Paper to be presented at the DRUID 2012

on

June 19 to June 21

at

CBS, Copenhagen, Denmark,

Why is outsourcing difficult

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Abstract

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Why is outsourcing difficult? The effect of knowledge codification on the probability of outsourcing

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The firm boundaries literature explains that firms outsource when their productive capabilities are deficient and when asset specificity is low. This paper analyzes why firms face difficulties in outsourcing simple activities when these fundamental conditions are fulfilled. I conduct a survival analysis of a seven years long outsourcing process in a large manufacturing firm. I find that a high level of available codified knowledge increases the probability of outsourcing and high variability of components, which drives the knowledge codification effort, reduces the probability of outsourcing. The main finding of this paper is that (insufficient) knowledge codification is a key factor that can inhibit or enable outsourcing.

INTRODUCTION

Decisions regarding the level of vertical integration are relevant for every firm. Over last two decades a wide range of industries have experienced a rapid increase of outsourcing. Since the seminal work of Ronald Coase (1937) who introduced the notion of transaction cost, strategy scholars have expressed much interested in explaining the factors affecting firm decisions between alternative forms for organizing economic activities. Existing theories focus primarily on explaining the rationale behind a firm's decision whether to perform an activity in-house or to contract it out to external suppliers. Transaction cost theory, the most dominant stream in the firm boundaries literature, postulates that vertical firm boundaries are set to minimize the transaction cost determined by asset specificity, uncertainty and a potential for opportunistic behavior (Williamson 1985, 1999). The capabilities approach proposes that firms internally perform activities in which they have a comparative advantage (Jacobides and Hitt 2005, Jacobides and Winter 2005, N. Argyres 1996, Leiblein and Miller 2003), or vertically integrate to achieve an advantage in coordination of tacit knowledge (Kogut and Zander 1992, 1996, Grant 1996). Firms adapt their vertical scope when the transactional environment changes and transaction drifts out of alignment with the regime used for a specific transaction (Williamson 1999) or the balance of relative capabilities among industry players shifts (Langlois 1992).

The processes of adapting vertical scope have been studied mostly in the context of vertical integration cycles at the industry level. Firms vertically integrate in the early stages of the industry life cycle, in the presence of radical technological discontinuities (Silver 1984, Langlois 1992, Robertson and Langlois 1995, Jacobides and Winter 2005, Fine 1998), or if emerging dominant design relies on integral product architecture (Fixson and Park 2008). Vertical disintegration follows in the presence of capability heterogeneity along the value chain, as firms gradually reduce transaction cost, enabling them to obtain benefits from specialization (Langlois 1992, Jacobides and Winter 2005). As the cost of coordinating across value chain stages decreases, firms gradually disintegrate, spinning off the activities most dissimilar to the firm's core competence (Jacobides and Winter 2005).

However, not every firm transitions from vertical integration to disintegration easily, risking transactional misalignment and consequently loss of performance (Williamson 1999, Nickerson and Silverman 2003). Argyres and Liebeskind (1999, 2002) found that there are cases where the governance of a new transaction is inseparably linked with the governance of other transactions that the firm is already engaged in. This may prevent the firm from switching the governance mode for existing transactions should underlying conditions change, or from selecting a desirable governance mode for a new related transaction. Firms may face constraints in disintegrating vertically due to path dependence (Gilson et al. 2009), contractual agreements with labor unions (Nickeson and Silverman 2003), or unanticipated increases of bargaining power of a group of stakeholders such as customers, suppliers or employees (Argyres and Liebeskind 2002).

While prior studies identified several factors inhibiting adaptation of vertical scope, none of them focused on explaining why firms may face difficulties with outsourcing when none of the above constraints is prevalent, asset specificity is low, and the firm lacks a comparative capability advantage over its suppliers. Prior studies also implicitly equate an outsourcing decision with the actual change in vertical integration, and do not explain the pace of transition from the hierarchical governcance to market transactions.

This study aims to address this gap by examining why manufacturing firms face difficulties in outsourcing simple activities. I conduct a survival analysis of an outsourcing process concerning 2470 similar components implemented over a period of seven years. In 2003 a group of managers in a major wind turbine manufacturing firm made a decision to outsource a group of components, manufacturing of which relies on generic machinery. The decision was motivated by a desire to focus on core production competencies and enforced by fast industry growth resulting in capacity constraints for the production facilities. The decision was followed up by 13 tactical outsourcing decisions for specific sub-categories of components. Outsourcing reached 97% in 2010, when data collection ended. All concerned components are similar in a sense that "they require the same capability for their undertaking" (Richardson 1972, p.888) and are subject to the same low level of asset specificity. Consequently, I refer to them as "similar components".

Seven years is a surprisingly long time to implement the outsourcing decision considering that it concerned an activity that was (a) technologically simple, (b) underpinned by a very low and homogenous level of asset specificity, (c) where existing and potential suppliers of the firm had superior productive capabilities. Under such circumstances the mainstream vertical integration theories, i.e. transaction cost economics and the comparative capabilities approach would predict that the firm should engage in outsourcing, but these theories do not explain the difficulties in the execution of outsourcing encountered by the firm. In this study I analyze the time lag between outsourcing decision and outsourcing implementation.

Survival analysis of the firm's purchase and production orders and a qualitative analysis of extensive interviews reveal that knowledge codification was the main bottleneck for outsourcing. Interview data shows that components with sufficiently codified product specifications were outsourced with a minimum involvement of engineers, and that for them outsourcing was primarily a commercial process. Outsourcing of components which required specific knowledge to be codified for the purpose of outsourcing relied heavily on the involvement of engineers not only in outsourcing implementation, but also in making tactical outsourcing decisions. Cox regression analysis confirms significant effects of several aspects of knowledge codification of the conditional probability of outsourcing.

My principal theoretical contribution lies in highlighting the role of knowledge codification in enabling outsourcing. While prior research explains that codification enables knowledge transfer (Nonaka 1994, Zander and Kogut 1995), the results of this study suggest that insufficient codification of even the simple “know what” type of knowledge is a major organizational constraint in vertical disintegration. This finding complements both transaction cost economics and the knowledge based view in explaining vertical disintegration. While the transaction cost theory cannot explain why firms remain vertically integrated when asset specificity is low, knowledge codification may hold the answer. Moreover, I adopt a behavioral view of decision-making to show how knowledge codification effort guides sequential attention to goals (Cyert and March 1963) of outsourcing particular sub-groups of components. I show that not only transaction characteristics and capability differences, but also organizational decision-making processes, are critical component of vertical disintegration processes.

THEORETICAL BACKGROUND AND HYPOTHESES

Transaction Cost Economics

Transaction Cost Economics (TCE) is the prevalent theoretical stream explaining vertical integration. According to TCE, transactions differ with respect to three principal dimensions which give rise to transaction costs: asset specificity, uncertainty and frequency of transaction. Asset specificity, which according to TCE is the most important driver of vertical integration, describes investments, which are significantly more valuable in a particular exchange than in any alternative exchange (i.e. that have a relatively unattractive outside option). TCE also relies on the assumption that people behave opportunistically and exhibit self-interest even to disadvantage of others (Williamson 1985). Therefore when a firm has made a relation-specific investment, the other party has strong incentives to behave opportunistically and extract quasi-rents from the specific investment, thereby taking advantage of the hold-up situation (Williamson 1985). Vertical integration protects firms from the risk of a hold-up situation. The main proposition of TCE is that under the assumption that firms do what is best for performance, in the context of repeated transactions subject to uncertainty, high asset specificity makes hierarchical governance more attractive than markets (Williamson 1981, 1985).

Although TCE has been the most influential theory explaining firm boundaries and received considerable empirical support (e.g. see meta-study of David and Han 2004), other studies point to its limitations. TCE has low explanatory power in the context of industries characterized by weak price competition (Nickerson and Silverman 2003), in the pre-shakeout stage of the industry life cycle (Argyres Bigelow Lyda 2007) or in innovative environments (Wolter and Veloso 2008). The relationship between uncertainty and vertical integration has also been challenged (David & Han, 2004; Poppo & Zenger, 1998). Other studies found that the overall vertical architecture of the firm cannot be fully explained by transactional alignment (Jacobides and Billinger 2006), or that TCE fails to explain concurrent sourcing choices especially of complementary products and services (Parmigiani (2007, Parmigiani and Mitchell 2009). The theory does not explain why firms would remain vertically integrated under low asset specificity, or why they would outsource only some of similar activities subject to the same level asset specificity. TCE is also silent about the process through which firms vertically disintegrate, and therefore does not explain why and how firms would implement outsourcing gradually. Since asset specificity is a necessary condition to explain vertical integration, then, according to TCE, frequency and uncertainty should not affect the level of vertical integration when the asset specificity is low.

Comparative Capabilities

The capabilities approach provides a complementary explanation of firm boundary choices that is independent of the opportunism assumption of TCE and therefore is able to shed light on the drivers and inhibitors of outsourcing under low asset specificity. According to the capabilities approach, in making vertical scope choices firms consider the differences in efficiency with which they carry out their productive activities in relation to other firms, and tend to specialize in activities where they have some comparative advantage (Richardson 1972, Argyres 1996, Teece 1986, 1996, Quinn and Hilmer 1994, Barney 1999, Kogut and Zander 1992, Hoetker, 2005,Jacobides and Winter 2005). Jacobides and Hitt conclude that firms internally perform operations where they have greater productive capabilities, i.e. "*the operational efficiency of a portion of production process*" (2005 p.1209), and contract out the activities where their productive capabilities are deficient. When relative capabilities change, firms adjust the level of vertical integration accordingly (Langlois 1992). These qualitative arguments have found support in large sample empirical studies of the role of capabilities in vertical integration choices (e.g. Leiblein and Miller 2003).

The core of the capability-based argument lies in the recognition that firms are heterogeneous in terms of resources and capabilities (e.g. Wernerfelt 1984, Barney 1991) which arise as a result of cumulative, path-dependent learning processes (Dierickx & Cool, 1989; Nelson & Winter, 1982; Winter, 1988).

Knowledge codification and outsourcing

A firm's capabilities are underpinned by idiosyncratic knowledge, coordination of which is more costly across than within firm boundaries. As firms provide an environment for creation and an exchange of knowledge, these coordination costs can be reduced by internal organization. Therefore valuable firm-specific knowledge often drives firm boundary choices (Conner and Prahalad 1996, Kogut and Zander 1992 1996, Grant 1995).

The diffusion and transfer of existing knowledge within or across firm boundaries is facilitated by knowledge codification (Zollo and Winter 1987, Zander and Kogut 1995, Nonaka 1994). Knowledge codifiability can be defined as "*the ability of the firm to structure knowledge into a set of identifiable rules and relationships that can be easily communicated*." (Kogut and Zander 1992, p. 387). Knowledge codification is a crucial element of knowledge transfer, as it enables its externalization (Kogut and Zander 1992, Balconi 2002, Cohendet and Steinmueller 2000). Prior studies have found that knowledge codifiability has a positive effect on the probability of early knowledge transfer in the context of horizontal transfers of manufacturing capabilities between manufacturing sites (Zander and Kogut 1995). Knowledge transfer is easier within the firm than across firm boundaries and codification is a key enabling factor of knowledge transfer. Therefore, codification of knowledge about the manufacturing capability should be a key enabling factor for outsourcing. Implementation of outsourcing therefore requires the firm to codify the knowledge about the outsourced goods and services. Prior studies have found that codification of technological practices facilitates vertical disintegration of manufacturing firms (Balconi 2002, Sturgeon 2002) or IT service firms (Vaast and Levina 2006). I therefore expect:

Hypothesis 1. Under low asset specificity, a high level of knowledge codification has a positive effect on the probability of outsourcing

However, codifying knowledge into written documents, such as manuals and blueprints, is not costless for the firm. Knowledge codification requires a high level of cognitive effort and involves direct costs including time, resources and attention for developing and maintaining documentation of knowledge (Zollo and Winter 2002). Attention involves opportunity cost, as it could be directed towards performing other task in the firm (Harris and Raviv 2002).

Codification generates a fixed cost which is largely independent from the scale of production (Balconi 2002). There are increasing returns in codifying arising from the intensity of use of codified information (Balconi 2002). In the context of outsourcing, the quantity of components outsourced through the application of a document codifying relevant technological knowledge generates returns of scale. I expect the intensity of use of codified documents to affect the prioritization of effort invested into knowledge codification.

Hypothesis 2. The greater the intensity of use of the document codifying knowledge, the greater the probability of outsourcing.

If at least a part of the technological knowledge is component/product specific, the codification effort and cost of codification increases with increasing product differentiation (Balconi 2002), and with increasing product variety. That leads to a lower level of codification in firms producing customized products compared to standardized products (Balconi 2002). However, firms outsourcing activities need to ensure a sufficient level of knowledge codification regardless of the level of product customization or variety of components subject to outsourcing. I argue that returns to scale in codification of technological knowledge in outsourcing affect the relative risk of outsourcing.

Hypothesis 3: The greater the codification effort driven by product variety, the lower the probability of outsourcing.

In sum, the central argument of this paper is that knowledge codification is a key determinant of outsourcing, which matters even when there is low asset specificity, an absence of comparative capabilities advantage and when outsourcing concerns technologically simple activities. The following section describes the settings in which I test the hypotheses.

METHODS AND MEASURES

Data and Sample

Empirical settings.

This research involves a case study of a major wind turbine manufacturing firm, which I will call Viento. I chose Viento not because it is necessarily representative of a larger population of firms, but because it provides a unique opportunity to gain insights into the role of knowledge codification in the process of outsourcing under conditions of low asset specificity and lack of comparative capabilities advantage (Yin 2003, Siggelkow 2007, Eisenhardt and Graebner 2007).

Viento is one of the top 10 wind turbine manufacturers based on global market share. During the period under consideration Viento produced three main models of state-of-the-art wind turbines and small numbers of older models, and serviced turbines already in operation. Even within the same model, wind turbines vary in height, and involve some degree of project/customer driven customization.

Viento provided a unique context to study a process of outsourcing of a large group of components that are characterized by very low and homogeneous level of asset specificity. In 2003 managers of Viento took a decision to outsource operations of harnessing copper-conductor cables. The decision was fully aligned with predictions of mainstream theories explaining vertical integration, as asset specificity was low and Viento did not have an advantage over suppliers in terms of productive capabilities. Furthermore, there was an available supply base, production workers could be redeployed to other assembly operations, outsourcing was borne out by cost benefit calculations, and functional managers heading key involved departments expressed their commitment. Surprisingly it took Viento seven years from the initial decision to actually implement outsourcing, and even after eight years the company had not reached full outsourcing. To put the time scale into perspective, a change in vertical integration towards transactional alignment of a more complex transaction in the trucking industry took 3 to 4 years on average (Nickerson and Silverman 2003). Figure 1 depicts the annual proportions of make-and-buy quantities over the analyzed period. The aim of this paper to explain this empirical puzzle and to examine why outsourcing of technically simple components can be difficult.

Insert Figure 1 about here

The outsourcing project concerned operations of harnessing low voltage copper-conductor cables. The process consists of cutting raw copper cable to length, stripping off the outer jacket from the cable and the insulation from individual conductors, mounting standard end pieces on the conductors, labeling the cables, and bundling individual cables into bundles specified in technical documentation. Harnessed cables are placed in the warehouse before reaching subsequent assembly stages, which demarcates a clear interface between technologically separable stages (Cable harnessing is technologically simple, follows cross-industry standards, and relies on standard machinery which may include hand tools or semi-automatic machines. The operations do not involve any physical asset specificity or skills specific to Viento, and Viento considers cable harnessing one of the simplest operations in their inhouse assembly processes. Therefore, the cables outsourcing project provides a case of vertical disintegration where all components are characterized by the same and very low level of asset specificity and required capabilities, and yet we observe heterogeneity in implementation of vertical disintegration. The slow pace of outsourcing can't be attributed to a search for suppliers and learning to outsource for two reasons: First, the transactions are conducted frequently –there are about 2,1 km of copper-conductor cables in a typical wind turbine. Second, Viento had been buying about 20% of its cables from external suppliers for several years before the main outsourcing decision, had kept close long term relationship, and made substantial use of their expertise in the outsourcing project.

An important aspect for understanding the outsourcing process is codification of cable processing knowledge, involving both codifying the "know-how" and the "know-what" (Johnson, Lorentz Lundvall 2002, Brown and Duguit 1998, Garud 1981). The "know how" describing the process of cable harnessing is codified in several generic instructions that apply to multiple components' (here: cables') IDs. Codifying the "know-what", i.e. knowledge about factors like cable length and a type of an end piece, is component specific and involves generating a separate technical specification for each individual cable ID. The amount of the documents codifying the "know-what" is therefore proportional to component variety.

Both types of documents are always prepared by internal engineers, regardless whether the cable is made internally or purchased from an external supplier. Technical specifications from Viento for inhouse cable production are typically less detailed than for external production, and part of the technical specifications is registered in the ERP system, but not in a separate document. This observation suggests that the level of knowledge codification within the firm is lower than across firm boundaries, as sharing knowledge inside the firm is easier due to the common ground developed among engineering and inhouse production employees (Kogut and Zander 1992, 1996, Grant 1996, Bechky 2003). That common ground allows for coordination when cable harnessing capability is coded into a lower degree of explicit knowledge. This suggests that implementing outsourcing may require effort in improving technical specifications for external use by suppliers, and this knowledge codification effort increases with the amount of unique cable IDs, i.e. with component variety.

Data collection.

The dataset comprises information on all purchase and production orders for cables placed in Viento from March 2003 to April 2010. The dataset was extracted from the ERP system of Viento and contains information about order date, order quantity, component ID and description, a make-or-buy indicator and a supplier ID. The dataset contains 22928 order entries for 2470 unique components. The unit of analysis in the final dataset is product module, which reflects the wind turbine product architecture[1].

Product architecture is "*the scheme by which the function of a product is allocated to physical components*" (Ulrich 1995 p.419). Modular architecture of complex products provides natural breaking points, which allow the firm to make vertical integration decisions at the module, not product level (Baldwin and Clark 2000, Baldwin 2008). Data sources about product architecture include detailed interviews with a purchasing manager and a production engineer in charge of the electrical system, schematics depicting the product architecture, and finally a dataset of nearly all bills of materials for wind turbines produced during analyzed period. Mapping the product architecture between bills of materials and order placements resulted in accuracy amounting to 96,8% of order quantity.

[1] Each of 64 identified product modules comprises an observation in the survival dataset. Modules are not replaced with other observations due to technological change. A module that enters the survival analysis stays in the analysis until outsourcing or end of analysis period.

Finally, I conducted 28 interviews with most of the employees involved in and knowledgeable about outsourcing decisions concerning cables. Besides the first major outsourcing decision of a strategic character that triggered vertical disintegration, I identified thirteen follow-up tactical decisions that guided implementation of outsourcing. These were taken at several points in time between 2003 and 2010 by various combinations of decision makers from purchasing, production and engineering departments. The scope of decisions varied from targeting single product modules to the whole array of inhouse produced cables. Interview data confirms that product modules provide a meaningful level of analysis of outsourcing. I linked the data about outsourcing decisions with the main dataset. For triangulation purpose I used various secondary data, which include production schedules and overviews, internal newsletters, reports and presentations. I used organization charts to identify the position of decision makers.

During the interviews I asked about the reasons for outsourcing and the conduct of its implementation, thereby searching for information supporting or disproving vertical integration theories. Confirming the explanatory power of vertical integration theories, I found evidence for motivation behind outsourcing decisions that reflect higher productive capabilities of suppliers, low asset specificity, tight inhouse capacity, desire to focus on core competence, to gain bargaining power over suppliers based on transaction volume. While this information helped to explain the reasons behind *decision-making*, I also searched for explanations of why outsourcing *implementation* took as long as seven years. I did not find evidence for workers' resistance, lack of qualified suppliers, idle capacity or high asset specificity. On the contrary, I found evidence for agreement among involved managers about the commitment to outsourcing. Analysis of the qualitative data pointed towards lack of established procedures for implementation of outsourcing, resources devoted to knowledge codification, and managing component variability in the context of inhouse manufacturing and outsourcing. Also, as in any manufacturing firm, I found evidence that inhouse production offers greater flexibility in processing urgent demands (Richardson 1996), what might have influenced the timing of outsourcing of some components. It was nevertheless clear that Viento was committed to outsource cables processing.

Measures

Dependent and independent variables.

The dependent variable is the ***outsourcing event***, which is a dummy coded as 1 when 99% of the module production was permanently outsourced[2]. This is the *status variable* in survival analysis which is analyzed in relation to a *time variable* which measures "exposure to the risk of outsourcing". The time variable measures the number of months it takes for a module to be outsourced. It starts when the module was first introduced, or at the first outsourcing decision if the module was produced before then. The period ends at the outsourcing event or at the end of analysis for right-censored observations for which the outsourcing event did not occur during the analysis period.

Module size counts the number of cables used in the module in one wind turbine. Module size reflects both the "static" variety of components within the module (ignoring the ratio of variability) and the effort needed to codify the "know what". Modules vary in size from 1 to 75 cables. Module size remains constant over the analysis period[3].

Project driven variability (or short: variability) measures the ratio of the number of unique cables registered as produced inhouse and used in given module at any point in time during the

[2] I choose 99% not 100% of outsourcing implementation in order to leave a margin for a coding error of assigning individual components to modules

[3] If module size fluctuates among bills of materials for individual wind turbines, variable module size reflects the average number of single cables in module.

analysis to the number of unique cables needed in that module in one wind turbine. E.g. if module size is 10 cables for one wind turbine, but there are 78 unique cables registered as produced inhouse and are used in that module in wind turbines for various projects, the variability is 78/10= 7.8. If this variability score is below 1 because most of the cables in the module are outsourced and only a fraction of what is needed is made inhouse, I recode variability to 1. I use squared term of variability to test the curvilinear effect. Variability reflects the component variety normalized by module size. Variability arises from different cable length needed for various wind turbines, changes in interdependent components that require a different cable, upgrading raw materials or customization for specific wind farms. Variability is an important feature in our study as there are about 190 different copper conductor cables in a typical Viento wind turbine, while there are 2470 unique copper conductor cables or cable bundles that were produced or purchased during the analysis period. All these cables were produced of 127 types of raw cables. Interview data provide evidence that high variability became an obstacle in outsourcing and that the engineers undertook initiatives to reduce it.

Codification ratio captures a method of implementing outsourcing, as interview data shows that components that had sufficiently codified documentation were outsourced with minimal involvement of engineers, and it was primarily a commercial process. In contrast, when sufficient documentation did not exist, engineers often chose to introduce new component IDs with new documentation for suppliers instead of improving documentation for existing components[4]. Outsourcing through this method would often coincide with introducing a new cable variant. *Codification ratio* therefore captures the degree of codification of knowledge about

[4]Not all individual components were outsourced. Some of them were phased out never to be used again and replaced with a new cable ID, relieving the engineers from the necessity of producing purchase specification for components at the end of their component life cycle. New components were either introduced as inhouse production and transitioned to outsourcing, or introduced as outsourced from day one.

cable production prior to outsourcing implementation. Codification ratio is measured as the amount of cables that were outsourced using existing component ID divided by the number of inhouse produced cables registered in given module.

Mean component life span is the life span of a cable measured from last to first order date, averaged over all components registered under given module. Mean component life span is a proxy for the intensity of use of codified knowledge, therefore I expect a positive relationship with the timing of outsourcing.

Control variables.

A number of control variables reflect the structure and process of outsourcing decision-making. Decision ***scope*** counts the number of modules to which given decision applies. ***Departments*** counts the number of departments among production, purchasing and engineering that participated in making given outsourcing decision. ***Engineering*** is a dummy coded as 1 when an engineer was involved in outsourcing decision-making and 0 otherwise. ***Hierarchy*** codes the hierarchy level of the lowest involved person. CEO would be coded as 7 and a front line employee as 1. As there were 14 outsourcing decisions of various scopes taken during the analysis period, many modules were targeted for outsourcing with multiple decisions. ***Decisions to date*** counts the number of (ineffective) outsourcing decisions that concern a given module to date, including current decision in question. ***Capacity utilization in previous period*** is a ratio of quantity of cables processed inhouse in the quarter prior to outsourcing event divided by the highest quantity of cables processed in the busiest quarter during the analysis period. It is used as the measure of maximum available capacity. Lagging the variable by one quarter ensures that reverse causality is not a problem. I also use dummies for the main models of the final product (wind turbines). While their core product architecture is very similar, they differ with respect to production volume and product life cycle stages. Table 1 provides descriptive statistics and correlations among the variables.

Insert Table 1 about here

ANALYSIS

I use the Cox Proportional Hazard Model (Cox 1972), which is widely used for the analysis of survival data. Survival analysis examines the time it takes for an event of interest to occur. The Cox model relies on the proportional hazard assumption which means that the hazard ratio remains constant over time. Scholars in political science (Box-Steffensmeier and Zorn 2001) and biostatistics (Andersen and Skovgaard 2010 p.p. 138) recognize that the proportional hazard assumption is restrictive and is often violated by data, i.e. the effect of covariates in fact often changes with time. I test the proportionality assumption by calculating the Schoenfeld residuals and find that it is violated by several covariates. To remedy the violation I employ the method of including time-dependent covariates in the model by interacting the covariates having time-varying coefficients with time(He 2005, Box-Steffensmeier and Zorn 2001, Hosmer and Royston 2002). The main results of the baseline Cox model and the model correcting for time-varying covariates are largely consistent in terms of sign and significance[5].

A positive coefficient in Cox regression means the covariate increases hazard of outsourcing, or, in other words, that the covariate has a positive impact on the timing of outsourcing. Negative

[5] Cox regression model requires dealing with right- truncated observations that may bias the results. I removed four right-truncated observations from the dataset which represent modules phased out due to late stage in the product life cycle. Based on the interview data I treat them as components which were not targeted by the outsourcing decision, as the managers decided to phase them out instead of outsourcing. This approach is consistent with prior research, as changes in vertical integration during the product life cycle have been found to be rare in other industries (e.g. in automotive industry, Novak and Stern 2008).

coefficients correspond to reduced hazard of outsourcing, which translates into more days until outsourcing. The coefficient b relates to hazard ratio in a way that for an increase of one unit of a covariate in one unit of time, the hazard ratio for the outsourcing event increases by a factor of Exp(b).

I analyze the data in two stages. The first analysis reported in Table 2 includes product level covariates and does not include variables capturing individual decisions. Thus the analysis captures how the decision makers prioritized various modules for outsourcing, i.e. what motivated the sequence of outsourcing decisions. 64 observations correspond to 64 product modules subject to outsourcing.

The models in Table 3 analyze the drivers of outsourcing *implementation* after making each of the fourteen individual outsourcing decisions. This analysis does not capture the prioritization criteria chosen by decision makers with respect to which modules should be targeted for outsourcing at given point of time. It explains the success of outsourcing implementation after prioritization at the decision making level had taken place.

The analysis presented in Table 3 incorporates the organization level variables characterizing individual outsourcing decisions. I transform the survival dataset to reflect the sequential nature of outsourcing decisions in the following way. The start date of the survival analysis is the date of the first outsourcing decision, and the end date is either outsourcing event or the date of subsequent outsourcing decision affecting given module. If a module was not outsourced before the subsequent decision, I re-set the start date to the date of subsequent decision and list the module as another observation exposed to the risk of outsourcing. The survival time is therefore partitioned to reflect the duration between subsequent outsourcing decisions. I code which outsourcing decision is being examined and merge decision-related variables. The number of observation increases to 287, as modules are listed several times to reflect each (unsuccessful) attempt to outsource under multiple decisions as well as the successful implementation of outsourcing decision. Each observation has a unique combination of module ID and survival time. Figure 2 depicts the structure of the dataset.

Insert Figure 2 about here

Results

Table 2 presents the result of the Cox regression analyzing the impact of product level variables on timing of outsourcing. Model 1 contains a set of control variables. Models 2 to 5 present specifications using the variables of interest. All models have significant explanatory power.

Insert Table 2 about here

Capacity utilization in the period prior to outsourcing has a positive effect on the hazard of outsourcing. The effect is significant only in Model 1 ($p<0.05$) and becomes insignificant after adding independent variables to the models; therefore capacity utilization is not sufficient for explaining the timing of outsourcing implementation. The coefficients for wind turbine model dummies are not significant.

The lower part of Table 2 reports coefficients for the covariates with time-varying coefficients, which are significant for variables module size, mean component life span, codification ratio and variability. Given the linear coefficient function in the form a+b*t, where t is one unit of time, the "Main effect" part of the table gives the estimates of a and the "Time varying covariate" part gives the estimates of b (He 2005). For example, the time varying covariate coefficient 0.002 for module size (Model 4) means that the log hazard ratio for every unit increase in module size increases by 0.002 every month. Consequently, we can calculate that after 3 years the log relative risk of a module that is one cable larger increases from -0.134 to -0.062(-0.134 +36*0.002). Having accounted for the effect of control variables, we now proceed to analyzing the key variables of interest that characterize knowledge codification and variability.

Knowledge codification ratio has a positive effect on the timing of outsourcing, i.e. the hazard of outsourcing increases with increasing knowledge codification ratio (Models 2-5). While the main effect is not significant, the coefficient of the time-varying covariate reveals a significant positive effect that increases over time. The ability to outsource components using existing documentation shortens the timing of outsourcing, what provides support for Hypothesis 1.

Model 2 shows a negative effect of mean component life span, which is a proxy for intensity of use of purchase specifications and for the returns of scale of knowledge codification. Components with relatively short life span are outsourced sooner, contradicting our prediction. This surprising result suggests that successful outsourcing may be implemented through introducing new cable IDs– causing a reduction in mean component life span in our dataset – or that the life span may not properly reflect the intensity of use of purchase specifications codifying component specific knowledge[6]. Analysis in Table 2 does not yield support for Hypothesis 2.

As expected, module size has a significant negative effect (Models 3-5), as larger modules tend to be more complex, require greater effort of knowledge codification, and therefore are more difficult to outsource. The strength of the negative effect decreases over time. Increasing variability significantly reduces the hazard of outsourcing ($p<0.01$); the magnitude of this effect decreases over time as indicated by the positive coefficient of the time-varying covariate in the lower part of Table 3. The effects of module size and variability provide support for Hypothesis

[6] The measure of mean component life span ignores transaction frequency measured as order quantity

3. High levels of component variety and variability increase the burden on inhouse engineering to codify component related knowledge into high quality documentation for suppliers.

The relationship between variability and the timing of outsourcing has a U-shape, as evidenced by the negative effect of the linear term and a positive effect of the squared term in Model 5. We observe high hazard of outsourcing for modules characterized by low and high variability, and low hazard of outsourcing for moderate level of variability. It is intuitive that modules with low variability are outsourced easily. Puzzlingly however, we find a high outsourcing hazard for modules with high variability. This is examined in detail in Table 3.

The results presented in Table 2 reveal that both availability of codified knowledge and variability of components within a module are critical for understanding the timing of outsourcing implementation in our study. We now move to analyzing the role that the structure and the process of outsourcing decision making play in outsourcing implementation.

Sequential nature of outsourcing decisions and component variability.

Table 3 presents the Cox regression analyses after transforming the dataset to reflect the sequential nature of outsourcing decisions, and analyses the drivers of outsourcing implementation after each individual decision. Model 1 contains the set of key explanatory variables at the product level. While the model is significant overall, the Chi-square is fairly low.

The main effect of knowledge codification ratio on the hazard of outsourcing is not significant, and the time-varying effect is positive and increasing (Model 1 and 3), which provides support for H1.

The main effect of mean component life span is not significant and it sthe time-varying effect is negative and decreasing, what again does not support H2. The negative effect of module size is significant only in Models 3 and 5, providing some support for H3Capacity utilization is not significant

Insert Table 3 about here

Interestingly, project driven variability changes sign in this analysis: it increases the hazard of outsourcing, and the strength of this effect fades away over time. This suggests that decision makers target specific modules with individual outsourcing decisions when the organization is ready to tackle variability, and therefore after a specific outsourcing decision has been made highly variable modules become outsourced sooner than modules of low variability.

Model 3 introduces organization level variables that capture the characteristics of decision-making processes. Decision scope has a significant negative effect on outsourcing, which weakens over time. The number of departments involved in an outsourcing decision-making does not show a direct effect on timing of outsourcing, and we investigate its moderating function later. The main effect of the hierarchy level at which outsourcing decisions are taken is not significant, but the coefficient of time-varying covariate of hierarchy reveals a negative effect decreasing over time. The lower the hierarchy level, the higher the hazard of outsourcing, as outsourcing decisions in our study are of tactical nature and require hands on involvement of line managers and front line employees.

The higher the number of (unsuccessful) outsourcing decisions targeted given module previously, the higher the hazard of successful outsourcing. This effect is moderated by the variability, as shown by the interaction effects in Model 3. That means that initially, in the early stages of the analysis period when only few outsourcing decisions have affected the modules, high variability reduced hazard of outsourcing. When more outsourcing decisions have targeted given module, high variability drives the hazard of outsourcing up. This relationship shows prioritization in the execution of outsourcing, where decisions difficult to implement due to variability were prioritized later. This is consistent with the positive effect of variability, as it confirms that later decisions targeted highly variable modules, and at that time the organization was prepared to successfully execute outsourcing of these challenging modules. This also helps to explain why we observe a curvilinear effect of variability presented in Table 2. These results reveal that decision makers exhibit sequential attention to goals (Cyert and March 1963), splitting a large outsourcing project into smaller, manageable decisions. The sequence of their attention devoted to outsourcing is guided by component variability within modules, what reflects the extent of knowledge that needs to be codified in order to execute outsourcing.

Component variability and organizational resources critical for knowledge codification.

Variability, which reflects the effort of knowledge codification, is a key variable explaining the timing of outsourcing in this study. Since knowledge related to outsourced components is codified by the engineering department, I check for a moderating effect of engineering. Investigating an interaction effect of variability and engineering (Model 4) shows that the higher the variability, the stronger the positive effect of involving an engineer in the decision making process This results confirms that the organization indeed approaches the challenging projects of outsourcing modules of high variability when appropriate resources are in place, and involvement of engineering capabilities is critical for success of outsourcing highly variable modules. The other side of the coin is that insufficient commitment of engineering resources hinders outsourcing of highly variable modules, which points to an organizational bottleneck in outsourcing. It is important to note here that the analysis does not investigate whether an engineer is involved in outsourcing implementation, but rather in the outsourcing decision making process. Therefore it is the initiative and commitment of persons with critical skills in the decision making phase that facilities outsourcing of modules which are challenging due to effort invested in knowledge codification driven by high variability.

Finally, we investigate the interaction effect between two aspects of scope: decision scope and the scope of decision makers, i.e. the number of departments involved in the decision making process. Model 5 shows a negative effect of number of departments involved in the decision making process, a negative effect of decision scope, and a positive effect of interaction term of these two variables. This indicates that when decision scope is low, adding additional department reduces the hazard of outsourcing, and when decision scope is moderate or large, then involving additional departments has a reduces the time to outsourcing. The organizational effort that matches the breadth of outsourcing decision has positive performance impact. Success of well-defined decision is underpinned by focused involvement of decision makers, while broad decisions spanning across a variety of product modules require broad involvement of several departments.

Summary of results

This paper presents a survival analysis of an outsourcing process a group of similar components characterized by low asset specificity and no comparative capabilities advantage of the outsourcing firm. The results show that the effort invested in knowledge codification related to outsourced components has an important impact on the timing of outsourcing. I find that a high level of available codified knowledge increases the hazard of outsourcing (Hypothesis 1). High effort needed to codify relevant knowledge driven by component variety and variability reduces the hazard of outsourcing (Hypothesis 3). I do not find empirical support for hypothesis 2 that the intensity of use of the document codifying knowledge is expected to increase the hazard of outsourcing. The key mechanism through which knowledge codification affects outsourcing implementation is the effort invested in generating the documents that codify the knowledge about outsourced activities that must be transferred to external suppliers. These results have several implications both for theory and practice.

DISCUSSION AND CONCLUSIONS

This paper addresses a gap in the vertical integration literature. It highlights a mechanism that inhibits outsourcing and may cause firms to stay overly vertically integrated under conditions of low asset specificity and no comparative capabilities advantage, what is not explained by TCE. It contributes to the stream of research on adaptation of firms' vertical scope (Jacobides and Winter 2005, Fixson and Park 2008, Fine 1998), and in particular to research on factors inhibiting reaching transactional alignment (Nickerson and Silverman 2003, Argyres and Liebeskind 1999, 2002, Gilson et al 2009). The main finding of this paper is that (insufficient) knowledge codification is a key factor that can inhibit or enable outsourcing. This is not only a new empirical finding but also extremely intuitive.

This study also contributes to the Knowledge Based View literature, in particular to the literature stream on knowledge codification. While KBV scholars argue that firms provide environment for knowledge transfer (Kogut and Zander 1992, 1996, Grant 1996), this study demonstrates that inability to transfer knowledge prevents firms from vertical disintegration. KBV focused primarily on transfer of tacit knowledge (Polanyi 1966). This study shows that codification is essential also for transferring the explicit "know what" type of knowledge, which in principle is easy to codify and transfer (Brown and Duguid 1998), and therefore the ease of transferring the "know what" may be taken for granted in firms. I add to the findings of Zander and Kogut

(1992) who found empirical evidence for a positive effect of knowledge codification on transfer of manufacturing capabilities between manufacturing sites. I extend findings of scholars who found that knowledge codification enables outsourcing (Balconi 2002, Sturgeon 2002, Vaast and Levina 2006). I add a nuance that insufficient codification of the “know what” inhibits outsourcing even if firms attempt to outsource activities that are very simple from the capabilities point of view, and the fundamental conditions of vertical integration according to TCE are fulfilled.

This paper addresses a behavioral aspect of decision making about outsourcing. In order to make up for the constraints on their cognitive resources, boundedly rational actors resort to structuring the process of decision making in time (March & Simon, 1958). I find that decision makers sequence individual tactical outsourcing decisions according to the criteria of knowledge codification availability and effort. Decision makers also turn to organization structure during the process of implementing an outsourcing project: they match the scope of decision with the scope of capabilities held by departments involved in outsourcing decision making and they involve low level employees in decision making, what facilitates outsourcing implementation. This decision-making behavior displays sequential attention to goals (Cyert and March 1963), and demonstrates how boundedly rational actors structure the decision making (March & Simon, 1958). It also demonstrates that decision makers apply satisficing (March & Simon, 1958), rather than maximizing principles in implementing vertical disintegration.

Managerial implications

In this study outsourcing of modules that require high effort of knowledge codification became the major bottleneck of vertical disintegration process. Successful outsourcing of such challenging components relied on commitment of employees holding the critical capability of codifying knowledge. This commitment was expressed not only through involvement in outsourcing implementation, but in making tactical outsourcing decisions. Insufficient commitment of resources at lower levels of one department having critical knowledge codification skills, which in this case was the engineering, had an important impact on the timing of outsourcing. This observation brings up the importance of aligning incentives across all involved departments and all involved hierarchy levels. In this study successful outsourcing initiatives involved lower level employees and employees possessing the key capability of knowledge codification into the decision making process. Since these lower lever actors were critical for successful outsourcing, it is not sufficient to ensure cooperation among higher rank managers like department heads in a large firm. It is critical to align goals at all involved hierarchy levels.

This highlights critical issue for managers in charge of outsourcing: misaligned incentives can slow down outsourcing implementation. Outsourcing is highly interdependent with many activities in a firm. If employees having the capability to codify relevant knowledge prioritize the task of knowledge codification lower than other tasks due to their incentive structure, implementation of outsourcing slows down. That means that the firm must support the high costs of concurrent sourcing (Parmigiani 2007, Hennart 1993), which among others includes maintaining and monitoring external suppliers, allocating plant and equipment capacity, staffing and carrying the cost of internal production and inventories. A managerial task is to assess the relative cost of ensuring additional resources for the bottleneck task of knowledge codification what speeds up outsourcing vs. the cost of sustaining concurrent sourcing over longer time periods.

Limitations

This research is based on a study of a single firm and a single group of components that were chosen due to their attributes of low asset specificity and simplicity of productive capabilities. These settings allow me to contrast the effect knowledge codification on the timing of outsourcing with the mainstream theoretical explanations of vertical disintegration. The extent to which the findings are generalizable to other settings requires additional research.

Prior studies pointed out that performance consequences of transactional misalignment are not significant in the early stages of the industry life cycles (Argyres and Bigelow 2007), which may explain why Viento did not invest more resources into the outsourcing process, as the competition in the wind turbine industry before the global financial crisis in 2008 was not based on competitive pricing. Nevertheless, this study reveals a mechanism that may inhibit outsourcing regardless of the competitive pressures, and which is of greater importance to firm operating in environment with strong selection pressures.

Further studies might fruitfully investigate the effect of knowledge codification on outsourcing for activities more heterogeneous in terms of underlying capabilities and also in environments with different strengths of competitive pressures that the increase negative performance consequences of transactional misalignment.

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Figure 1. Proportion of make and buy quantities during the cables outsourcing project

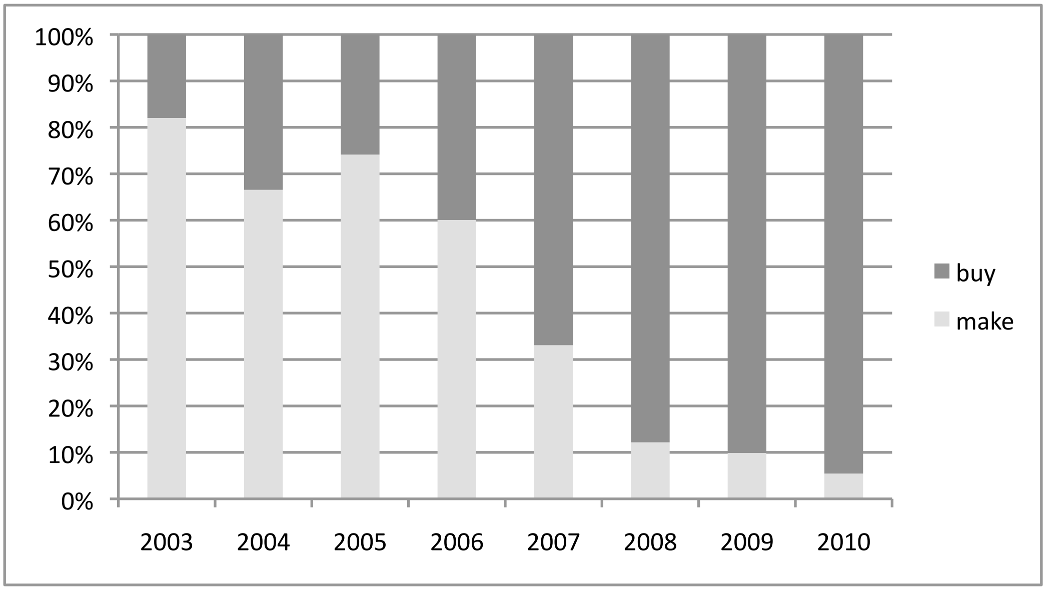

Figure 2 . Structure of the survival dataset with consideration of individual outsourcing decisions

module ID	module description	start exposure to risk	stop exposure to risk	next decision date	time at risk	active decision ID	outsourcing event	decisions to date
1	hub module 1	2004m12	2007m1	2007m1	25	2	0	2
1	hub module 1	2007m1	2008m7	2008m7	18	6	0	3
1	hub module 1	2008m7	2009m1	2009m1	6	8	0	4
1	hub module 1	2009m1	2009m8	2010m1	7	10	1	5
2	tower module 1	2003m10	2004m12	2004m12	14	1	0	1
2	tower module 1	2004m12	2007m1	2007m1	25	2	0	2
2	tower module 1	2007m1	2007m10	2008m7	9	6	1	3
3	nacelle module 3	2003m10	2004m12	2004m12	14	1	0	1
3	nacelle module 3	2004m12	2005m3	2005m3	3	2	0	2
3	nacelle module 3	2005m3	2008m7	2008m7	40	3	0	3
3	nacelle module 3	2008m7	2009m4	2009m4	9	8	0	4
3	nacelle module 3	2009m4	2010m1	2010m1	9	12	0	5
3	nacelle module 3	2010m1	2010m3	2010m3	2	14	1	6
…								
64	tower module 4	2003m10	2004m12	2004m12	14	1	0	1
64	tower module 4	2004m12	2005m3	2005m3	3	2	0	2
64	tower module 4	2005m3	2008m3	2008m7	36	3	1	3

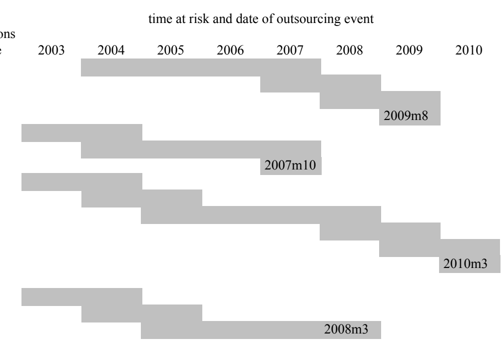

Table 1. Correlations and descriptive statistics

		Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10
1	Capacity utiliz. previous	0.382	0.255	0.122	1	1.000									
2	Mean component life span	661.790	631.936	18.500	2757.710	-0.161*	1.000								
3	Codification ratio	0.242	0.334	0	1	0.101	0.219*	1.000							
4	Module size	12.140	20.323	1	75	-0.354*	0.095	-0.234*	1.000						
5	Variability	4.256	7.213	1	46	0.016	-0.027	-0.018	0.093	1.000					
6	Decision scope	44.468	23.034	3	69	0.058	-0.080	0.039	-0.090	-0.033	1.000				
7	Departments	2.212	0.719	1	3	0.002	-0.130*	0.021	-0.080	-0.114	0.189*	1.000			
8	Hierarchy	-4.805	1.034	-7	-4	-0.022	0.030	-0.033	-0.047	0.034	0.694*	-0.139*	1.000		
9	Decisions to date	3.010	1.652	1	8	-0.037	-0.004	-0.129*	0.162*	0.031	-0.797*	-0.472*	-0.396*	1.000	
10	Engineering	0.457		0	1	-0.039	-0.075	-0.082	0.015	-0.084	-0.133*	0.779*	-0.054	-0.097	1.000

Table 2. Cox regression with time-varying coefficients. The effect of product level variables on the hazard of outsourcing

	Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Main effect						
	Capacity utilization previous	1.583***	0.385	-0.279	0.368	0.246
		(0.608)	(0.742)	(0.799)	(0.752)	(0.756)
	Turbine model 1	0.281	0.616	0.799	0.505	0.152
		(0.545)	(0.774)	(0.776)	(0.763)	(0.766)
	Turbine model 2	0.562	0.963	0.987	0.972	0.682
		(0.446)	(0.654)	(0.648)	(0.606)	(0.604)
	Turbine model 3	-0.770	0.648	0.678	0.345	-0.123
		(0.710)	(0.901)	(0.897)	(0.908)	(0.911)
	Mean component life span		-0.004***	-0.003***	-0.003***	-0.003***
			(0.001)	(0.001)	(0.001)	(0.001)
	Codification ratio		-0.512	-0.827	-1.023	-1.136
			(0.849)	(0.847)	(0.791)	(0.796)
	Module size			-0.105*	-0.134**	-0.143**
				(0.055)	(0.063)	(0.064)
	Variability				-0.651***	-0.860***
					(0.209)	(0.256)
	Variability squared					0.004**
						(0.002)
Time-varying covariate						
	Mean component life span		0.000**	0.000**	0.000**	0.000*
			(0.000)	(0.000)	(0.000)	(0.000)
	Codification ratio		0.078***	0.080***	0.066***	0.066***
			(0.023)	(0.023)	(0.021)	(0.021)
	Module size			0.001*	0.002*	0.002**
				(0.001)	(0.001)	(0.001)
	Variability				0.009***	0.010***
					(0.003)	(0.003)
	Observations	64	64	64	64	64
	chi-square	14.13	56.82	63.70	85.26	90.16
	Prob > chi2	0.001	0.000	0.000	0.000	0.000

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3 Cox regression with time-varying coefficients. The effect of product level and organization level variables on the hazard of outsourcing

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Main effect					
Capacity utiliz. previous	-0.025	-0.020	0.094	0.339	-0.109
	(0.621)	(0.613)	(0.618)	(0.647)	(0.624)
Mean component life span	0.001	-0.000	0.001*	0.000	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Codification ratio	-1.299	-0.138	-0.964	-0.966	-0.552
	(0.851)	(0.887)	(0.919)	(0.973)	(0.925)
Module size	-0.008	-0.016	-0.027**	-0.015	-0.021*
	(0.010)	(0.011)	(0.013)	(0.011)	(0.012)
Variability	0.101***	0.115***	-0.410	0.087***	0.115***
	(0.028)	(0.031)	(0.294)	(0.033)	(0.031)
Decision scope		-0.052**	-0.041*	-0.069**	-0.084***
		(0.022)	(0.024)	(0.028)	(0.031)
Departments		-0.208	-0.309	0.649	-0.678*
		(0.254)	(0.273)	(0.887)	(0.365)
Hierarchy		0.478	0.321	0.732	0.401
		(0.408)	(0.420)	(0.573)	(0.408)
Decisions to date		0.646***	0.395*	0.970***	0.781***
		(0.172)	(0.230)	(0.224)	(0.190)
Decisions x variability			0.104*		
			(0.056)		
Engineering				-3.547**	
				(1.765)	
Variability x engineering				2.940**	
				(1.143)	
Decision scope x departm.					0.025*
					(0.013)
Time-varying covariate					
Mean component life span	-0.000**		-0.000**	-0.000	-0.000*
	(0.000)		(0.000)	(0.000)	(0.000)
Codification ratio	0.148**	0.055	0.121*	0.107	0.098
	(0.060)	(0.058)	(0.065)	(0.066)	(0.064)
Variability	-0.019**	-0.020**	-0.006	-0.014*	-0.017**
	(0.008)	(0.008)	(0.009)	(0.008)	(0.007)
Decision scope		0.004**	0.003	0.005***	0.002
		(0.002)	(0.002)	(0.002)	(0.002)
Hierarchy		-0.105***	-0.094**	-0.102**	-0.087**
		(0.040)	(0.042)	(0.046)	(0.042)
Engineering				0.219**	
				(0.087)	
Variability x engineering				-0.306*	
				(0.184)	
Observations	287	287	287	287	287
chi-square	29.98	117.9	127.7	133.9	126.1
Prob > chi2	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1