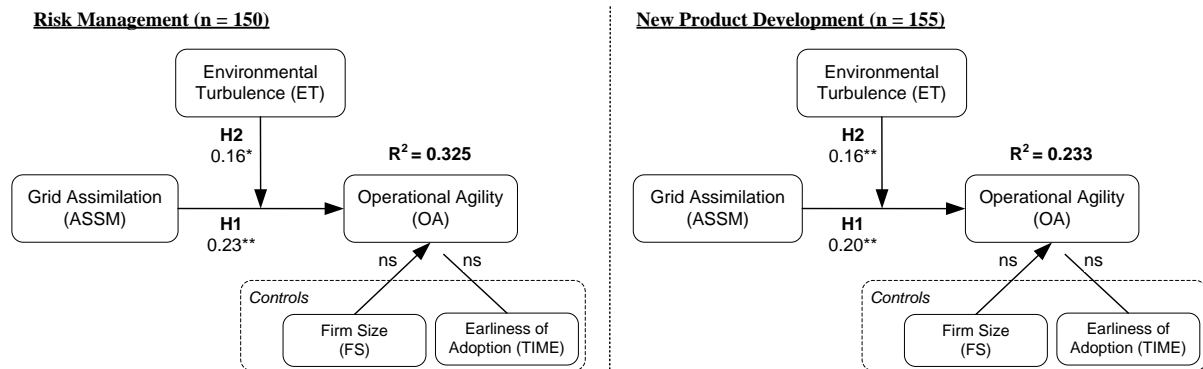


Figure 2. Empirical results; ** $p < 0.01$, * $p < 0.05$ (two-tailed)

6 Discussion of the Results

Since the hypotheses H1 and H2 are supported by the survey data for both investigated business processes, our research model provides a good illustration of how organizational assimilation of Grid technology eventually leads to greater operational agility. Moreover, the survey data suggest that this relation is positively moderated (strengthened) by environmental turbulence. Accordingly, this study discovered that the assimilation of Grid technology has a significant and positive impact on the agility of business processes, resulting in greater cost-efficiency, speed, effectiveness, quality, responsiveness, and flexibility.

Exploring the relations more closely, the empirical results indicate that later stages of Grid assimilation for the risk management and the new product development process lead to strong operational agility improvements. Enhancements in the speed, effectiveness, and quality of optimization and risk calculations can be achieved through Grid technology due to the availability and exploitation of a large network of computing and storage resources which are crucial for an accurate and comprehensive risk management. Improvements in cost-efficiency in the use of IT resources as well as enhancements with regard to the flexibility and responsiveness to changing market conditions can be achieved due to the scalable nature of a Grid-based IT landscape that is beneficial for the increasing demand for new financial products. For these products, the risk/return ratio has to be evaluated by complex and compute-intensive calculations that have to be adjusted with regard to the entire risk/return structure of the financial services provider. Once the ratio is evaluated, adjusted, and approved by the senior management, the product is market-ready. Therefore, a fast, accurate, and comprehensive risk valuation to meet the new capital requirements by laws and regulations is becoming a key driver for reducing time-to-market. Moreover, due to the capability of a scalable and, hence, a “breathing” IT infrastructure, Grid technology allows for the flexible and cost-efficient provision of large computing and storage capacities to dynamically sense changing business needs and to respond to them by developing new financial products.

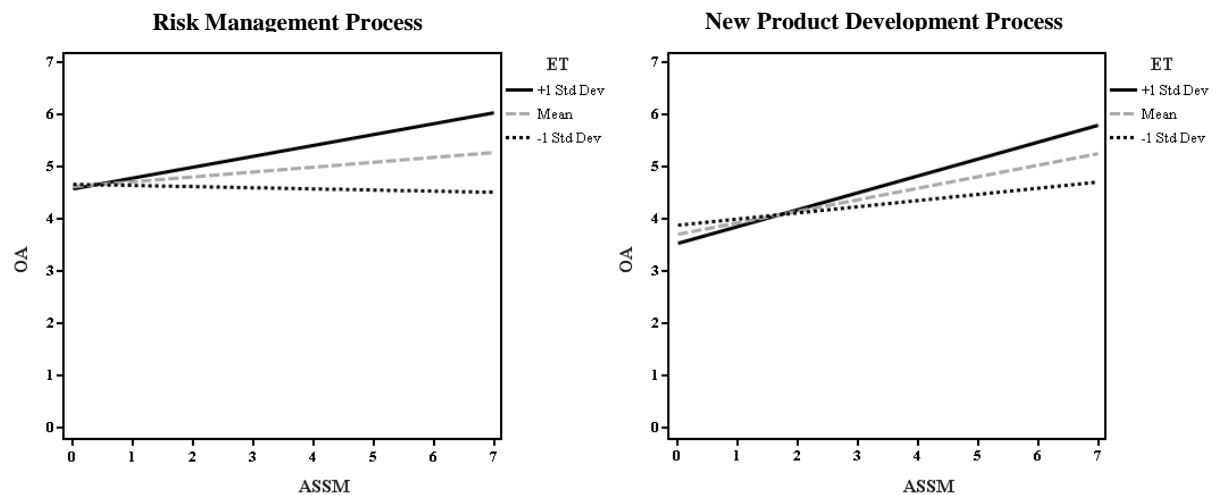


Figure 3. Interaction plots for high (+1 SD) and low (-1 SD) environmental turbulence

Besides these findings, the study results indicate that companies operating in highly innovative and turbulent markets, compared to stable market environments, significantly benefit from the assimilation of Grid technology. These interaction effects are illustrated in Figure 3. High and low lines in the interaction plots represent ± 1 standard deviation from the mean value (middle line) of ET. The interpretation of interaction effects plots relies on comparing the slope (rather than absolute values) of the relationship between the predictor (ASSM) and the dependent variable (OA) for varying levels of the moderator (ET) (Edwards and Lambert 2007). The steeper slope of the solid black line, compared to the dotted black line, illustrates that an increase in ASSM is associated with a larger (smaller) increase in OA when ET is high (low). These findings clearly demonstrate that firms in turbulent markets can leverage from Grid technology and thereby enhance their agility. In contrast, due to the dotted line that exhibits a lower slope, it seems that for firms operating in stable markets, the additional costs and effort associated with the implementation of the Grid infrastructure appear to outweigh the positive effects, such as speed, responsiveness, and flexibility.

7 Conclusion and Further Research

Grounded in the extensive research on business agility, we developed and tested a research model that examines the impact of Grid technology assimilation on operational agility. We perceive the findings as extremely valuable, considering the limited empirical research on the interplay between technology assimilation, operational agility, and environmental turbulence. Our results provide a better understanding of the business value (i.e., operational agility) of Grid assimilation since the data analysis reveals that an increased level of Grid assimilation leads to greater operational agility of the risk management and the new product development process. Moreover, this positive effect of Grid assimilation on the operational agility of Grid-enabled business processes is even greater in turbulent markets that are characterized by massive and rapid changes in technological developments and market preferences. These results are of importance for theory as well as for practice. Since our study is one of the first that empirically analyzes to what extent turbulent environmental conditions affect the agility of business processes, our results significantly contribute to the existing literature. From a theoretical point of view, we sharpen our understanding of the relation between IT capabilities and operational agility, strengthened by environmental turbulences. Thereby, we refer to the request of, e.g., Sambamurthy et al. (2003) and Overby et al. (2006) who encouraged further research in the field of digital option generation and the realization of agility capabilities resulting from IT investments. Besides the theoretical contribution, the implications for practitioners are also extremely valuable. Our study results clearly demonstrate that Grid technology is not only capable of accelerating resource-demanding computations and data mining operations, but can also be used as an effective and efficient strategic response to unpredictable and rapid changes in the market. Especially for the risk management and the new product development process, the timely assessment of risk exposure and complex financial products becomes feasible with the move to a Grid-based IT infrastructure.

As there are only a few empirical studies (e.g., Lee et al. 2009, van Oosterhout et al. 2009) that attempted to measure operational agility in an empirical setting, our research contributes to the existing body of knowledge on operational agility. The validation of our measurement model indicates that our operationalization of the OA construct, which is based on a thorough literature review, is suitable for measuring operational agility in an empirical setting. Despite these rich implications, the depicted work is limited with regard to the specific country, technology, industry, and the specific business processes, thus restricting the generalizability of the supported hypotheses. In addition, longitudinal instead of cross-sectional data might be better suited since it provides information that cannot be obtained from cross-sectional data and, hence, permits more sophisticated and nuanced analyses and increased precision in estimation. Furthermore, a more comprehensive operationalization of business agility according to the conceptualization of Sambamurthy et al. (2003) and Overby et al. (2006) might extend the theoretical and practical implications regarding the different dimensions of business agility, like market, network, and operational agility. Finally, objective primary or secondary performance data on the process level could be integrated to assess the impact of Grid assimilation.

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Appendix

Grid Assimilation (ASSM) (formative measure)		7-item Guttman scale	Sources: Rai et al. (2009), Fichman (2001)	
ASSM1	Are you aware of initial or prior Grid-related activities at site?		ASSM5	Are more than 5% but less than 25% of the business applications for the <i>PROCESS</i> running on a Grid?
ASSM2	Are you aware of plans to use a Grid environment for the <i>PROCESS</i> within the next 12 months?		ASSM6	Are more than 25% but less than 50% of the business applications for the <i>PROCESS</i> running on a Grid?
ASSM3	Is any Grid environment for the <i>PROCESS</i> currently being evaluated or trialed?		ASSM7	Are more than 50% of the business applications for the <i>PROCESS</i> running on a Grid?
ASSM4	Are any Grid application development projects for the <i>PROCESS</i> planned, in progress, implemented, or cancelled?			
Environmental Turbulence (ET) (reflective measures)		7-point Likert scale (1 = strongly disagree; 7 = strongly agree)	Sources: Pavlou and El Sawy (2006), Jaworski and Kohli (1993)	
ET1	The environment in our industry is continuously changing		ET5	In our kind of business, customers' product preferences change a lot over time
ET2	Environmental changes in our industry are very difficult to forecast		ET6	Marketing practices in our product area are constantly changing
ET3	The technology in our industry is changing rapidly		ET7	New product introductions are very frequent in our market
ET4	Technological breakthroughs provide big opportunities in our industry		ET8	There are many competitors in our market
Operational Agility (OA) (reflective measures)		7-point Likert (1 = strongly disagree; 7 = strongly agree)	Sources: see Table A2	
Grid implementation has...				
OA1	... lowered our costs in the <i>PROCESS</i>		OA4	... improved the quality of our <i>PROCESS</i>
OA2	... decreased the time-to-market of new financial products due to an improved <i>PROCESS</i>		OA5	... made us more adaptive to a changing business environment due to an improved <i>PROCESS</i>
OA3	... improved the effectiveness of our <i>PROCESS</i>		OA6	... improved the flexibility of our <i>PROCESS</i>
Controls (1-item measures)		Open questions	Sources: Fichman (2001), Rogers (1995)	
FS	Number of employees (worldwide)		TIME	Years elapsed since the first Grid adoption

Table A1. Measurement items; *PROCESS* = risk management process / new product development process

Literature Sources	Characteristics of Operational Agility					
	(1)	(2)	(3)	(4)	(5)	(6)
Dove (2001), Ren et al. (2003), Yusuf et al. (1999)	x	x	x	x	x	x
Tsourveloudis and Valavanis (2002)	x	x	x	x	x	
Lin et al. (2006), Yang and Li (2002)	x	x	x		x	x
Jain et al. (2008)	x	x		x	x	x
Flidner and Vokurka (1997)	x	x	x	x		
Overby et al. (2006)	x	x	x		x	
Vázquez-Bustelo et al. (2007)	x	x		x		x
Menor et al. (2001)	x			x	x	x
Goldman et al. (1995), Goranson (1999), Raschke and David (2005), Sambamurthy et al. (2003), van Hoek et al. (2001)		x	x		x	x
Ganguly et al. (2009)	x	x			x	
Total = 17	12	16	13	8	15	13

Table A2. Results of the literature research on the characteristics of operational agility; (1) cost-efficiency, (2) speed, (3) effectiveness, (4) quality, (5) responsiveness, (6) flexibility