Implementing Modular Design In Digitized Products: Contingencies of Environmental Turbulence And Customer Involvement

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IMPLEMENTING MODULAR DESIGN IN DIGITIZED PRODUCTS: CONTINGENCIES OF ENVIRONMENTAL TURBULENCE AND CUSTOMER INVOLVEMENT

Research in Progress

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Abstract

Firms today operate in an environment that is characterized by increasing digitization and rapid transformation. Implementing modular architectural design in software incorporated in digitized products thereby provides them with the flexibility needed to successfully adapt their offering to changing environmental conditions. However, this is not a straightforward task. Factors influencing the implementation of modular design are thus of great importance to system engineers. While existing research highlights the relevance of customer involvement as well as environmental factors individually, their contingent effects remain unexplored. Our paper addresses this gap in the literature by empirically investigating the interaction of customer knowledge integration mechanisms with market and technological turbulence, to determine their effect on the implementation of modularity in products’ software architecture. We thereby draw upon theories of modularity as well as insights on customer involvement from information systems (IS) and new product development (NPD) literature.

Keywords: modularity, architectural design, software architecture, customer involvement.

1 Introduction

Digitization of products is, without doubt, becoming increasingly commonplace across a broad range of industries (Yoo, 2010; Yoo et al., 2012; Lyttinen, Yoo and Boland, 2016). Undeniably, software and software-based capabilities have thereby become crucial in determining products’ success (Yoo, 2010; Yoo et al., 2012; Nambisan, 2013). Software architecture is “the fundamental technical organization of a system” (Dingsøyr et al., 2017, p. 495). As such, firms operating in this digital day and age must carefully consider the architectural design of software integrated in their products. Design “is concerned with how things ought to be, with devising artefacts to attain goals.” (Simon, 1996, p. 114). In other words, it is concerned with adapting a system to fit its environment (Simon, 1996). In dynamic environments, a design criterion that products’ software architecture must fulfil is flexibility, as this enables quick adaptation to changing conditions (MacCormack, Verganti and Iansiti, 2001). In this context, the benefits afforded by modular architectural design have been highlighted (Parnas, 1972; Sanchez and Mahoney, 1996; Schilling, 2000). Theories of modularity thereby identify environmental pressure caused by diverse and uncertain customer and technological demands as a factor, which drives systems towards greater levels of modularity (Schilling, 2000).

Nonetheless, implementing modularity to adapt to dynamic environments does not occur by chance. It is the result of actively planning product architecture and involves purposefully defining modules’ scope and interfaces (Ulrich and Tung, 1991; Tiwana, 2008a; Marion, Meyer and Barczak, 2014).
Product developers must acquire a good understanding of market demands to accurately determine the need for modularity and the best design for modules (Tu et al., 2004). Involving customers in the development process can help developers gain such an understanding (Cui and Wu, 2016). For example, customer closeness, i.e. “the practice of keeping close contact with customers, to communicate with customers effectively, and to understand customers’ individual needs” (Tu et al., 2004, p. 150), has been positively linked to the implementation of modularity-based manufacturing practices (Tu et al., 2004). Similarly, co-production has proved beneficial to modular software design, such as service-oriented architecture (Ordanini and Pasini, 2008). However, existing studies have thus far stopped short of providing a more nuanced view, i.e., exploring the influence of different mechanisms of customer knowledge integration and accounting for environmental contingencies. We seek to fill this gap in the literature by addressing the question of how different forms of customer involvement interact with market and technological turbulence and how this impacts the implementation of modular architectural design of software in digitized products. We thereby draw upon theories of modularity (e.g., Schilling 2000) as well as insights on customer involvement from information systems (IS) and new product development (NPD) literature. Our research thus follows calls in the literature, highlighting the need for an interdisciplinary approach (Namibian, Wright and Feldman, 2019). Integrating existing concepts and knowledge from IS and NPD thereby allows us to generate novel insights.

Our study contributes to IS research in several ways. First, we add to the growing body of research discussing modularity as a design strategy for digitized products (Namibian, 2003, 2013; Henfridsson, Mathiasen and Svahn, 2009, 2014; Yoo et al., 2012). While extant literature widely acknowledges modularity’s benefits, less empirical evidence exists with regard to its implementation. This cross-sectional survey study therefore focuses specifically on antecedents of modularity. Our second contribution lies in empirically testing research propositions related to Schilling’s (2000) general modular systems theory-building paper. Specifically, we extend the related discussion by investigating environmental factors’ effectiveness in driving modularity through their interaction with customer involvement. Furthermore, inconsistent findings in previous studies suggest contingencies in the effectiveness of customer involvement in NPD (Cui and Wu, 2017, 2018). Thus, our third contribution is the identification of such boundary conditions in the context of implementing modular design in digitized products. In particular, we answer calls to investigate how environmental conditions “such as market and technological uncertainty may affect whether involving customers introduces unmanageable ambiguity” (Cui and Wu, 2017, p. 76).

2 Theoretical background and hypotheses development

2.1 Customer involvement as a driver of modularity

It has been widely discussed, that modular design is beneficial for firms operating in today’s dynamic environments, as it enhances strategic flexibility (Sanchez and Mahoney, 1996; Baldwin and Clark, 2000; Schilling, 2000; Worren, Moore and Cardona, 2002). The concept of modularity is grounded in Simon’s (1962) premise that complex systems are composed of distinct, interacting subsystems, that are to a certain extent independent and interdependent (Karim, 2006; Tiwana, 2008b). While elements within each module are highly interdependent, relationships between modules are characterized by a high degree of independence. Changes in one module therefore do not require changes in another (Baldwin and Clark, 2000). Modules can be designed independent of one another but will still support the system as a whole (Parnas, 1972). The afforded possibilities for flexible recombination of components make modular systems easy to adapt and upgrade (Schilling, 2000). This increases their desirability in dynamic environments, where there is pressure on firms to provide a wide range of different options to address changing customer demands and to incorporate a diverse and changing set of components into products (Schilling, 2000; Kotabe, Parente and Murray, 2007). A single, integrated solution is unlikely to meet the demands of such environments (Schilling, 2003).
Despite broad acceptance of modularity’s benefits (Simon, 1962; Schilling, 2000), considerably less is known about factors driving its implementation. One notable exception identifies customer closeness, i.e., “the practice of keeping close contact with customers, to communicate with customers effectively, and to understand customers’s individual needs” (Tu et al., 2004, p. 150), as an antecedent of modularity. To further investigate the mechanisms by which interaction with customers contributes to the implementation of modular design of digitized products, this study follows Cui and Wu (2017) in distinguishing two forms of customer involvement: customer involvement as an information source (CIS) and customer involvement as co-developers (CIC). With CIS, customers play a passive role in providing information and are not directly involved in the product development process. To gather information about customers’ wants and needs, organizations conduct marketing research, such as market surveys, interviews and focus groups. Information on needs is then transferred to NPD (New Product Development) teams, where digitized products, their development continues even after launch (Nambisan et al., 2017). Frequent and continuous customer involvement thus offers the potential to identify how such needs diversify and change over time. Hence, CIS and CIC may alert organizations to the need for modularity at any stage in the development process, even after market launch. Thus, we hypothesize:

**Hypothesis 1:** CIS positively relates to modularity in products’ software architecture.

**Hypothesis 2:** CIC positively relates to modularity in products’ software architecture.

### 2.2 The role of environmental contingencies

The value of customer involvement lies in helping organizations accurately determine the need for modularity (Tu et al., 2004). According to Schilling (2000), who draws upon systems research from various disciplines to build a general modular systems theory, this need is created by environmental factors within the system’s context. In particular, she identifies two environmental factors, heterogeneity of demand and heterogeneity of input as having a direct, positive effect. Heterogeneity of demand thereby refers to diversity in customer needs (Schilling, 2000). This is the case in turbulent markets, where the composition of customers and their preferences changes at high rates and products must continuously be modified to meet changing customer needs (Jaworski and Kohli, 1993). Heterogeneity of input refers to the “diversity of technological options available” (Schilling, 2000, p. 2000). Technological turbulence, i.e. high rates of change of technology in an industrial or market environment, can increase the number of technological options available as well as suddenly render existing technologies less useful (Jaworski and Kohli, 1993; Danneels and Sethi, 2011). Both market and technological turbulence require systems to flexibly adapt, enhancing the value of modularity (Schilling, 2000). However, we argue, that their individual interactions with CIS and CIC produce contingencies that influence the effectiveness of both forms of customer involvement.

Translating diverse customer knowledge into successful products is challenging (Cui and Wu, 2017). In turbulent markets, where customer demands change frequently, knowledge transfer is particularly difficult (Von Hippel and Katz, 2002; Cui and Wu, 2016). With CIS, information gathered from customers may alert organizations to the need for modularity. However, CIS represents a discrete form of interaction between customers and NPD employees, meaning that it is limited to one time inquiry made by the firm, whose key challenge thereby is “how to fully understand and utilize customer inputs” (Cui and Wu, 2017, p. 66). Limited interaction makes it hard for developing teams to prioritize and clarify when confronted with conflicting information (Olsson and Bosch, 2014). Under conditions of high market turbulence information provided by customers about their needs is likely to be...
conflicting (Jaworski and Kohli, 1993). As a result, confusion and uncertainty may arise regarding the design of modularity, decreasing the chances of CIS leading to its implementation. This is especially relevant for software development, where the tacitness of needs can make their translation particularly challenging (Olmos-Sánchez and Rodas-Osollo, 2017). In this regard, Olsson and Bosch (2014) highlight the problem of the open loop, where insufficient transformation of information from the customer to development teams leads to issues in software development. With CIC, frequent interaction between customers and NPD employees over an extended period of time does enable clarification of needs (Knudsen, 2007). In the context of software development, such active participation can be particularly effective (Kaulio, 1998; Kabbedijk et al., 2009). However, the number of customers that will provide feedback is limited, bearing the danger of a focus on customized solutions (Alam, 2006; Blazevic and Lievens, 2008). Under conditions of high market turbulence, where customer demands change frequently, responding to conflicting customer needs identified through CIC poses challenges for and binds resources of development teams. This diverts attention from implementing modular design and, like with CIS, creates confusion and uncertainty. Therefore, we hypothesize:

**Hypothesis 3a:** The positive effect of CIS on modularity in products’ software architecture is weaker under high levels of market turbulence.

**Hypothesis 3b:** The positive effect of CIC on modularity in products’ software architecture is weaker under high levels of market turbulence.

Previous research has demonstrated that the benefits of involving customers in NPD are especially pronounced in technologically turbulent environments (Chang and Taylor, 2016). MacCormack, Verganti and Iansiti (2001) for example, describe that in such environments, the main challenge for software developing firms is learning “about new technical solutions and their potential application” (p.137). They find that customer feedback thereby helps to improve project performance (MacCormack, Verganti and Iansiti, 2001). Diverse technological options can cause customers to demand more flexible solutions (Schilling, 2000). They can also render existing technologies less useful (Danneels and Sethi, 2011). Both of these factors enhance the value of integrating customer knowledge to implement modularity (Schilling, 2000). With CIS, firms control which type of information customers provide (Cui and Wu, 2017). By asking the right questions, firms can thus learn from customers how exactly their needs are changing as a result of rapid technological change (Chang and Taylor, 2016). Despite the potential open loop problem (Olsson and Bosch, 2014), we argue that this provides an opportunity to gather specific information, that may guide organizations in the implementation of modular design in their products’ software architecture. Technological turbulence also increases the value of CIC, as firms can benefit not only from customers’ knowledge about their needs but also possible solutions (Lilien et al., 2002; Piller and Walcher, 2006; Chang and Taylor, 2016). Existing literature in this regard has highlighted benefits of co-development in modular IS design. It thereby draws attention to the opportunity for obtaining frequent feedback on technological options, the design of individual modules as well as the system as a whole (Ordanini and Pasini, 2008). Therefore, we hypothesize:

**Hypothesis 4a:** The positive effect of CIS on modularity in products’ software architecture is stronger under high levels of technological turbulence.

**Hypothesis 4b:** The positive effect of CIC on modularity in products’ software architecture is stronger under high levels of technological turbulence.

### 3 Method

#### 3.1 Sample and data collection procedure

In line with prior studies focused on modular product architecture (Jacobs, Vickery and Droge, 2007; Tiwana, 2008a) we conducted a cross-sectional survey study. We devised an online survey including all constructs relevant to the research model. Given the nature and objectives of our research, we chose
senior information technology (IT) and research and development (R&D) managers (e.g., Chief Information Officers or IT and product development heads) as key informants. Following existing literature on customer involvement (e.g., Cui and Wu 2017) we included a diverse set of industries to enhance generalizability of results. Nonetheless, we chose only industries for which digitalization is said to play an important role (Westerman et al., 2012; Bosch-Sijtsema and Bosch, 2015). We focused on German organizations, which we identified using the data base NexisUni. The majority of our sample is made up by firms operating in IT (34%), financial services (12%), automotive and related industries (11%), electronics (10%) and mechanical engineering (10%). Further fields include retail, telecommunications, and health-related industries, such as MedTech. Targeted organization had at least 50 employees, as this increases the likelihood of them having a dedicated NPD or IT department.

Our response rate was 11.12%, resulting in 244 completed surveys. We included only companies that conduct product development inhouse, resulting in 67 responses being dropped. Another 7 responses were dropped based on latent constructs not being answered sufficiently. For observations missing less than 10% of values, data was imputed by mean for numerical and by median for categorical variables. Our final sample consists of 170 responses. 53% of respondents are heads of IT or NPD departments, 27% are board members and 20% are project leaders or other employees. Respondents have, on average, 18 years of IT-related experience, 13 years of experience related to product development, and 13 years of firm tenure. To ensure adequacy and clarity of our survey, we pre-tested it with practitioners and academics. In addition, respondents were assured that they would remain anonymous and the validity of all answers was highlighted (Podsakoff et al., 2003). Choosing senior management in NPD and IT functions ensures that respondents are knowledgeable with regard to the firm and this study’s questions (Carlo, Lytyinen and Rose, 2012). In addition, respondents were asked to self-assess their knowledge on modularity of products’ software architecture as well as product developing capabilities within their firm on a seven-point Likert scale. The means of 5.21 and 5.47 respectively, provide validation for our study’s use of the single-informant approach (Schilke, 2014). In addition, we also conducted several tests to ensure that there is no potential bias before testing our hypotheses.

3.2 Measures

We operationalized all variables relying only on established measurement scales. Our dependent variable, modularity, measures the degree to which software incorporated across a firm’s products exhibits modularity. We borrow from Tiwana (2008b), whose construct of technological modularity examines the relationship between firms’ software systems. We confirmed the items’ suitability for the context of products’ software architecture with multiple IT experts, e.g. project leads in the software solution space, solution architects, and IT consultants. Moreover, we used their input, to adapt the introductory question to fit our study’s context. For our independent variables, we include two types of customer involvement, CIS and CIC. The items for both are adopted from Cui and Wu (2017). Finally, our moderating variables market turbulence and technological turbulence, relate to dynamism in the environment. They are measured using items previously defined by Jaworski and Kohli (1993). All latent constructs are measured using seven-point Likert-scales. Control variables at the firm-level were also included (R&D intensity, B2B or B2C focus and high-tech or low-tech focus).

4 Results

4.1 Validity and reliability

To establish validity and reliability of latent, reflective measures we conducted a confirmatory factor analysis. Table 1 presents correlations for all variables. As is also shown in table 1, AVEs of the multi-item constructs surpass the common threshold of 0.5 and all composite reliabilities exceed the threshold of 0.7 (Bagozzi, Yi and Phillips, 1991; Hair et al., 2014). Discriminant validity is established using the Fornell and Lacker (1981) criterion. Our model also demonstrated good fit (χ²/df = 1.65, CFI = 0.97, SRMR = 0.05, RMSEA = 0.06, PClose = 0.16).
<table>
<thead>
<tr>
<th>First-order factor</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
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<td>(1) Modularity</td>
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<td></td>
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<tr>
<td>(2) CIS</td>
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<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Market turb.</td>
<td>0.18**</td>
<td>0.28***</td>
<td>0.20**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Technol. turb.</td>
<td>0.18**</td>
<td>0.19**</td>
<td>0.21***</td>
<td>0.47***</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) R&amp;D intensity</td>
<td>0.05</td>
<td>0.27***</td>
<td>0.22***</td>
<td>0.07</td>
<td>0.05</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) B2B or B2C focus</td>
<td>0.00</td>
<td>0.14*</td>
<td>0.19*</td>
<td>-0.02</td>
<td>0.03</td>
<td>0.12</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>(8) High- or low-tech</td>
<td>0.15*</td>
<td>0.28***</td>
<td>0.18**</td>
<td>0.12</td>
<td>0.27***</td>
<td>0.19**</td>
<td>0.20***</td>
<td>1.00</td>
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<tr>
<td>AVE</td>
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<td>0.69</td>
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<td>0.57</td>
<td>n.a.</td>
<td>n.a.</td>
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<tr>
<td>CR</td>
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<td>0.87</td>
<td>0.89</td>
<td>0.87</td>
<td>0.87</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Note: Pearson correlation coefficients. * p < 0.1; ** p < 0.05; *** p < 0.01. Two-tailed significances.

Table 1. Correlations

4.2 Hypothesis testing

To test our hypotheses we used ordinary least squares (OLS) regression analysis. All independent moderating variables were mean-centered before entering them into the regression analyses (Aiken and West, 1991). Tables 2 and 3 show the preliminary results of the regression analyses. Including CIS and CIC in a single model would likely produce biased regression coefficients due to multicollinearity. To assure that multicollinearity between CIS and CIC is not an issue in our analysis, we conducted regression analyses including their interactions in separate models, as is a commonly used practice (Ray, Muhanna and Barney, 2005; Wiengarten et al., 2013). For each independent variable separately, Models 1 (CIS) and 4 (CIC) include only controls. In Models 2 (CIS) and 5 (CIC) linear direct effects are added, and finally Models 3 (CIS) and 6 (CIC) also contain interaction effects. Consistent with hypotheses 1 and 2, CIS (b = 0.17, p = 0.07) (Model 2) and CIC (b = 0.13, p = 0.05) (Model 5) were positively related to modularity of products’ software architecture. Hypotheses 3a and 3b suggest that the positive effect of CIS and CIC respectively, is weaker under conditions of high market turbulence. Despite being in the hypothesized direction, the interaction of CIS and market turbulence in Model 3 had no significant effect. Hypothesis 3a is therefore not supported. In Model 6, the coefficient for the interaction term of CIC and market turbulence was significant and in the hypothesized direction (b = -0.09, p = 0.05). This provides support for hypothesis 3b. Hypotheses 4a and 4b state that high levels of technological turbulence strengthen the positive effect of CIS and CIC respectively. The interaction of CIS and technological turbulence in Model 3 also had no significant effect, albeit being in the hypothesized direction. Our data thus does not provide support for hypothesis 4a. In Model 6 however, the interaction term of CIC and technological turbulence was significant and in the hypothesized direction (b = 0.15, p = 0.03), supporting hypothesis 4b. With regard to control variables, technological intensity had a significant impact on modularity. Overall, our results suggest that only CIC interacts with environmental factors in a manner that produces a significant effect on the implementation of modularity in products’ software architecture. Post-hoc analyses confirmed our initial findings.
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<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
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<tbody>
<tr>
<td><strong>Controls</strong></td>
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<td></td>
<td></td>
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<tr>
<td>R&amp;D intensity</td>
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<td>-0.00 (0.05)</td>
<td>-0.01 (0.05)</td>
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<td>-0.24 (0.33)</td>
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<td>High- or low tech</td>
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<td>0.26 (0.24)</td>
<td>0.25 (0.25)</td>
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<td><strong>Main effects</strong></td>
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<tr>
<td>CIS</td>
<td>0.21** (0.09)</td>
<td>0.17* (0.09)</td>
<td>0.14 (0.10)</td>
</tr>
<tr>
<td>Market turbulence</td>
<td>0.07 (0.08)</td>
<td>0.08 (0.08)</td>
<td></td>
</tr>
<tr>
<td>Technological turbulence</td>
<td>0.11 (0.10)</td>
<td>0.12 (0.10)</td>
<td></td>
</tr>
<tr>
<td><strong>Moderating effects</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CIS x Market turbulence</td>
<td></td>
<td>-0.08 (0.07)</td>
<td></td>
</tr>
<tr>
<td>CIS x Technological turbulence</td>
<td></td>
<td>0.07 (0.09)</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>4.40*** (0.49)</td>
<td>4.52*** (0.50)</td>
<td>4.53*** (0.50)</td>
</tr>
<tr>
<td>R-squared</td>
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<td>0.07</td>
<td>0.08</td>
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<tr>
<td>Adjusted R-squared</td>
<td>0.03</td>
<td>0.04</td>
<td>0.04</td>
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</table>

Note: Unstandardized coefficients; standard errors in parentheses; *** p ≤ 0.01 ** p ≤ 0.05 * p ≤ 0.10

Table 2. Results of regression analysis: effect of environmental factors and CIS on modularity in products’ software architecture

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
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<td><strong>Controls</strong></td>
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<tr>
<td>R&amp;D intensity</td>
<td>-0.00 (0.05)</td>
<td>-0.00 (0.05)</td>
<td>-0.01 (0.05)</td>
</tr>
<tr>
<td>B2B vs B2C focus</td>
<td>-0.38 (0.33)</td>
<td>-0.34 (0.33)</td>
<td>-0.19 (0.33)</td>
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<td>High- or low tech</td>
<td>0.40* (0.23)</td>
<td>0.32 (0.24)</td>
<td>0.32 (0.24)</td>
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<tr>
<td><strong>Main effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIC</td>
<td>0.15** (0.06)</td>
<td>0.13* (0.07)</td>
<td>0.13** (0.07)</td>
</tr>
<tr>
<td>Market turbulence</td>
<td>0.08 (0.07)</td>
<td>0.07 (0.07)</td>
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</tr>
<tr>
<td>Technological turbulence</td>
<td>0.10 (0.11)</td>
<td>0.12 (0.11)</td>
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</tr>
<tr>
<td><strong>Moderating effects</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CIC x Market turbulence</td>
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<td>-0.09* (0.05)</td>
<td></td>
</tr>
<tr>
<td>CIC x Technological turbulence</td>
<td></td>
<td>0.15** (0.07)</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>4.36*** (0.48)</td>
<td>4.48*** (0.49)</td>
<td>4.34*** (0.49)</td>
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<tr>
<td>R-squared</td>
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<td>0.11</td>
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<tr>
<td>Adjusted R-squared</td>
<td>0.04</td>
<td>0.05</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Note: Unstandardized coefficients; standard errors in parentheses; *** p ≤ 0.01 ** p ≤ 0.05 * p ≤ 0.10

Table 3. Results of regression analysis: effect of environmental factors and CIC on modularity in products’ software architecture

5 Discussion

5.1 Theoretical and managerial implications

By integrating concepts from NPD and IS in an interdisciplinary approach (Nambisan, 2003, 2013; Nambisan, Wright and Feldman, 2019), we make several theoretical contributions. We shed light on antecedents of modularity, a previously underresearched topic. In particular, our study builds upon and extends insights from modularity literature, which has identified the integration of customer knowledge (Tu et al., 2004) and environmental factors (Schilling, 2000) as drivers of modularity. We
examine both drivers in the context of digitized products and find that, despite their individual positive contribution, their interaction does not necessarily increase the level of modularity implemented. By investigating the interaction of CIS and CIC with market and technological turbulence, this study thus identifies contingencies regarding the effectiveness of customer involvement for the implementation of modular design. In particular, our data shows that in technologically turbulent environments, involving customers increases the degree of modularity implemented, whereas it lessens the degree in markets characterised by frequently changing customer demands. The inclusion of market and technological turbulence further allows us to test relationships theorized by general modular systems theory (Schilling, 2000). We thereby provide empirical support and add nuance to related discussions. Our study also offers important insights for practitioners considering product design in today’s digital world. The relevance of modular IS design in today’s dynamic and uncertain environment is undeniable. This is reflected in the increasing efforts firms direct towards implementing modularity in software, such as service-oriented architecture and more recently microservice architecture (Choi, Nazareth and Jain, 2010; Baškarada, Nguyen and Koronios, 2018). Despite being aware of the potential benefits such design offers, factors influencing its successful implementation remain unclear to many firms. Our findings draw attention to the fact, that the effectiveness of customer involvement cannot be determined independent of environmental conditions in which a firm operates. Environmental conditions may indeed influence to what extent customers should be involved.

5.2 Limitations and areas for further research

Despite its contribution, our study naturally faces some limitations. These provide opportunities for future research. First, while our study finds that customer involvement’s effectiveness for the implementation of modular software architecture in digitized products is contingent upon environmental factors, it does not consider CIS and CIC in a single model, due to strong correlations between the two. Exploring different forms of customer involvement in a single model as well as integrating alternative sources of information, such as competitors, suppliers or other channel members (Barringer and Bluedorn, 1999), through environmental scanning offers promising avenues for further work. Second, our research does not distinguish between different stages of the development process at which customer involvement may occur. Existing literature has established, that the timing of customer involvement influences its effectiveness (Chang and Taylor, 2016). Future research could therefore examine the impact of different methods of customer knowledge integration at the idea generation phase, compared to later phases. In doing so, it must consider that with digitized products, changes to architectural design can be implemented even after the product has been launched (Yoo et al., 2012; Nambisan et al., 2017). Third, we control for a B2B versus B2C focus, but do not explicitly consider individual customer characteristics. Narrowing the scope in this regard also presents opportunities to investigate aspects such as the previous relationship between the firm and its customers as well as specific solution-related knowledge customers may have. Finally, investigating firms of different size and age may also generate valuable insights. For example, studies may focus specifically on start-ups or small-to-medium enterprises.
References


