Vertical Integration and the Scope of Uncertainty
– Evidence from the PC Gaming Industry

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Abstract: Uncertainty challenges the performance of both markets and hierarchies. However, it is still unclear whether hierarchies or contractual relationships are better able to cope with uncertainty. Existing literature has therefore tried to distinguish different dimensions of uncertainty (such as market or technological uncertainty), but empirical results remain ambiguous. We think distinguishing different uncertainty dimensions is not enough, but one has to first understand which parts of an organization are affected by uncertainty. Our main theoretical argument is that if uncertainty affects multiple vertical stages, vertical integration should become more attractive, but if uncertainty affects only one vertical stage, contractual relationships should become more attractive. We use the PC gaming industry to test our arguments as this industry has two distinct vertical stages (publishers and developers), there is consistent heterogeneity regarding governance choice (make and ally), and we can directly observe performance as well as two types of uncertainty (market and technological uncertainty). Using US market data from 2001 to 2010 we find strong support for our theoretical predictions as market uncertainty (which affects both developers and publishers) makes hierarchies more attractive, whereas technological uncertainty (which mainly affects developers) makes contractual relationships more attractive.

Keywords: vertical integration, uncertainty, PC gaming industry

JEL Classification: B23, L22, L24

1. Introduction

Adaptation to environmental change has long been identified as one of the main economic challenges (Barnard 1938, Hayek 1945, Williamson 1996). Even though it is straightforward that the uncertainty induced by environmental change should influence performance of both hierarchical and contractual relationships, existing literature gives no clear answer about the relative adaptive ability of those organizational archetypes. We therefore introduce the scope of environmental uncertainty as an important additional driver of relative performance differences. We argue that if uncertainty affects multiple vertical stages, hierarchical solutions should become more attractive, whereas, if only one vertical stage is affected, contractual relationships should perform relatively better.

We study the relationship between uncertainty and relative organizational performance of hierarchical and contractual relationships in the PC gaming industry. Using US market data from 2001 to 2010, we show that there is a positive relationship between demand uncertainty (that affects two vertical stages) and the relative performance of hierarchies, whereas technological uncertainty (that mainly affects one vertical stage) works the other way and makes contractual relationships more attractive.

Transaction cost theory identifies uncertainty as one of the three main determinants of governance performance beneath asset specificity and transaction frequency (Williamson 1985). Uncertainty is expected to increase transaction costs if assets are specific and should thus increase the relative performance advantage of hierarchies over markets. However, the empirical evidence as surveyed by David and Han (2004) has produced mixed results: out of 87 tests of transaction costs with uncertainty as an independent variable, 21 tests supported the predictions, 14 rejected them, and the remaining did not produce significant results.

One approach to reconcile the conflicting empirical results is to distinguish between different types of uncertainty. For example, Walker and Weber (1984, 1987) distinguish between volume uncertainty and technological uncertainty and find that volume uncertainty leads to more make decisions while technological uncertainty leads to more buy decisions. However, these results stand in stark contrast to Schilling and Steensma (2002) who split up uncertainty in commercial and technological uncertainty and find that commercial uncertainty makes integration less attractive whereas technological uncertainty increases threats of opportunism, which in turn makes integration more attractive. Other examples of studies disentangling different dimensions of uncertainty are Andersen and Schmittlein (1984), Harrigan (1986), Sutcliffe and Zaheer (1998), Santoro and McGill (2005), or McCarthy et al. (2010). So splitting up different dimensions of uncertainty does not help to fully explain the ambiguous results (David and Han 2004).

We argue that the question 'How does the type of uncertainty influence the performance of different governance modes?' is the wrong question to ask. Instead, one has to understand which parts of an organization are affected by turbulence. The type of uncertainty alone does not define which parts of a value chain are affected by uncertainty. For example, technological uncertainty could hit a supplier and not the buyer if this supplier is providing a well-specified module with standardized interfaces for a product. On the other hand, technological uncertainty could also hit multiple stages in a value chain if technological changes on the side of a supplier have immediate implications on the performance and design of the buyer's final product. Our main theoretical argument is that if uncertainty affects multiple vertical stages, vertical integration should become more attractive, but if turbulence affects only one vertical stage, market coordination should become more attractive.

Our paper directly relates to the three studies of Gulati et al. (2005), Hoetker el al. (2007), and Wolter and Veloso (2008). First, while the primary focus of Gulati et al. (2005) is to bring attention to coordination problems in vertical relationships, they also explicitly consider transaction instability and interdependencies between tasks. They find that transaction instability makes markets more attractive, while interdependencies make them less attractive. In addition to using objective performance data and being able to circumvent many other problems with our panel structure, our study also differs with regard to Gulati et al. (2005) in that we argue that the scope of uncertainty cannot be analyzed without considering uncertainty itself. Second, in line with our study, Hoetker et al. (2007) find that suppliers of highly modular components benefit more from autonomy than those of low-modularity components. Our study differs in that we observe discrete governance modes and not only suppliers with varying degrees of autonomy. Furthermore, we argue that performance differences do not arise due to differences in modularity, but that different scopes of uncertainty ultimately drive the performance differences. Third, our work also relates to Wolter and Veloso (2008), who propose that benefits of vertical integration depend on the kind of innovation a firm reacts to. Using Henderson and Clark's (1990) typology of innovations, they propose that modular innovations should lead to less integration, whereas architectural and radical innovations should result in higher levels of integration. This is in line with our predictions as only a modular innovation's impact will be restricted to one vertical stage. Our study goes beyond Wolter and Veloso (2008) in that we use the broader concept of uncertainty and in that we also empirically test our theoretical predictions.

We use the PC gaming industry to find empirical evidence for our arguments. This industry is well suited to perform a study on the relative performance of governance choice as there are two distinct vertical stages (developers who create the game and publishers who bring the game to the market), there is consistent heterogeneity regarding governance choice, and we can directly observe performance[1]. Furthermore, the industry faces two main challenges that can be mapped to two different kinds of uncertainty. First, the industry faces market uncertainty, as customer preferences regarding the kinds of games played change frequently. This is the more demanding, the more turbulent the market changes and requires strong coordination between the publisher (who knows how to address the customer) and the developer (who provides the content of the game). We therefore argue that market uncertainty increases the relative performance of integrated firms over non-integrated firms. The second challenge for the PC gaming industry is to make sure that a game exploits the potential of upcoming consumer hardware, while still not having too high hardware requirements as to diminish market potential. This task becomes the more demanding, the more turbulent the available hardware changes and has to be mainly addressed by the developer. We therefore argue that technological uncertainty increases the relative performance of non-integrated firms over integrated firms.

We use data on the PC gaming industry from 2001 to 2010 to test our hypotheses and construct measures for market and technological uncertainty. Our unit of observation is on a game-month level, which allows us to exploit the panel structure of our data[2]. Furthermore, we don't have to deal with a survivor bias caused by studying only the largest, surviving firms (David and Han 2004), as we have data on nearly all games published in our period of observation. Our dependent variable is the logarithm of the monthly revenue achieved by a PC game, for which we have more than 50,000 observations distributed over more than 2,000 games. We regress these revenues on our measures of uncertainty and their interaction with the integration decision. Applying a conservative set of fixed effects on the level of the game, the age of the game in months, the calendar month, and the year, we are still able to identify the influence of uncertainty by the variation within each game. Additionally, the game fixed effect already captures the impact of governance choice, which doen selection issues (Poppo and Zenger 1998, Gulati et al. 2005).

[1] Most studies on vertical integration only observe the vertical integration decision but not the relative performance of integrated and non-integrated firms (David and Han 2004). Notable exceptions are the studies by Poppo and Zenger (1998) and by Gilley and Rasheed (2000). However, in contrast to our study, their studies use subjective performance measures and these measures are only available in a cross-section.

[2] David and Han (2004) observe the lack of longitudinal studies for testing the proposition of transaction cost economics and mention only Fan (2000) as a notable exception.

Our results support our hypotheses, as technological uncertainty makes contractual relationships more attractive while market uncertainty makes hierarchies more attractive. Our paper is methodologically and industry-wise related to Gil and Warzynski (2010), who also use the setting of the video gaming industry to infer performance implications from vertical integration decisions. However, they only discuss the absolute performance differences between integrated and non-integrated projects and do not consider uncertainty.

The main contribution of our study is to offer and test an alternative underlying mechanism that links uncertainty and the relative performance of governance modes and thereby hopefully helps to resolve some of the ambiguity experienced in prior studies. Furthermore, our study is one of only few studies that observes relative performance of governance modes instead of integration decisions (David and Han 2004), and therefore allows for a more direct observation of the impact of uncertainty. Finally, we do not have to depend on survey measures for uncertainty but are able to construct the uncertainty measures directly from industry data.

The remainder of this paper is structured as follows. In section 2 we discuss in how far differences in the scope of uncertainty influence the relative performance of vertical integration, before we map our general propositions to specific hypotheses regarding the PC gaming industry in section 3. We then bring our hypotheses to data in section 4 and conclude in section 5.

2. Scope of uncertainty and the relative performance of vertical integration

2.1. Adaptation to uncertainty

As we have already noted, adaptation to environmental change is one of the main economic challenges. This argument goes back to Hayek (1945) and Barnard (1938). While agreeing that the ability of reacting to changing environments is of utmost importance, Hayek and Barnard have contrasting opinions on which governance form features the best adaptive capacity. Hayek argues that markets have the best adaptive capacity because of the high-powered incentives of a market's price system. Contrary, Barnard praises the adaptive capabilities of internal organizations because of a hierarchy's ability to tightly coordinate actions across departments.

These at a first glance exclusionary positions are at the heart of transaction cost economics (Williamson 1985), respectively the competence perspective of the firm (Foss 1993)[3]. We follow current literature, in that we combine the governance and the competence perspective to derive our

[3] In line with Wolter and Veloso (2008), we use competence to refer to the resource-based view (Barney 1991, Wernerfelt 1984), to the knowledge-based view (Kogut and Zander 1992), as well as to evolutionary theory (Nelson and Winter 1982).

theoretical arguments (Williamson 1999, Silverman 1999, Jacobides and Winter 2005, Gulati et al. 2005, Wolter and Veloso 2008).

This also points to the basic trade-off between firms and markets. On the one hand, integration increases commitment as coordination problems (Grant 1996, Gulati et al. 2005) and cooperation problems (Kreps 1996, Nickerson and Zenger 2004, Williamson 1991) become less severe. On the other hand, disintegration increases flexibility because search processes between partners are less tightly coupled (Williamson 1996, Rivkin and Siggelkow 2003) and because new partners can be selected (Balakrishnan and Wernerfelt 1986, Harrigan 1984, Williamson 1991). We use the distinction between benefits of commitment and benefits of flexibility as an analytical framework to derive our propositions.[4]

2.2. Scope of uncertainty

In addition to the vertical integration decision, our second dimension of interest is the uncertainty a firm faces. As we have discussed above, the classification of uncertainty into distinct dimensions has produced mixed empirical results (David and Han 2004) and seems therefore to be no feasible way to explain the influence of uncertainty on the relative performance of different organizational forms. Instead, we establish the distinction between uncertainty which affects mainly one vertical stage and uncertainty that affects multiple vertical stages. That is, we do not make general predictions whether some kind of uncertainty makes contractual or hierarchical solutions relatively more attractive but have to consider first if one or multiple parts of the value chain are affected by uncertainty. Uncertainty is only restricted to one vertical stage if the links between vertical stages are well-specified and standardized (Ethiraj and Levinthal 2004) so that changes in the product design of one component do not necessarily require adaptations in other components. On the other hand, uncertainty affects multiple vertical stages if product components have complex reciprocal interdependencies (Thompson 1967).

The assessment of the scope of uncertainty requires a good understanding of firm or industry characteristics. For most types of uncertainty (such as demand or technological uncertainty), it is not possible to assume the same scope of uncertainty across different industries. Different industries have usually different ways of how their product design processes are set up. For example, CPUs for personal computers usually come in a standardized form and technological turbulence affecting the CPU suppliers would have little immediate influence on computer manufacturers. In contrast, CPUs

[4] Similar to the distinction between benefits of commitment and benefits of flexibility, other studies distinguish between cooperative and autonomous adaptation (Williamson 1991), integration and differentiation (Lawrence and Lorsch 1967, Gulati et al. 2005, Kretschmer and Puranam 2008), or divergence and discovery (Almirall and Casadesus-Masanell 2010).

for mobile phones are usually specifically adapted to the needs of the handset manufacturer so that technological changes in the CPU of the phone would have a much more direct impact on the product design process of the handset manufacturer. There can also be differences within industries, which could make firm- or product-specific assessments of the scope of uncertainty necessary. Going back to the example of mobile phones, some firms might opt to have a self-designed CPU (that would have high levels of bilateral interdependence with the rest of the hardware), while other use a third-party CPU with fairly standardized interfaces. It is important to note that the scope of uncertainty does not have to be the same for different types of uncertainty affecting the same vertical relationship. For example, the aforementioned technological uncertainty could have another scope than market turbulence, even when considering the same product.

2.3. Performance implications

We now combine vertical integration and uncertainty and discuss in how far differences in the scope of uncertainty affect the relative performance advantage of vertical integration. We first consider the case where uncertainty affects multiple vertical stages before turning to uncertainty that mainly affects one vertical stage. For the different scopes of uncertainty, we first discuss how benefits of commitment are altered by uncertainty before turning to the influences on the benefits of flexibility.

2.3.1 Uncertainty affecting multiple vertical stages

Uncertainty alters the performance of product designs, which results in the need for adaptation. For example, if consumer tastes change, it could be necessary to alter a product so that it meets the new taste. If uncertainty affects multiple vertical stages and the interdependencies between the vertical stages are reciprocal (Thompson 1967), the performance contributions in each of these stages will also be altered and joint adaptation processes will be necessary.

To achieve optimal performance in these joint adaptation processes, it is important to set common goals by aligning incentives and to coordinate actions by fostering continuous communication and tacit interaction between the vertical stages. As these cooperation and coordination mechanisms can best be implemented within the boundaries of a firm (Srikanth and Puranam 2010), we expect benefits of commitment to increase with increasing multi-stage uncertainty. That is, from a commitment perspective we expect increases in the relative performance of hierarchies as multi-stage uncertainty increases.

As the interdependent problems created by multi-stage uncertainty require joint adaption, we can expect little benefits from independent exploration of new solutions. This holds true both for existing partners as well as for potential new partners. If search processes within an existing partnership diverge, interdependencies between problem domains are no longer considered and the impact of changes in one vertical stage could have detrimental implications on other stages without any feedback loop to the responsible unit. Interdependencies created by multi-stage uncertainty also imply that it is not possible to just plug in a new partner without any further adaptation processes. The option value created by having new potential partners is thus also limited. Taken together, we do not expect increasing benefits of flexibility for higher levels of multi-stage uncertainty. Therefore, we should also see no changes in the relative performance of markets over contractual relationships. However, this only holds true as long as uncertainty does not become so large that existing knowledge is rendered obsolete and new solutions cannot be derived anymore from existing ones. Then, we would expect increasing benefits of flexibility created from non-hierarchical governance forms.

Under the assumption of uncertainty not being so strong as to destroy existing competencies, we expect the benefits of commitment to outweigh the benefits of flexibility and derive our first proposition.

Proposition 1: Uncertainty affecting multiple vertical stages increases the relative performance of hierarchies over contractual relationships.

2.3.2 Uncertainty affecting one vertical stage

We now turn to uncertainty that only affects one vertical stage. If uncertainty affects only one stage, the search processes needed to adapt to the induced changes can be confined to the affected stage. Furthermore, search processes in the affected processes should also not create changes in the performance contributions of the other vertical stages. We therefore have to analyze how different organizational forms support local adaptation processes.

As before, we start with the benefits of commitment. As there are no interdependencies between the vertical stages, it is not necessary to improve coordination and cooperation processes by integrating vertical stages. Furthermore, integration could even have detrimental performance implications over non-integrated solutions for two reasons. First, from a cooperative point of view, due to the impossibility of selective intervention (Williamson 1991, 1996) firms are not able to emulate the high-powered incentives of markets if their firm-specific cooperation mechanisms are not needed. This argument is also in line with Puranam and Kretschmer (2008), who show that collaborative incentives can reduce organizational performance below levels achieved when interdependence is ignored. Second, from a coordinative point of view, firms will invest more time in coordinative activities between vertical stages than non-integrated firms. Given scarce resources, these coordinative activities are then no longer available within a vertical stage. From a commitment perspective, we would therefore expect decreases in the relative performance of hierarchies as single-stage uncertainty increases.

As uncertainty in one vertical stage increases, new solutions have to be discovered for this stage. To find the best performing solutions, agents should therefore be able to independently search for better solutions. For existing partners, it is therefore beneficial if they are not obliged to follow the same search trajectory as agents on other vertical stages. Furthermore, the parallel search efforts by potential new partners become the more attractive, the more single-stage uncertainty alters the performance of the current solution. Benefits of flexibility from existing or new partners are thus higher for higher levels of single-level of uncertainty. Non-hierarchical governance forms should therefore become more attractive.

Both from a commitment perspective as well as from a flexibility perspective, we can therefore expect markets to become more attractive as single-stage uncertainty increases and derive our second proposition.

Proposition 2: Uncertainty affecting one vertical stage decreases the relative performance of hierarchies over contractual relationships.

Our main theoretical arguments and the resulting propositions are summarized in Figure 1.

INSERT FIGURE 1 HERE

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3. Uncertainty and vertical integration in the PC gaming industry

We use the PC gaming industry as the empirical context of our study. The PC gaming industry is one part of the video gaming industry, with other parts being games for consoles and handhelds (Williams 2002). We first introduce possible governance forms between publishers and developers before discussing how these governance forms are able to adapt to market and technological uncertainty in the PC gaming industry.

3.1. Vertical integration of developers and publishers

Our study focuses on the vertical relationship between developers and publishers. Even though manufacturing, distribution, and retail are other elements in the value chain (Williams 2002), most of a game's success will depend on the capabilities of developer and publisher.

Developers are responsible for the actual development of a game. Game development is a complex process, which requires close collaboration between different functional areas. In addition to supporting tasks like audio design, game testing, and quality assurance, four main occupational tasks can be distinguished: producer, game designer, artist, and programmer (Novak 2008, Chandler 2009, Dezso et al. 2010). Producers are project managers that have to ensure that the game development process is completed on time and on budget. Game designers develop the story and set the rules of the game while artists create the graphical assets of a game. Finally, programmers interact closely with designers and artists to create the game code. The game development process can take anything between around a year to more than three years. In contrast to console games, there is still some possibility to update PC games once they are released with the help of software patches (Williams 2002).

Publishers usually hold the rights for the game and have to make sure that it becomes a commercial success. They are already involved in the game development process from a very early stage, as they have to secure funding. Once the game development process is finished, they decide when to release a PC game, how to manufacture the game, and where to distribute it. Finally, the probably most important task of a publisher is marketing the game. As PC games are usually short-lived products, most of the marketing activities take place around the launch date of a game.

Publishers and developers are either independent legal entities or are integrated vertically. The integration decision is made on a game-by-game basis at the very beginning of the game development process. Once a partnership is decided upon, it is maintained throughout the whole development and sales phase. Therefore, the non-integrated governance form can be considered to be more similar to a vertical alliance than to a spot-market purchase, where partnerships can be broken up anytime. Many large publishers operate their own development studios, but are also sourcing games from independent developers at the same time.

As it can be seen in Figure 2[5], there exists consistent heterogeneity of governance choice within our study period from 2001 to 2009. Around one third of all games are developed internally and over time there is a slight trend towards more integrated games. This trend can probably be explained by the fact that progress in technological capabilities makes game development projects larger and more complex (Corts and Lederman 2009) and that this can better be managed within the boundaries of a firm. In this study we do not focus on the vertical integration decision but on the performance implications of different governance modes. We are therefore only interested in the

[5] The data discussed in this section is introduced later in section 4.1.

governance decision as to make sure that there exists enough heterogeneity of governance choice to allow for identification.

INSERT FIGURE 2 HERE

3.2. Performance implications of market and technological uncertainty

3.2.1 Market uncertainty

To derive our first hypothesis, we discuss two main demand-side challenges in the PC gaming industry: overall market decline und unpredictability of game success.

As we can see in Figure 3, the overall gaming market grew enormously: revenues more than doubled from less than $2.5bn in 1995 to over $5bn in 2001 and then grew to more than $10bn in 2008, followed by a decrease to around $9bn during the economic crisis in 2009. From 1995 to 2001, the PC gaming industry experienced similar growth rates as the overall market went from less than $500mn to nearly $1.5bn. However, the development of the PC market decoupled from overall market development beginning in 2001, with revenues going back to little more than $500mn in 2009.

INSERT FIGURE 3 HERE

So why did the PC industry experience such a strong decline in an otherwise booming industry? Industry observers identify several reasons that jointly lead to the decline (Radd 2009). First, desktop computers were increasingly replaced by less powerful notebooks that are less suitable to play hardware-demanding games. Second, the PC market had more problems with pirated software than the other segments of the gaming market. Game developers reacted with restrictive digital rights management measures, which only partly helped to reduce piracy, but made the PC gaming market even less attractive. Third, Microsoft entered the console market with their Xbox in 2001. With the large majority of PC games being designed for Microsoft operating systems, Microsoft now basically maintains two competing platforms. As Microsoft is able to collect much higher royalties for their proprietary Xbox platform, they also have incentives to drive game developers to their console platform. For all these reasons, the PC gaming industry experienced an extremely challenging phase in our study period, which goes from 2001 to 2009.

Similar to other creative industries like movies or books, it is very hard to predict the success of a game (Binken and Stremersch 2009). Figure 4 plots cumulated industry revenues against the sales rank of each game and shows that commercial success is fairly skewed. The top 1% of games account for 20% of the revenues achieved in the whole industry, while the top 10% account for 63% of all industry revenues. The 100 most successful titles all generated more than $10mn in revenues. However, the mean revenue is at a much lower $2.6mn.

INSERT FIGURE 4 HERE

Several risk-reducing strategies are used in the industry: the success of one game is exploited by releasing sequels, many games are based on licenses from popular movies or professional sports, and firms use standardized graphics engines. However, it is still very hard to predict the frequently changing consumer tastes.

Handling market uncertainty requires joint adaptive action of developers and publishers. Publishers usually closely monitor the market and should thus be able to identify upcoming trends early on. Meeting the requirements of changed customer preferences cannot be achieved by means of adjusting the marketing campaign of the game alone, but the game itself has to be also adapted. As this can only be implemented by the developer, we expect complex and interdependent coordination processes between developer and publisher to become necessary.

Comparing integrated and non-integrated developers and publishers, integrated firms have more access to non-formal and tacit interaction channels between developer and publisher side. For example, a marketing specialist on the publisher side is more likely to directly interact with a game designer on the developer side if they have access to the same company-internal communication system or if they had prior contact from working on other projects. Also, there is no need for costly renegotiations of the publishing contract if requirements change within the development period. As the reactions to market uncertainty need to be closely coordinated, we also do not expect any gains from the more independent search processes that disintegrated firms could use.

In line with Proposition 1 we can therefore derive our first Hypothesis.

Hypothesis 1: Market uncertainty in the PC gaming industry increases the relative performance of hierarchies over contractual relationships.

3.2.2 *Technological uncertainty*

Our second hypothesis deals with the technological uncertainty that is created by improvements in PC hardware power.

Figure 5 plots the average benchmark scores submitted to the website of the benchmarking specialist Futuremark. Benchmark programs measure the performance of a user's PC and are therefore a good proxy for the increasing hardware power of home PCs.[6] We can see that the average performance of users submitting a benchmark score increased by a factor of 22.6 over our nine-year study period, which is in line with the biannual doubling of processing speed proposed by Moore's law. We can also see that performance growth is non-constant, i.e. there are some periods with moderate growth and other periods with faster increases in average hardware power.

INSERT FIGURE 5 HERE

As the average performance of user hardware increases both during the development phase and during the sales phase, developers have to aim at a moving target when setting the hardware requirements of their game (Williams 2002). Setting the right hardware requirements implies a critical trade-off. On the one hand, higher hardware requirements allow for the implementation of better graphics and more intelligent artificial intelligence. This makes a game more attractive for potential customers. On the other hand, setting higher hardware requirements limits market potential as fewer potential customers will have the hardware required to play the game.

Handling this trade-off is a critical task that has to be handled by the developer, but it requires little interaction with the publisher. The developer is the party having the technological competencies for developing a game and is therefore solely able and responsible to judge future developments in hardware availability.

As there is no need for joint adaptation when reacting to technological uncertainty, there are also no coordination or cooperation problems between developer and publisher that have to be overcome. However, coordination and cooperation mechanisms of an integrated firms cannot just be switched off, if they are not needed in a specific case (Williamson 1991, 1996), making vertical integration less attractive. For example, a manager from the publishing unit would possibly cut the budget needed to address technological uncertainty to suboptimal levels if their incentive system would mainly be directed to not exceeding budget limits. Furthermore, non-integrated firms can search more flexible

[6] Windows 7 now even features an integrated benchmarking tool called "Windows Experience Index".

than integrated firms. For example, a publisher could restrict their developer to using firm-specific graphic engines to develop the game if the developer is integrated. In contrast, non-integrated developers could more flexibly react to technological opportunities without regarding interdependencies introduced by the corporate framework.

In line with Proposition 2 we can therefore derive our second hypothesis.

Hypothesis 2: Technological uncertainty in the PC gaming industry increases the relative performance of hierarchies over contractual relationships.

4. Empirics

4.1. Data

The main data set for our analysis comes from the NPD Group, a market research firm that covers the gaming industry since 1995.[7] NPD collects retail sales data on nearly every game which has been published in the US and captures all distribution channels, including online sales (Dezso et al. 2010). We use NPD data from 3/2001 to 2/2010 for our analysis. The data set contains revenue data on a game-month level, as well as information about the genre, the developer, and the publisher. We also collected additional data on the vertical integration decision between developer and publisher from the game documentation project MobyGames[8].

Our second data set is constructed from the publicly available benchmark scores published on the website of Futuremark[9]. Futuremark benchmark programs are among the most frequently used programs to measure the computing power of a PC[10]. After users of the benchmark programs have completed their measurement, they can opt to put their anonymous test results on the Futuremark website, so that other users can compare their results. We gathered 1.5mn observations that were put on the Futuremark website between 3/2001 and 2/2001, which allows us to get detailed information about consumers' computing power at each point within this timeframe.[11]

[7] NPD data on the video gaming industry has been used for several other studies (Shankar and Bayus 2003, Clements and Ohashi 2005, Corts and Lederman 2009, Binken and Stremersch 2009)

[8] The data was collected from their website http://www.mobygames.com.

[9] Benchmarking results from Futuremark can be found at http://3dmark.com/search.

[10] Even though the Futuremark benchmark programs can easily be installed and operated, we expect our data to have an upward bias towards higher performing systems. However, this should pose no problem as long as distortions vary systematically over time (for which we don't have any evidence).

[11] As Benchmark results come from different versions of the Futuremark software, we convert all results to Futuremark 2001 values.

4.2. Variables

4.2.1 Dependent variable

Our dependent variable is the revenue of game i in month t. To account for inflation, we deflate revenues to 1995 dollar. As discussed in section 3.2.1, revenues in the PC gaming industry are highly skewed. We therefore use the natural logarithm of deflated monthly revenues as our dependent variable. As many games stay in the NPD database for very long amounts of time, while selling only negligible amounts, we define cutoff values for monthly revenues smaller than $1,000 or the game being longer than 36 months on the market[12].

4.2.2 Independent variables

While the definition of the vertical integration variable VI_i as developer and publisher belonging to the same firm is straightforward, the operationalization of the uncertainty measures is less straightforward.

As discussed above, market uncertainty in the PC gaming industry stems both from changes in consumer preferences and from changes in market size. Changed consumer preferences imply that consumers find other types of games interesting than before. Therefore, a good proxy for changes in consumer preferences would be a measure that is higher the more rapid consumers switch their interest between different game types. Video games are categorized into genres, so it is easy to track which types of game are popular at each point in time.

For our preferred measure of market uncertainty, we sum up the absolute differences of current genre market share s_{gt} and the genre market share in the previous period s_{gt-1}. In total, the NPD data set distinguishes between 54 genres, so we sum up differences in genre market shares for each of these 54 genres.

$$MarketUncertainty_t = \sum_{g=1}^{54} \left| s_{gt} - s_{gt-1} \right|$$

In addition to the detailed genres, NPD also distinguishes between 14 so called super-genres. Therefore, we use the sum of absolute differences of super-genre market shares as an alternative measure $MarketUncertainty_t\ (alt. A)$.

The second trigger of market uncertainty is changed market size. We therefore construct a second, alternative measure $MarketUncertainty_t\ (alt. B)$:

[12] We conduct robustness checks for theses cutoff values in section **Error! Reference source not found.**.

$$MarketUncertainty_t(alt.B) = \left|\frac{MarketSize_t - MarketSize_{t-1}}{MarketSize_{t-1}}\right|$$

Technological uncertainty is induced from rapid changes in the hardware installed base of game players. We therefore define $TechUncertainty_t$ to be the relative change in the average benchmark compared to the previous period.

$$TechUncertainty_t = \left|\frac{AvgBenchmarkValue_t - AvgBenchmarkValue_{t-1}}{AvgBenchmarkValue_{t-1}}\right|$$

As it can be seen in Figure 6, we analyze the impact of uncertainty during the sales period of a game. However, we have already discussed that once a game is released on the market, there are relatively few possibilities to adapt the game to changes in the environment.[13] Therefore, the main challenge for developers and publishers is to bring a product to the market that is inherently adaptive to changing market conditions. For example, a game could auto-detect the available hardware to always exploit the currently available hardware or it could try to be attractive for different genres. We therefore do not mainly address short-term adaptation to changes, but compare how well different governance forms are able to build "uncertainty-resistant" products.

INSERT FIGURE 6 HERE

Summary statistics and pairwise correlations for the dependent variable and the independent variables can be found in Table 1 and Table 2.

INSERT TABLE 1 HERE

INSERT TABLE 2 HERE

4.3. Estimation strategy

We estimate the logarithmic revenue of game i at time t with the following baseline specification.

[13] Examples for possible after-release reactions are software patches or changes in the marketing campaign.

$$\ln(Revenue)_{it} = a_i + a_{age} + a_{month} + a_{year} + MarketUncertainty_t + TechUncertainty_t + VI_i * MarketUncertainty_t + VI_i * \mathrm{TechUncertainty_t} + \varepsilon_{it}$$

Our regression contains fixed effects on the level of the age of the game in months (a_{age}), the calendar month (a_{month}), the year (a_{year}), and the game (a_i). The fixed effects for the age of the game in months capture the short lifecycles of the video game industry, where around 80% of a game's revenues are generated within the first 12 months after launch (Dezso et al. 2010). In addition, the age fixed effects also captures that most of the marketing expenditures are spent around the launch time of the game. The calendar month fixed effects capture the strong seasonality of the industry and the year fixed effects capture macro-economic and industry-wide factors that change over time.

The game fixed effects capture all factors that do not change over the sales period of the game. These constant factors include the project budget, the identity and size of developer and publisher team, the genre, professional sports or movie licenses, graphics engines, and most importantly for our study, the vertical integration decisions.

Being able to use game fixed effects, we do not have selection problems regarding the vertical integration decision as encountered in Masten et al. (1991), Poppo and Zenger (1998), or Gulati et al. (2005). If one wanted to correct the selection bias (Heckman 1979), one would have to estimate the inverse-mills ration in a separate selection stage regression and then use it as an additional explanatory variable in the second stage estimation. However, the inverse mill-ratio per game would be time-invariant and is thus also captured by the game fixed effect.

Due to our large set of fixed effects, identification of our focal effects is accomplished by the variance within each game that is not driven by the age of the game in month, the calendar month, or the year. We test our hypotheses by interacting the vertical integration dummy with our measures of turbulence. Thus, if we get a positive sign for any of the interactions terms, we would have evidence for vertically integrated firms being able to better cope with uncertainty (and the other way round). Of course, we also have to include the base effect of our uncertainty measures, but we do not include the base effect for the vertical integration dummy as this is captured by the game fixed effect.

4.4. Results

4.4.1 Preferred regression

The OLS regression results for our preferred model are presented in Table 3. We have a total of 44,243 observations distributed over 2,213 games, i.e. we have on average 22.8 observations for each game. We always include the full set of fixed effects on the level of the game, the age of the game, the calendar month, and the year.

INSERT TABLE 3 HERE

We add our two uncertainty measures in column (2). Taken alone, both uncertainty measures have significantly positive coefficients. Given the often implicit negative connotation of uncertainty, this seems to be surprising at a first glance. However, it seems as if the changes that are induced by market and technological uncertainty seem to have a positive net effect in the PC gaming industry.

We add the interaction terms of uncertainty measures and vertical integration dummy in column (3). The interaction term between vertical integration and market turbulence is significantly positive, i.e. the higher market turbulence, the higher the relative performance advantage of hierarchies. In contrast, the interaction term between vertical integration and technological turbulence is significantly negative, i.e. the higher technological uncertainty, the higher the relative performance advantage of disintegration. Both results are fully in line with our hypotheses.

It is furthermore interesting to analyze the main effect and the interaction effect in column (3) together. The main effect for market turbulence (that can be interpreted as the effect of the disintegrated firms) is insignificant. This suggests that only integrated firms are able to profit from market uncertainty. In contrast, the main effect of technological uncertainty is positively significant and only becomes significant as the interaction term with vertical integration is added. This suggests that only disintegrated firms can benefit from technological uncertainty.

4.4.2 Non-linear influence of market uncertainty

When deriving Proposition 1, we argued that multi-stage uncertainty makes hierarchies only more attractive, if uncertainty is not so strong as to destroy existing competencies. To test, whether hierarchies become less attractive for large levels of market uncertainty, we allow for non-linear relationships by adding a quadratic term of market uncertainty and interact this quadratic term with the vertical integration dummy. Results are presented in Table A. 1 and show that the non-quadratic coefficients stay fairly stable. However, the coefficient of quadratic market uncertainty is significantly positive, suggesting that the performance advantage of integration declines over time.

We illustrate our results in Figure 7, which shows that vertical integration becomes more attractive as long as our uncertainty measure is smaller than around 0.55. However, if uncertainty becomes larger, integration becomes less attractive again.

INSERT FIGURE 7 HERE

We relate these results to the range of values market uncertainty takes (Table 1). As the mean value of market uncertainty is at 0.256 and the standard deviation is 0.193, market uncertainty should in most cases increase the relative attractiveness. Out of our sample, only 9.46% of the observations experience a measure of market uncertainty which is larger than 0.55. Therefore, we find some evidence for uncertainty also making hierarchies less attractive. However, uncertainty is most of the time low enough so that benefits of commitment outweigh benefits of flexibility.

4.4.3 Robustness checks

We perform three further sets of tests to verify the robustness our results. First, we replace our preferred measure of market turbulence with the other two measures that we have defined. Second, we vary the values for the cutoff values to see in how far they drive the results. Third, we vary the time lags used for calculating the uncertainty measures.

Table A. 2 depicts the results for the different measures of market uncertainty. Comparing our preferred regression in column (1) with the results in column (2), we can see that our results do not hinge on whether we distinguish between 54 genres or between 14 super-genres. This result is not very surprising as the two measures of market uncertainty have a pairwise correlation coefficient of 0.949 (Table 2). The results for market uncertainty as measured by changes in market size can be found in column (3) and provide further support for our hypothesis 1, as more rapid changes in market size result in higher relative benefits of firms compared to markets.

In Table A. 3, we systematically vary our cutoff values. We change the minimum monthly revenue from $1,000 to $2,000 in column (2) and $500 in column (3). Furthermore, we increase the maximum time on market from 36 months to 48 months in column (4) and reduce it to 24 months in column (5). Our results stay stable.

Finally, in Table A. 4 we vary the time lags used for calculating the uncertainty measures. In our base line regressions, we calculate the uncertainty measures by comparing with the state of the environment at t – 1 month. We use t – 2 months in column (2) and t – 3 months in column (3) to see if results depend on the exact time structure of our specification. Again, our results stay stable.

5. Conclusion

The goal of our study is to establish and test an alternative way of reconciling ambiguous empirical evidence on the interdependencies between vertical integration and uncertainty. We argue that the puzzle can only be solved if one first considers whether vertical integration affects multiple vertical stages or only one vertical stage. We use the empirical context of the PC gaming industry to test our theoretical predictions that multi-stage uncertainty should make markets more attractive, whereas single-stage uncertainty should make hierarchies more attractive. Using US market data from 2001 to 2010 we find strong support for our theoretical predictions as market uncertainty (which affects both developers and publishers) makes hierarchies more attractive, whereas technological uncertainty (which mainly affects developers) makes contractual relationships more attractive.

Our results are not only statistically significant, but are also economically significant: a one standard deviation increase in technological turbulence leads to 2.5% higher revenues of non-integrated firms over integrated firms. And a one standard deviation increase in market turbulence results leads to 2.2% higher revenues of integrated firms over non-integrated firms.

We can also interpret our results from a more general point of view: we basically argue for and find a complementarity between interdependencies of the problem domain and of the organizational structure (Sanchez and Mahoney 1996, Hoetker 2006). That is, if problems can be solved without interdependencies, it is better to not have unnecessary organizational interdependencies. However, if problems require coordinated action, it is better to also have these interdependencies on an organizational level.

Even though we are confident in our results, this study is only a first step in generating a better understanding of how the scope of uncertainty influences relative performance differences between hierarchies and markets. One obvious next step would be a thorough literature review similar to David and Han (2004), that explicitly considers the scope of uncertainty. Furthermore, more empirical evidence from other industries is needed to increase the external validity of our results.

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Figures and tables

Figure 1: Summary of theoretical arguments and propositions

	Scope of Uncertainty	
	Multiple vertical stages	One vertical stage
Commitment (coordination and cooperation)	Positive impact ➔ Advantage of hierarchies	Negative impact ➔ Disadvantage of hierarchies
Flexibility (existing and new partners)	No impact ➔ No advantage of markets	Positive impact ➔ Advantage of markets
Performance Implications	Increased relative performance of **hierarchies**	Increased relative performance of **markets**

Figure 2: Share of games with integrated developer and publisher

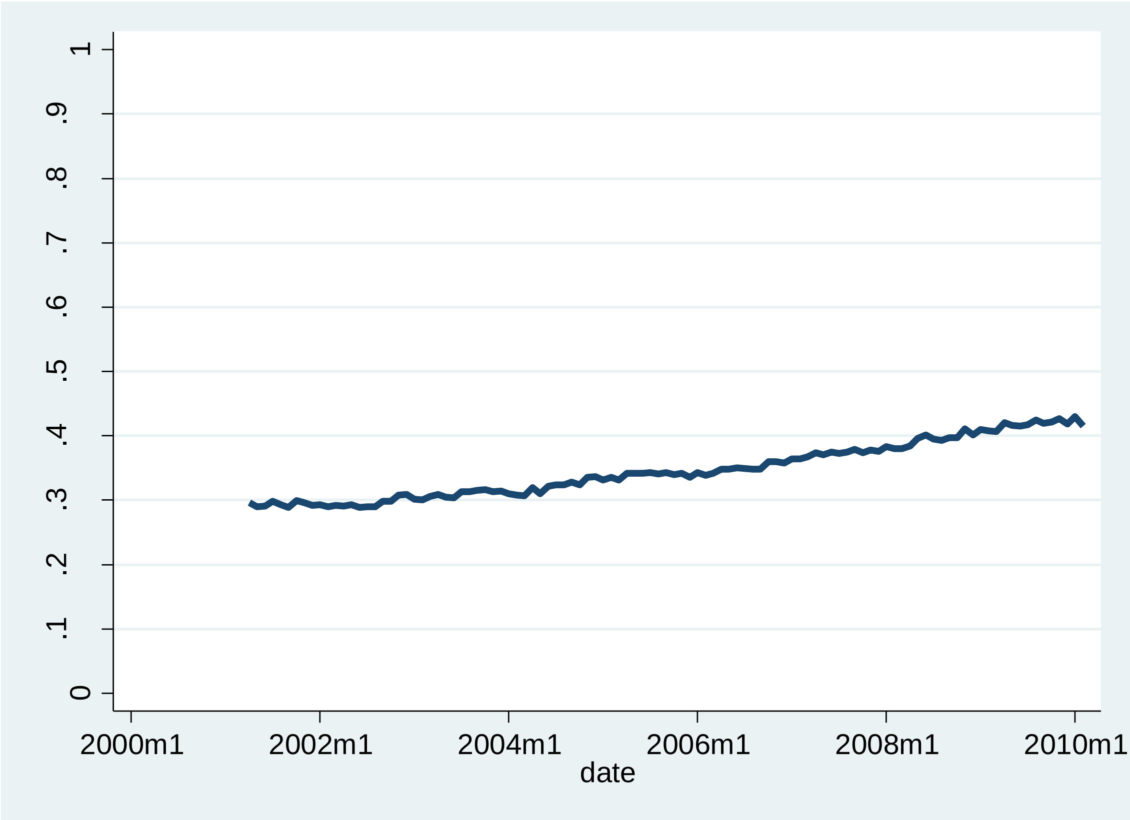


Figure 3: Revenue development of software sales in the PC gaming market in the total gaming market

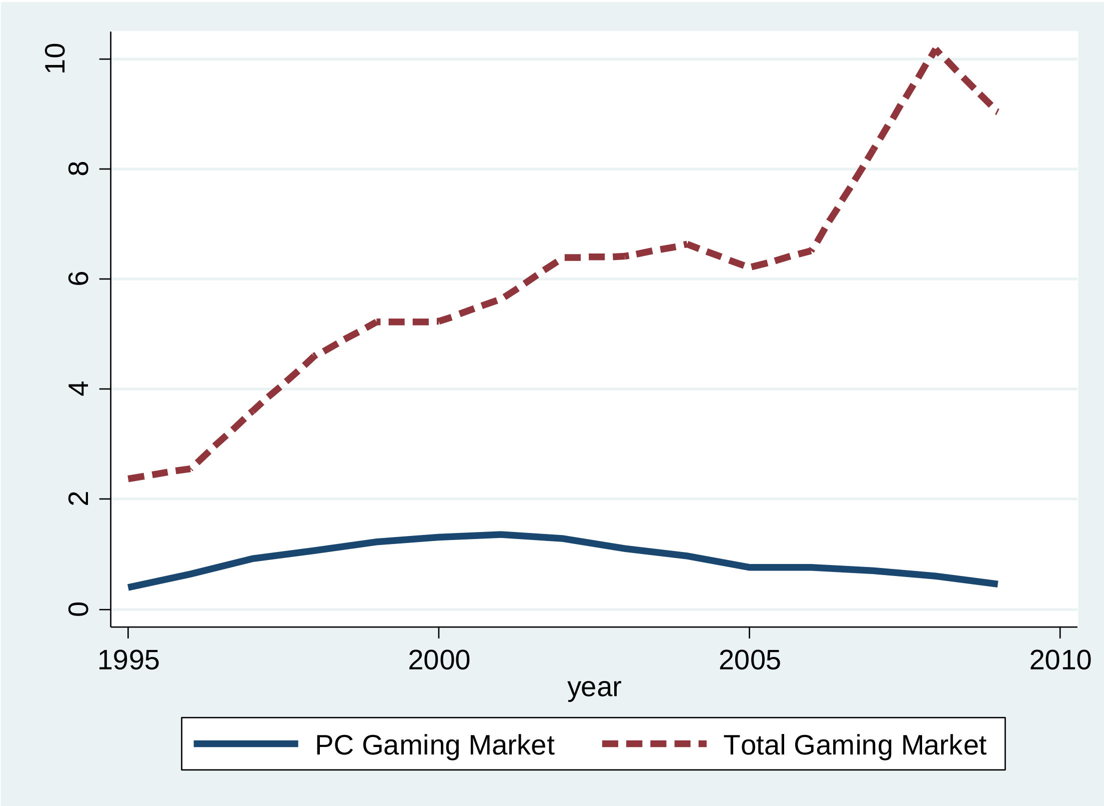


Figure 4: Distribution of revenues

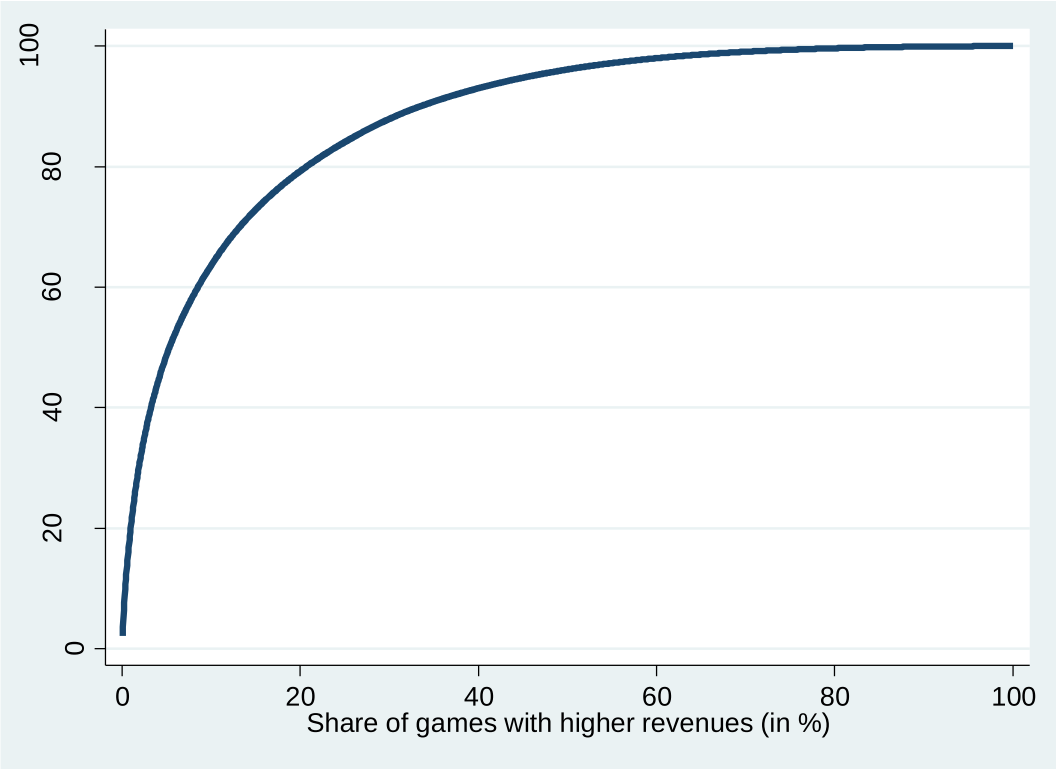


Figure 5: Technological development in the PC gaming market

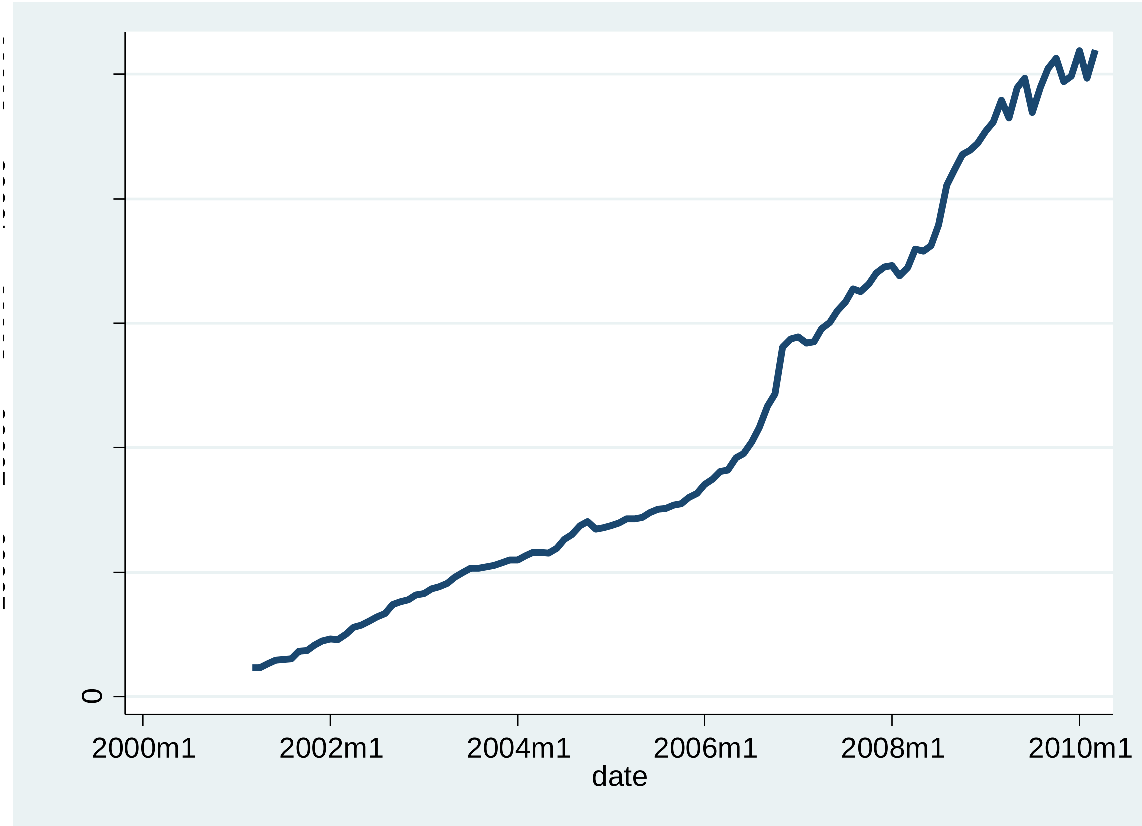


Figure 6: Life-cycle of a PC game

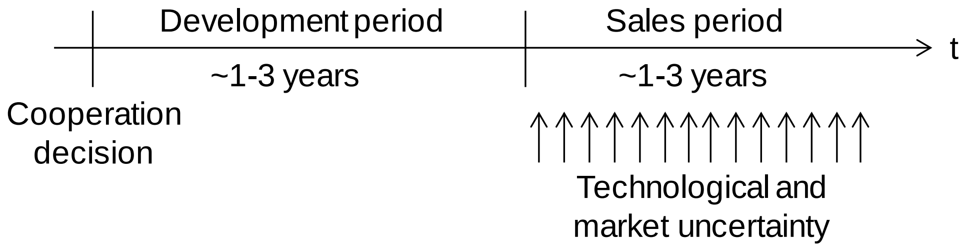


Table 1: Summary statistics

VARIABLE	N	Mean	SD	Min	Max
$ln(Revenue)$	48243	9.781	1.805	6.908	17.524
$VerticalIntegration$	48243	0.390	0.488	0	1
$TechUncertainty$	48243	0.031	0.027	0.000	0.197
$MarketUncertainty$ (change in genre shares)	48243	0.256	0.193	0.069	0.933
$MarketUncertainty$ (alt. A) (change in super-genre shares)	48243	0.194	0.165	0.039	0.839
$MarketUncertainty$ (alt. B) (change in market size)	48243	0.363	0.329	0.002	1.779

Table 2: Pair-wise correlations

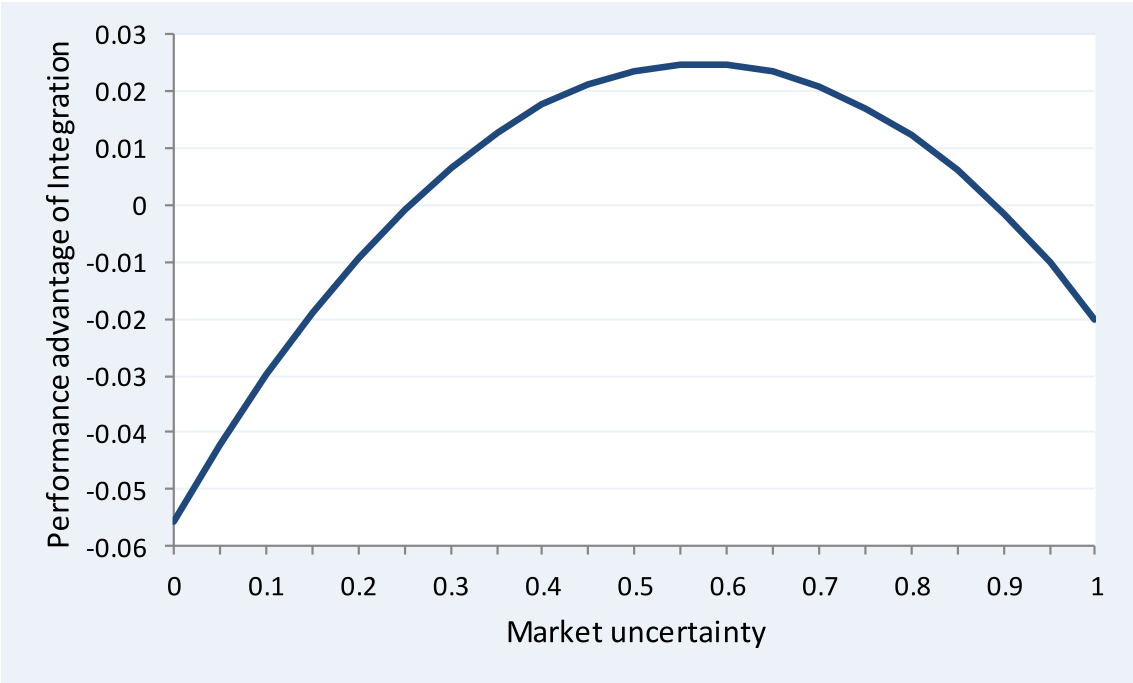
VARIABLE		(1)	(2)	(3)	(4)	(5)	(6)
$ln(Revenue)$	(1)	1.000					
$VerticalIntegration$	(2)	0.101	1.000				
$TechUncertainty$	(3)	0.059	-0.024	1.000			
$MarketUncertainty$ (change in genre shares)	(4)	-0.042	0.037	-0.142	1.000		
$MarketUncertainty$ (alt. A) (change in super-genre shares)	(5)	-0.036	0.034	-0.164	0.949	1.000	
$MarketUncertainty$ (alt. B) (change in market size)	(6)	0.029	0.016	-0.073	0.392	0.331	1.000

Table 3: Preferred regression

INDEPENDENT VARIABLES	(1)	(2)	(3)
	DEPENDENT VARIABLE: ln(Revenue)		
MarketUncertainty		0.0949***	0.0444
		(0.0239)	(0.0299)
MarketUncertainty * VI			0.116***
			(0.0422)
TechUncertainty		0.605***	0.942***
		(0.181)	(0.213)
TechUncertainty * VI			-0.910***
			(0.307)
Game Fixed Effects	Yes	Yes	Yes
Age Fixed Effects	Yes	Yes	Yes
Calendar Month Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	48,243	48,243	48,243
Number of Games	2,213	2,213	2,213
R-squared	0.631	0.632	0.632

Notes: Fixed-effect OLS point estimates. Asterisks denote significance levels (*** p<0.01, ** p<0.05, * p<0.1). All specifications control for fixed effects on the level of the game, the age of the game in month, the calendar month, and the year. The constant is not reported.

Figure 7: Influence of market uncertainty when allowing for non-linear effects



Appendix A

Table A. 1: Quadratic market uncertainty

INDEPENDENT VARIABLES	(1)	(2)
	DEPENDENT VARIABLE: ln(Revenue)	
MarketUncertainty	0.0444	-0.0344
	(0.0299)	(0.0509)
MarketUncertainty^2		0.216*
		(0.113)
MarketUncertainty * VI	0.116***	0.122*
	(0.0422)	(0.0728)
MarketUncertainty^2 * VI		-0.0296
		(0.164)
TechUncertainty	0.942***	0.909***
	(0.213)	(0.208)
TechUncertainty * VI	-0.910***	-0.845***
	(0.307)	(0.302)
Game Fixed Effects	Yes	Yes
Age Fixed Effects	Yes	Yes
Calendar Month Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	48,243	48,243
Number of Games	2,213	2,213
R-squared	0.632	0.632

Notes: Fixed-effect OLS point estimates. Asterisks denote significance levels (*** p<0.01, ** p<0.05, * p<0.1). All specifications control for fixed effects on the level of the game, the age of the game in month, the calendar month, and the year. The constant is not reported. Uncertainty measures have been centered around their mean.

Table A. 2: Robustness check for alternative measures of market turbulence

INDEPENDENT VARIABLES	(1)	(2)	(3)
	DEPENDENT VARIABLE: ln(Revenue)		
Measure for MarketUncertainty	Change in genre shares (preferred)	Change in super-genre share	Change in market size
MarketUncertainty	0.0444	0.0476	-0.00770
	(0.0299)	(0.0339)	(0.0191)
MarketUncertainty * VI	0.116***	0.157***	0.0541**
	(0.0422)	(0.0491)	(0.0237)
TechUncertainty	0.942***	0.906***	0.934***
	(0.213)	(0.212)	(0.213)
TechUncertainty * VI	-0.910***	-0.979***	-0.869***
	(0.307)	(0.306)	(0.308)
Game Fixed Effects	Yes	Yes	Yes
Age Fixed Effects	Yes	Yes	Yes
Calendar Month Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	48,243	48,243	48,243
Number of Games	2,213	2,213	2,213
R-squared	0.632	0.632	0.632

Notes: Fixed-effect OLS point estimates. Asterisks denote significance levels (*** p<0.01, ** p<0.05, * p<0.1). All specifications control for fixed effects on the level of the game, the age of the game in month, the calendar month, and the year. The constant is not reported.

Table A. 3: Robustness check for alternative cutoff values

INDEPENDENT VARIABLES	(1)	(2)	(3)	(4)	(5)
	DEPENDENT VARIABLE: ln(Revenue)				
Minimum Monthly Revenue	\$1000	\$2000	\$500	\$1000	\$1000
Maximum Time on Market	36m (preferred)	36m	36m	48m	24m
MarketUncertainty	0.0444	0.0302	0.0409	0.0501*	0.0180
	(0.0299)	(0.0305)	(0.0295)	(0.0295)	(0.0314)
MarketUncertainty * VI	0.116***	0.125***	0.138***	0.101**	0.154***
	(0.0422)	(0.0424)	(0.0421)	(0.0417)	(0.0444)
TechUncertainty	0.942***	0.750***	0.934***	0.962***	0.699***
	(0.213)	(0.210)	(0.215)	(0.214)	(0.213)
TechUncertainty * VI	-0.910***	-0.733**	-0.847***	-0.996***	-0.694**
	(0.307)	(0.303)	(0.311)	(0.306)	(0.315)
Game Fixed Effects	Yes	Yes	Yes	Yes	Yes
Age Fixed Effects	Yes	Yes	Yes	Yes	Yes
Calendar Month Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	48,243	42,079	53,924	51,922	39,843
Number of Games	2,213	2,175	2,233	2,213	2,212
R-squared	0.632	0.613	0.649	0.632	0.595

Notes: Fixed-effect OLS point estimates. Asterisks denote significance levels (*** p<0.01, ** p<0.05, * p<0.1). All specifications control for fixed effects on the level of the game, the age of the game in month, the calendar month, and the year. The constant is not reported.

Table A. 4: Robustness check for different time lags of the uncertainty measures

INDEPENDENT VARIABLES	(1)	(2)	(3)
	DEPENDENT VARIABLE: ln(Revenue)		
Lag of uncertainty measures	1 month (preferred)	2 months	3 months
MarketUncertainty	0.0444	0.0357	0.00241
	(0.0299)	(0.0341)	(0.0343)
MarketUncertainty * VI	0.116***	0.0928*	0.120**
	(0.0422)	(0.0487)	(0.0487)
TechUncertainty	0.942***	0.802***	1.019***
	(0.213)	(0.138)	(0.104)
TechUncertainty * VI	-0.910***	-0.698***	-0.721***
	(0.307)	(0.187)	(0.134)
Game Fixed Effects	Yes	Yes	Yes
Age Fixed Effects	Yes	Yes	Yes
Calendar Month Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	48,243	48,231	48,199
Number of Games	2,213	2,213	2,213
R-squared	0.632	0.632	0.632

Notes: Fixed-effect OLS point estimates. Asterisks denote significance levels (*** p<0.01, ** p<0.05, * p<0.1). All specifications control for fixed effects on the level of the game, the age of the game in month, the calendar month, and the year. The constant is not reported.