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## Joining supply and demand conditions of IT enabled change: toward an economic theory of inter-firm modularisation

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Judith Gebauer\*

Department of Information Systems and Operations Management,  
Cameron School of Business,  
University of North Carolina Wilmington,  
Wilmington, NC 28403-5920, USA  
Email: gebauerj@uncw.edu  
\*Corresponding author

Joseph T. Mahoney

Department of Business Administration,  
College of Business,  
University of Illinois at Urbana-Champaign,  
Champaign, IL 61820, USA  
Email: josephm@illinois.edu

**Abstract:** This paper examines emergent information systems and technologies and explains under what supply and demand conditions inter-firm modularisation of information-based products and services and subsequent vertical de-integration of organisations is more likely. Research in organisational economics identifies transactional attributes such as coordination costs, asset specificity, and the economic non-separability problem to help explain and predict vertical de-integration. We extend this perspective by considering the modularisation of information-based products and services that is noticeable to the customer to develop a framework that joins the four cornerstones of (a) transaction-related efforts; (b) commitment-related contractual risks; (c) measurement-related contractual risks; and (d) modularisation-related impacts on value.

**Keywords:** information technology; modularisation; vertical de-integration; contractual risk; information-based products and services; transaction cost economics; coordination; asset specificity; non-separability problem; consumer economics.

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**Biographical notes:** Judith Gebauer is an Associate Professor of Information Systems at the University of North Carolina Wilmington. She holds both master and doctoral degrees from the University of Freiburg, Germany, and has held positions at the University of Illinois at Urbana-Champaign and at the University of California, Berkeley. Her research focuses on the design, management, and implications of business information systems. Her work has

been published in such journals as *Decision Support Systems*, *Journal of Information Technology*, *Journal of the Association for Information Systems*, and *Communications of the ACM*.

Joseph T. Mahoney received his BA, MA, and PhD from the University of Pennsylvania, with a Doctorate in Business Economics from the Wharton School of Business. He joined the College of Business of the University of Illinois at Urbana-Champaign in 1988, and is currently the Caterpillar Chair in Business, and Director of Research for the Department of Business Administration. In 2011 he received the Irwin Outstanding Educator Award from the BPS Division of the Academy of Management. In 2012 he was elected as a member of the Academy of Management Fellows. In 2013 he was elected as a Strategic Management Fellow.

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## 1 Introduction

This research seeks to explain the differential impacts across industries of the modularisation of information-based products and services as a result of the application of modern IT and internet-based standards for data and communication. In particular, we consider contemporary information systems and technologies and the firm-level supply-side and consumer-level demand-side conditions that will likely influence the modularisation of information-based products and services, and the vertical de-integration of organisations.

Extant theoretical and empirical literature considers the impact of changes in information technology on organisational scope and structure (Afuah, 2003; Hitt, 1999). In some cases, information technology has been shown to reduce organisational scope and increase vertical de-integration (e.g. Brynjolfsson et al., 1994; Malone et al., 1987), while in other cases information technology has led to greater organisational scope and vertical integration (e.g. Clemons et al., 1993; Gurbaxani and Wang, 1991).

Traditionally, research has considered the decision making of *one* organisation responsible for various parts of its value chain and final product, be it as part of internal operations or through external procurement and outsourcing. An important – albeit typically implicit – assumption is that the *final product and scope of the product portfolio remain unchanged from the point of view of the end-buyer* even as the product itself may become increasingly modular, and the value chain may become increasingly vertically de-integrated. Thus, the current paper seeks to build upon and extend the organisational economics approach to product modularisation and vertical de-integration (e.g. Lajili and Mahoney, 2006; Mukhopadhyay and Kekre, 2002), which focuses primarily on supply-side factors, and to highlight the decisions by *individual* buyers of end-products or services, as is often the case with information-based and -enabled products and services. In so doing, we join organisational economics (e.g. Mahoney, 2005; Williamson, 1985), which emphasises value chain decisions from a focal firm's point of view, with consumer economics with its emphasis on individual consumers' decisions and their responses to bundling and pricing (Bakos and Brynjolfsson, 2000; Bakos et al., 2005), and mass customisation (Priem et al., 2012; Stremersch et al., 2003).

Information systems research that builds on organisational and consumer economics has considered the conditions and implications of modular versus integrated designs of products (Baldwin and Clark, 2000; Staudenmeyer et al., 2005). In the context of information technology, this research has identified two key changes: (a) many products and services are now based on information, and use data standards to enable readily available combinations of individual modules to be organised as an integrated whole (Bakos et al., 2005; Shapiro and Varian, 1999); and (b) this shift towards product modularisation and the re-combination of modules into an integrated whole often shifts decision making from the firm to the individual end-consumer (Schilling, 2000).

The current paper thus considers changes in information technology (Lanzolla and Suarez, 2010; Orlikowski and Iacono, 2001) that impact the modularisation of information-based products and services that is noticeable to end-customers, and thereby impact organisational scope and the extent of vertical de-integration. In the next section, we provide a value-based research framework that combines three transactional attributes – i.e. coordination costs, asset specificity and economic non-separability – that influence the design and modularisation of information-based products and services, and hence the extent of vertical de-integration (Park and Ro, 2013; Zaheer and Venkatraman, 1994). We extend this value-based framework by combining the four cornerstones of (a) transaction-related efforts; (b) commitment-related contractual risks; (3) measurement-related contractual risks; and (d) modularisation-related impacts on value. The third section incorporates a consumer (demand-side) perspective. The final section offers a discussion and conclusions.

## **2 Supply-side: a value-based framework to explain and predict modularisation and vertical de-integration of information-based products and services**

Product modularisation refers to changes in the internal structure of products and services from an integrated entity to a structure that allows for the clear distinction of separate parts that can be traded efficiently in a market. Product modularisation can be planned and coordinated centrally within an organisation, or can be emergent, which often occurs in decentralised settings through the actions of many (quasi-independent) participants and without central coordination (Langlois, 2002). This current paper largely focuses on emergent (i.e. market-based) modularisation processes that are supported or enabled by IT (Zammuto et al., 2007).

Modularity has been described as the “degree to which a system’s components can be separated and recombined” (Schilling, 2000, p.315), which is often related to the degree to which a system conforms to interface standards (Sanchez and Mahoney, 1996; Wilson et al., 1990). The extent of product modularisation is thought to be influenced by economic factors such as market size, inter-firm diffusion of technology and the evolution of interface standards (Christensen et al., 2002; Stigler, 1939; Wilson et al., 1990) in particular in combination with concepts such as information hiding, which have long been used in computer science (Parnas, 1972).

IT plays a key role as it allows for the separation of physical products and services on the one hand and information on the other hand, and results in differing requirements of economic value-adding activities in physical versus virtual business environments (Hagel

and Singer, 1999). There is considerable evidence of product modularisation in industries that are manufacturing-related (Baldwin and Clark, 2000). However, even though many information-based products and services are now available electronically and can be offered as distinct components, for example via internet-based web service platforms, inter-firm product modularisation has not followed a uniform and predictable pattern in terms of speed and quality (Cacciatori and Jacobides, 2005) across industries where information is a major part of the product or service, such as real estate (Sawyer et al., 2003), financial services (Markus et al., 2006), music (Anand and Cantillon, 2004), software (Demirkan and Goul, 2006), and travel (Chircu et al., 2001). Among the suggested reasons that hinder the diffusion of product modularisation and greater vertical de-integration are: organisational inertia and path dependencies (Argyres and Liebeskind, 1999), continued economic benefits for organisations and individuals associated with product bundling (Bakos et al., 2005), a lack or immaturity of adequate component interfaces (Shapiro and Varian, 1999), and various counter-measures by incumbents to preserve an existing competitive advantage (Schilling, 2000).

Organisational economics has traditionally been concerned with the scope of the firm (Coase, 1937; Williamson, 1975) based on a discriminating alignment of transaction characteristics and governance structures to achieve comparative efficiency (Williamson, 1996), which can then lead to competitive advantage (Kim and Mahoney, 2006; Lado and Zhang, 1998). Consistent with a majority of empirical findings, we posit a fit between modular products and services and modular organisations (Sanchez and Mahoney, 1996; Sosa et al., 2004), in the sense that modular products and services tend to be more vertically de-integrated (Hoetker, 2006; Jacobides, 2005; Jacobides and Billinger, 2006). The current paper extends this framework to also consider the scope of the product portfolio that an organisation produces, and the opportunity for new firms to enter a market with a focus on producing and selling one or several modules, and for consumers to obtain a formerly integrated product or service through multiple separate transactions.

Organisational economics generally seek to explain and predict changes in governance structures and the boundaries of the firm based on transaction-related characteristics, such as asset specificity (Williamson, 1985) and the non-separability problem (Alchian and Demsetz, 1972). The next section builds on the efficiency perspective and considers that inter-firm product modularisation can impact transactional value (Zajac and Olsen, 1993). For each of the four cornerstones, we discuss the role that IT might play for developments towards modularisation.

### *2.1 Cornerstone 1: transaction-related efforts (coordination costs) and the role of IT*

Business *transactions* are defined as the exchange of goods and services in a business environment, which typically includes search, negotiation, exchange and post-transaction activities that require certain efforts and costs (Coase, 1937; Williamson, 1975). Even when incentives are aligned, substantial coordination costs are typically still to be expected (Foss, 2011; Kim and Mahoney, 2005). Effective coordination requires the management of interdependencies (Malone and Crowston, 1994; Schepker et al., 2014) and can be achieved through the exchange of information (e.g. based on written documents or verbal communication) and data transfer (e.g. based on structured reports).

Internal coordination costs represent the economic costs incurred for various activities intended to manage interdependencies *within* a firm. Internal coordination typically requires establishing internal management procedures, hierarchical protocols, and routines (Becker and Murphy, 1992; Leiblein, 2003), as well as operational activities for administration and planning (Im et al., 2013). In contrast, external coordination costs stem from the complexity and efforts associated with the management of modular organisational structures, sales, and market procurement, and result in the need to establish and maintain relationships with business partners, customers and suppliers, and to conduct multiple market transactions, including activities, such as search, negotiation and exchange (Gurbaxani and Wang, 1991; Schepker et al., 2014). Efforts to coordinate a system, such as an organisation, tend to increase with the size and complexity of the system as a result of the increasing numbers of both the elements that are part of the system and the relationships between the elements (Simon, 1962). The efficient level of product modularisation and thereby the efficient boundary of the firm (i.e. the efficient level of vertical de-integration) are affected by trading off external and internal coordination costs (Clemons et al., 1993; Malone et al., 1987).

*The role of IT:* IT can help reduce costs of both internal and external coordination, and some forms, such as electronic mail, instant messaging, or video conferencing, are so generic in their support of primarily unstructured communication that they seem to support internal and external forms of coordination equally well (Hinds and Kiesler, 1995; Markus, 1994). Internal coordination costs in particular can be reduced by improving the quality and speed of information processing and managerial decision making within the firm, thus improving the efficiency of centralised management structures (Malone et al., 1987). Notable forms of IT applied in integrated organisational settings, include Enterprise Resource and Planning (ERP) systems as comprehensive transaction management applications that join many kinds of information processing abilities into a single database (Akkermans et al., 2003; Maybert et al., 2003). ERP systems can improve operational efficiency (Jasperson et al., 2005; McAfee, 2002), as they facilitate the management and transparency with which resources flow through the organisation, including production material, financial information (accounting), and human resources. In addition, internal coordination is also enabled by IT systems that focus on collaboration and problem solving, including intranet-applications, knowledge management, and group support systems (Alavi and Leidner, 2001; Nunamaker et al., 1996; Sambamurthy and Subramani, 2005). To date, the various technologies that support internal coordination have reached a remarkable level of maturity and diffusion within modern organisations.

In terms of reducing external coordination costs, IT can reduce efforts required to conduct market transactions. Among many examples are systems to facilitate cost-effective access to market information, such as search engines, supplier directories (Österle et al., 2001), and online markets (Bakos, 1991); and interactive systems to enable inter-organisational data exchange, supply management, and online collaboration (Markus et al., 2002). In addition, applications such as online auctions and bidding platforms enable negotiations and transaction settlement (McIntyre and Subramaniam, 2009; Pinker et al., 2003).

The net effect of IT on coordination costs has long been discussed in the information systems literature. Gurbaxani and Whang (1991) suggest that the net effect of IT on firm size varies depending on the cost structure of the firm and the modes of synergy generated by integration, and Sahaym et al. (2007) emphasise the need to include

additional organisational variables to analyse coordination costs. Legner and Schemm (2008) note that substantial IT supports internal coordination (e.g. ERP systems, internal reporting). However, overall the more specific prediction is that of Malone et al. (1987), which predicts that because IT systems generally reduce coordination costs associated with search and communication with transacting parties, they favour external procurement over vertical integration. Other research predicts more outsourcing as part of long-term relationships with a reduced set of suppliers (Ang and Straub, 1998; Loh and Venkatraman, 1992; Steinfield et al., 1995). In a recent longitudinal study, Im et al. (2013) largely corroborate these predictions, and find a bi-directional association between organisational size and information technology. As organisations grow in size, information technology spending increases, but is later followed by a reduction in organisational size, likely indicative of increased outsourcing activities. In Im et al.'s (2013) study, a large part of the interaction was mitigated and explained by coordination costs that first increase as a result of organisational size, but later decrease as a result of increased spending on information technology.

We suggest that a close look at the specific systems and technologies that are available to support coordination and the decisions associated with their development, implementation, and operation can offer important, additional insights: despite the potential benefits, information technology that targets external coordination has in fact been much more difficult to implement than internal systems, largely because of the more decentralised nature of required decision making (Gebauer and Buxmann, 2000). The added complexity might explain the longstanding comparative advantage of *intra*-organisational systems over *inter*-organisational counterparts in terms of technological sophistication and actual use. Still, the focus on systems that explicitly support external coordination is strong and continues to grow for data exchange and electronic market platforms, and to satisfy security concerns and legal requirements, such as Sarbanes-Oxley (Braganza and Desouza, 2006; Phillips and Meeker, 2000). Recent technology frameworks and platforms such as service-oriented architectures have enabled and supported inter-organisational information-based modular products and services (Legner and Schemm, 2008). For example, sophisticated collaboration and trading platforms, such as *Covisint* and *SupplyOn*, have made continued progress in the automotive industry; and innovative, cloud-based and service-oriented architectures enable cost-efficient combinations of software modules from various sources (Gerst and Bunduchi, 2005; Papazoglou and Georgakopoulos, 2003). Our theory development, which builds on and extends previous predictions (Malone et al., 1987), thus leads to our first proposition.

*Proposition 1: Ongoing developments in IT will lower the costs of external coordination relative to internal coordination, which will lead to an increase in the inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.*

## *2.2 Cornerstone 2: commitment-related contractual risks due to asset specificity and the role of IT*

Besides the costs to coordinate complex relationships within and between organisations, costs result from the management of different types of contractual risk that occur when agents act opportunistically (Mahoney, 2001; Williamson, 1975). Transaction costs

theory maintains that contractual difficulties can be anticipated when at least some opportunistic agents engage in transactions of sufficient demand uncertainty and/or technological uncertainty to surpass bounded rationality capabilities (Leiblein, 2003; Simon, 1982). The contractual risk of some opportunistic agents utilising asymmetric information to their advantage – and thus potentially leading to adverse selection, moral hazard, and economic hold-up problems – is high in such business environments; and vertical financial ownership is an adaptive response to this potential inadequacy of market contracting (Mahoney, 2005; Williamson, 1985).

Transaction costs theory emphasises contractual risks that are associated with commitments that a firm makes when investing in various forms of transaction-specific assets, including human, physical, and site asset specificity (Williamson, 1985). Human asset specificity involves uniquely related learning processes and often involves teamwork (Brouthers and Hennart, 2007; Masten et al., 1989). Physical asset specificity includes requirements for specialised machine tools and equipment (Caves and Bradburd, 1988; Leiblein, 2003). Site specificity occurs when unique locational advantages exist, as, for example, when a power plant is located near a coal mining area to save on transportation costs (Dyer and Singh, 1998; Joskow, 1985).

Commitment in the form of unilateral investments in relationship-specific assets can leave a firm vulnerable to an opportunistic business partner. The unified and integrated solution of vertical financial ownership (Lajili and Mahoney, 2006; Mahoney, 1992) is viewed as an organisational choice to mitigate the small-number bargaining problem, since it entails a hierarchical authority relationship and residual rights of control from an incomplete contracting perspective (Bakos and Brynjolfsson, 1993a; Brynjolfsson, 1994; Grossman and Hart, 1986) that is more likely to reduce economic hold-up problems under conditions of asset specificity.

As an alternative, mutual commitments in the form of relationship-specific investments can serve as economic safeguards to substitute for vertical integration in mitigating economic hold-up problems (Williamson, 1996). Alternative forms of mutual commitment related to IT include the voluntary limitation of the number of suppliers in exchange for relationship-specific investments (Bakos and Brynjolfsson, 1993b), and mutual relation-specific investments in IT systems (Kim and Mahoney, 2006). Indeed, the efficient level of product modularisation, and thereby the efficient level of vertical de-integration, is affected by the level of asset specificity in the exchange relationship.

*The role of IT:* To the extent that IT systems reduce transaction risks through reduced relationship-specific investments, theory suggests that higher levels of product modularisation and vertical de-integration can be expected (Clemons et al., 1993; Gurbaxani and Whang, 1991). Generic (non-asset-specific) forms of IT correspond with off-the-shelf components for hardware and software, and open standards for data interchange, such as what is commonly applied in connection with the public internet (e.g. XML-based open standards) (Shapiro and Varian, 1999). With increasing maturity of technology and users, and development and diffusion of open standards, specificity is less prominent, even for advanced and sophisticated IT systems (Legner and Schemm, 2008). One current limit seems to be posed by recent developments, as some vendors, such as Salesforce.com, Microsoft, and Amazon, have been promoting technology-platforms (force.com, Axure, EC2, respectively) that despite their inherently modular architecture are not necessarily compatible with the offerings of the competition. In comparison with older technologies, however, modern applications tend to be web-based,

easier to install, often hosted externally (e.g. cloud-based); easier to learn and use (e.g. graphical user interfaces); and allow for more efficient set-up of new business connections across time and space, which leads to our second proposition.

*Proposition 2: Ongoing developments in IT will lower the level of asset specificity, which thus lowers the contractual risks in the supply chain, which will lead to an increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.*

### 2.3 *Cornerstone 3: measurement-related contractual risks due to non-separability and quality assessment, and the role of IT*

Another type of contractual risk results from problems in measuring output due to asymmetric information among various transactional parties. Organisational economics identifies the problem of non-separability in team production (Alchian and Demsetz, 1972) and of quality-assessment in multi-stage production (Ouchi, 1979). Mahoney (1992) joins elements of transaction cost economics and agency theory to show that reductions in asset specificity and in measurement problems in team production can play an important role in explaining increased vertical de-integration. Here, we focus on reductions in measurement problems. In cases of non-separability, the productivity of an individual team member can be difficult to measure by simply observing the output of the entire team (Coff and Kryscynski, 2011). Vertical integration is suggested as a solution to the extent that it allows for adequate effort (input) control. Vertical de-integration and product modularisation is expected to become more prominent to the extent that it becomes easier to assess individual contributions from observing the output of team production, a prediction that has been corroborated empirically (Poppo and Zenger, 1998). In addition to the *metering problem*, the efficient level of vertical de-integration is also related to the difficulty of assessing the *quality* of intermittent products in multi-stage production (Eisenhardt, 1985; Ethiraj and Levinthal, 2004). Vertical de-integration and product modularisation are more likely to occur in cases where the quality of intermittent products is comparatively easy to assess or becomes easier to assess over time, which is the case for many information-based products and services offered as distinct modules on common platforms. The economic value of integrated products may be considered partly a function of the risks and challenges associated with the correct measurement of the value and quality of individual modules. Agency theory suggests that non-separability and measurement problems can be mitigated cost-efficiently if individual efforts are monitored closely via vertical integration (Alchian and Demsetz, 1972; Barzel, 1982).

*The role of IT:* IT has the potential to reduce risks associated with market transactions in situations of high non-separability, most notably through improved information sharing, mutual monitoring, and evaluation schemes that can be implemented for both inter-firm and intra-firm collaborations (DeSanctis and Gallupe, 1987; Gurbaxani and Wang, 1991). For example, Argyres (1999) describes a case where digital design tools and agreed upon ways to transmit and store data electronically allowed four separate firms to successfully collaborate on the design of a complex military aircraft. The problems of non-separability and quality assessment were mitigated with a product definition system that served to “codify pieces of design data that would have otherwise

left tacit and hence open to interpretation, [whereas the system] provided unambiguous measures of data quality” (Argyres, 1999, p.173). More recent developments include the emergence of web-based and social media tools that support and enable collaboration between the members of a dedicated team or general online community (O’Reilly, 2005); as well as various forms of web services and virtualised IT applications that allow for the combination of individual components into complex offerings of comprehensive services, such as in real estate (owners.com), travel (kayak.com), or retail (amazon.com). While advanced collaboration tools can allow for a more granular assessment of the contributions of individual team members than what was possible before, the use of self-contained applications generally makes it easier to measure the value of individual components as part of more comprehensive offerings. For many products and services, the separation of individual components of a formerly integrated product and their individual assessment will become easier as a result of the use of innovative technologies that have increasingly become available (Jacobides and Billinger, 2006). These ongoing developments in IT lead to our third proposition.

*Proposition 3: Ongoing developments in IT will lower contractual risks associated with non-separability and measurement problems, which will lead to an increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.*

#### *2.4 Cornerstone 4: modularisation-related impacts on the quality and value of products and the role of IT*

For the final cornerstone, we suggest that outcome-related aspects help to explain and predict developments of product modularisation to the extent that they offset transaction-related cost and risks, and thus contribute to a positive net benefit of modularisation. For example, from the perspective of the supply-side, modular designs and design rules enable clear architectures, clean interfaces (Parnas, 1972), and a set of well-specified functional tests of module performance can enhance the quality of physical products (Baldwin and Clark, 2000). Adhering to design rules based on product platforms can support markets for specialised components that can further increase the overall level of product quality (Robertson and Ulrich, 1998; Schilling, 2000) and opens the possibility of innovative combinations through mixing and matching (Baldwin and Clark, 2000; Brusoni and Prencipe, 2001). Such product modularisation is expected to dominate the market to the extent that the resulting level of product quality exceeds the level of quality that is obtained from an integrated design that allows for intricate interaction of individual components (Schilling, 2000), and to the extent that the benefits outweigh the increased complexity associated with the added number of interfaces between components (Ethiraj and Levinthal, 2004; Gill and Kemerer, 1991; Parnas, 1972).

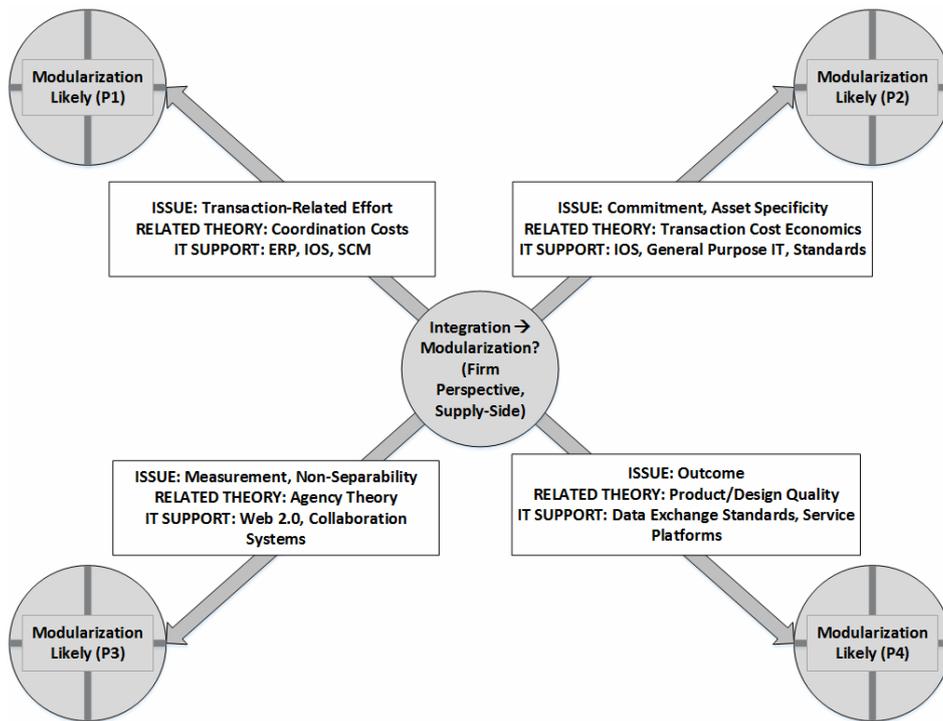
*Role of IT:* Macher et al. (2002) show how well-defined links between specialised applications impact higher production quality in the semiconductor supply chain. Shapiro and Varian (1999) consider how clean and standardised data interfaces support interactions between individual product modules to maintain high overall quality. Legner and Schemm (2008) provide empirical evidence for the continued emergence of standards for product data interchange in the supply chains of retail and consumer goods industries that are expected to increasingly meet inter-organisational coordination

requirements. Companies, such as Owners.com and Kayak.com, provide web-based access to services in real estate and travel, respectively. Both industries have traditionally been dominated by agents that provide integrated offerings. In contrast, the new web-based platforms strive to allow access to specialised service modules by a network of business partners to provide comprehensive and high-quality service and value to customers. In both cases (and many others), the IT platform replaces the role of the agent as an integrator of various service activities into one comprehensive offering. These developments lead to our fourth proposition.

Proposition 4: *Ongoing developments in IT will increase the quality and value of modularised information-based products and service, which will lead to an increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.*

Figure 1 summarises our developed framework, which provides the four cornerstones for explaining – and the four propositions for predicting – when and to what extent there will likely be a development from integration to inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.

**Figure 1** Four cornerstones of product modularisation and vertical de-integration (firm perspective, supply-side)



For each of the four cornerstones, Figure 1 illustrates a key economic *issue* that is associated with the suggested developments towards modularisation, namely transaction-related effort, commitment and asset specificity, measurement and non-separability and

outcome, respectively. Second, it lists a *related theory*, as an area of research that we suggest is particularly well suited to address the developments towards modularisation in relation with each issue, namely the areas of coordination costs, transaction cost economics, agency theory and product/design quality, respectively. Third, it highlights the role of IT by listing types of systems and technologies that we suggest to be particularly supportive of a move towards modularisation (*IT support*). Each of the propositions 1 through 4 refers to the suggested interplay between an issue, a related theory, and IT support for one of the four cornerstones. We suggest that modularisation in a particular context (industry) is determined in sum by the extent to which each of propositions 1 through 4 applies.

### 3 Extending the value-based framework to include a consumer-perspective (demand-side)

In the canonical vertical coordination problem, there is a given product or service of a given quality; and the task is to minimise the sum of production and transaction costs via a comparative assessment of imperfect governance alternatives (Williamson, 1985). Here, we build on and extend this supply-side approach by considering cases where consumers have *different* preference-orderings across vertical coordination arrangements (Adner and Snow, 2010; Priem et al., 2012). On the one hand, heterogeneous consumer groups may value 'mix and match' product and service options (Adner and Levinthal, 2001; Adner and Zemsky, 2006) that become available from vertical de-integration and therefore tend to increase the demand of such modularisation (Sanchez and Mahoney, 1996; Wilson et al., 1990). On the other hand, some product and services modularisation results in consumers becoming 'co-producers' in the production process (Vargo and Lusch, 2004), which can increase the effort required to obtain a complex, modularised product or service, and subsequently dampen demand. Therefore, we suggest that the analysis of recent developments in IT impacting product modularisation and vertical de-integration requires a *value-based approach* that extends organisational economics theories of cost minimisation to consider maximising *transactional value* (Zajac and Olsen, 1993).

For example, we expect a comparatively slow diffusion of modularisation to occur when the benefits from specialisation for the supply-side are offset to a large extent by an increased effort required by customers (demand-side) to obtain and recombine individual components into a comprehensive product or service. This section revisits our four cornerstones from the perspective of the demand-side, whereby we join our framework (Figure 1) with concepts from consumer economics and marketing (for a summary see Figure 2 at the end of Section 3).

#### 3.1 Cornerstone 1: transaction-related efforts (opportunity costs) and the role of IT

An increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration can require the end-consumer to conduct multiple transactions with several vendors, followed by the need to combine the components into an integrated whole. This change could substantially increase

transaction-related efforts on the part of a consumer who now effectively takes on the role of a co-producer (Lusch et al., 2007; Vargo and Lusch, 2004). The question then arises of how this increase in transaction-related efforts will affect consumer behaviour and revenues. Besides potential differences in market power between firms and individual consumers as buyers (Dewan et al., 1998) that can occur with vertical de-integration, a comparative analysis also must take into account the efforts associated with the *combination* (assembly) of individual modules into an integrated whole (Sheth et al., 1991). In particular for complex offerings, such as computer systems (Steffens, 1994) or real estate services (Levitt and Syverson, 2005), it can be difficult for individual consumers to fully recreate the added value of an integrated system or service offering by interfacing individual modules (Schilling, 2000).

Consumer economics emphasises the concept of opportunity costs to explain and predict consumer decision making, and consider the economic value of allocating alternate resources, such as financial assets and time (Becker, 1965). For example, Fox and Hoch (2005) applied the concept of opportunity costs to explain consumer searches for low prices across several grocery stores. Among the factors identified were the value of time, household wealth, travel time to a store, and storage costs in relation to home-ownership. Research on mass customisation, a concept related to our notion of customer-led configuration and component combination, suggests that the complexity associated with custom configuration during the purchasing process is an important factor to explain and predict consumer behaviour (Dellaert and Stremersch, 2005). Transaction-related efforts and opportunity costs associated with increased consumer involvement and multiple transactions can impact consumer behaviour as they potentially limit the economic attractiveness of modularised products and services from an end-consumer's perspective (Bendapudi and Leone, 2003; Kivetz and Simonson, 2003).

*The role of IT:* The impacts of IT on transaction-related efforts (e.g. cognitive, physical, financial) and end-customer behaviour have been considered in business-to-consumer electronic commerce (Bailey and Bakos, 1997), behavioural decision making (Todd and Benbasat, 2000), consumer marketing (Bechwati and Xia, 2003), and consumer-focused markets and auctions (Alba et al., 1997). For example, advances in IT have led to so-called long-tail marketing, where online retailers, such as Amazon and Ebay, provide consumers with a broader range of products and services than what can typically be accommodated in a physical store. From the individual buyer's perspective, transaction-related efforts can be reduced to the extent that the online store covers a larger variety of individual preferences, thus limiting the need to shop at different places (Brynjolfsson et al., 2011; Brynjolfsson et al., 2006).

IT is also applied to business models that include some form of assembly-related effort, such as in mass customisation and the use of self-service tools that are often offered online (Dellaert and Stremersch, 2005; Meuter et al., 2005). Buyers of mass-customised products configure and price a product or service in terms of functions, features, and scope. The available range of customisable products is substantial and growing, including personal computers, cars, backpacks, clothes, and shoes. Research shows that the level of complexity that is associated with mass-customisation and self-service offerings can impact consumer behaviour (Dellaert and Stremersch 2005), which is likely to differ between customer groups (Fox and Hoch, 2005; Meuter et al., 2005).

When assessing the impact of IT on coordination and opportunity costs, one key aspect to consider is the extent to which IT provides common interfaces between individual modules. The efforts required for reconfiguration and assembly can be

substantially reduced when information about characteristics and module prices, and possibly even the modules themselves (Bhattacharjee et al., 2006), is offered via a unified, e.g. web-based, platform featuring reciprocal links and references to a wide range of suitable components and expert information (Bakos, 1997; Brynjolfsson et al., 2006). Examples can be found in advanced online platforms, such as what is available in the real estate (Levitt and Syverson, 2005) and travel service sectors (Chircu et al., 2001) where data that are used for one service (e.g. home search, flight reservation) are automatically transferred to another service (e.g. school information, car rental). IT in general and the internet in particular can limit overall transaction costs from the perspective of the customer, even in the case of multiple transactions, which leads to our fifth proposition.

*Proposition 5: Changes in IT are expected to lower opportunity costs associated with the acquisition and combination of modules by consumers, which will lead to an increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.*

### 3.2 Cornerstone 2: commitment-related contractual risks (switching costs)

Similar to the impact of asset specificity on the relationships between firms, high switching costs can sometimes unexpectedly lock individual consumers in with a particular seller (James et al., 2013; Peteraf, 1993). These customer switching costs have been classified as procedural, financial, and relational (Burnham et al., 2003). Procedural switching costs involve the expenditure of time and effort, and consist of economic, risk, evaluation, learning, and set-up costs as a result of the changed business relationship. Financial switching costs involve the loss of financially quantifiable resources, and consist of benefits-loss and financial-loss costs. Relational switching costs involve psychological costs due to personal- and brand-relationship loss.

Switching costs can be especially high for consumers when switching from *one* integrated product or service and market relationship to *several* distinct (and comparatively smaller) modules and relationships that each require separate initiation, set-up, and development.

*Role of IT:* In cases where users lack the knowledge required to combine modules, intermediaries, such as general contractors or agents, typically emerge and offer individualised help. However, the same role can also be performed by IT that enables quick access and lowers specificity and that can therefore, on net, reduce consumers' contractual hazards and switching costs (Shapiro and Varian, 1999; Steinfield et al., 1995). Examples are generic online commerce platforms (e.g. Amazon, Ebay) and data exchange standards (e.g. XML) that support a multitude of potential transactional relationships. Sophisticated and powerful search engines, tools, and consumer portals have effectively allowed for a unified transaction environment that gives users access to a wide variety of information, products, and services, while limiting the specificity of individual transactions and exchange relationships, which limits switching costs between vendors (Floyd et al., 2007), and supports modularised product offerings in an online environment. These developments have increased consumers' bargaining power (Porter, 1980; Porter, 2001), and lead to our sixth proposition.

Proposition 6: *Changes in IT are expected to lower switching costs and contractual risks from commitments related to the purchase and combination of modules by consumers, which will lead to an increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.*

### *3.3 Cornerstone 3: measurement-related contractual risks (quality assessment and value determination)*

The ability to assess and assure product quality contractually concerns not only firms on the supply-side, but also individual end-consumers on the demand-side. The organisational economics literature emphasises risk-mitigating mechanisms, such as product and service warranties and the use of brand names (Barzel, 1982; Mosakowski, 1993), to reduce the risks associated with the correct assessment of quality. To extend this literature, we consider consumer-oriented research on how product modularisation and subsequent vertical de-integration influence the ability to assess and assure product quality. For example, a vertically integrated firm often provides product and service bundling by offering multiple products or services in a single package for a single price (Schmalensee, 1984). Modularisation and vertical de-integration often leads to unbundling (Wilson et al., 1990) in which the boundaries between individual organisational and product components are initially ill-defined, possibly overlapping, and only are resolved over time (Schilling, 2000). The likely result in such situations in the short-run is an increase in uncertainty about product and service quality.

Additional uncertainty results when individual components need to interact and function well with each other, meaning that the value of service and product components may be different when assessed as stand-alone components than when obtained as an integrated whole (Guiltinan, 1987; Wilson et al., 1990). Uncertainty in value determination can make it difficult for consumers to substitute modularised service models for traditional full-service (integrated) models. However, as we discuss next, changes in IT can help to reduce consumers' quality uncertainty on net, and therefore play a role in developments towards product modularisation and vertical de-integration.

*Role of IT:* The risks associated with quality assessment of consumer goods and services also apply to online environments (Malone et al., 1987). Despite limitations and perceived risks in an online trading environment (Teo and Yeong, 2003), research results show that IT often has a strong positive effect on market transparency, and thus reduces measurement-related contractual risks. End-user-oriented technology innovations have increased market transparency and alleviated the quality assessment problem for products and components that had previously been difficult to describe and evaluate (Lajili and Mahoney, 2006). For example, Levitt and Syverson (2005) show the information advantage held by real estate agents over their clients to be notably reduced as a result of available internet-based information.

Based on the various developments in user-generated content (e.g. reviews) and participation, there is a continuous increase in the range of products and services that can be measured and traded economically in a market at a risk that is acceptable to buyers. A case in point is provided by services, such as real estate, where formerly comprehensive and integrated offerings have been dissected into separate modules that are offered online by new competitors, such as Zillow.com and Owners.com. Individual users now have more choices regarding which part(s) of the formerly comprehensive

service offerings they want to buy into, whereby the online platform and online community can help with measurement and metering problems. These developments lead to our seventh proposition.

*Proposition 7: Changes in IT are expected to lower the risks associated with the assessment and valuation of individual modules by consumers, which will lead to an increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.*

### 3.4 Cornerstone 4: modularisation-related impacts on value (preciseness)

Consumer choice theory emphasises the positive association between the effort that a buyer makes in the purchasing process, such as the search for information on the quality of various product offerings, and the precision of the resulting purchasing decision in satisfying individual preferences (Johnson and Payne, 1985; Stigler, 1961). Product modularisation is considered a likely result in situations where an increase in the preciseness with which consumer preferences are met coincides with an increase in customer-perceived value of the product or service (Alba et al., 1997).

Buyer heterogeneity can therefore be considered an important driver for modularisation since it allows buyers to substitute individual modules and to choose the scope of the product according to individual preferences (Wilson et al., 1990). To the extent that buyer preferences vary, modularisation provides more buyers the opportunity to obtain a product that more precisely matches individual preferences regarding components and scope than what may be possible with a limited number of pre-configured, integrated product offerings (Pralhad and Krishnan, 2008).

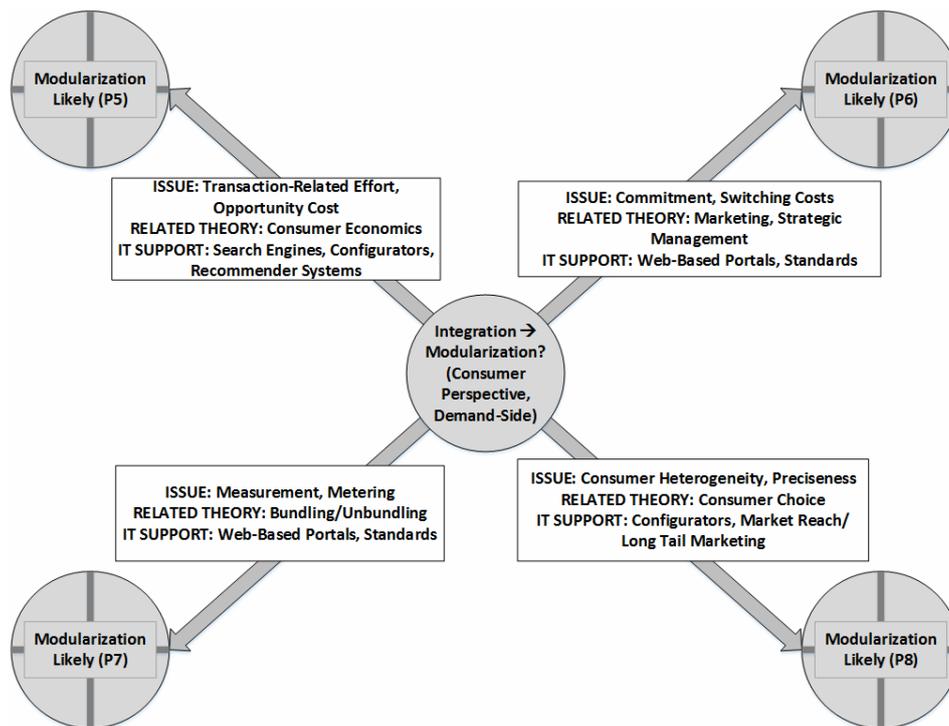
*Role of IT:* IT can play an important role to help increase the preciseness with which customer preferences are met, especially in cases of high customer heterogeneity (Alba et al., 1997). Online platforms can make it convenient for individual consumers to mix and match modular offerings of even complex products and services, and to accommodate a wide variety of tastes without compromising product quality, effort, or cost (Dellaert and Stremersch, 2005). Similarly, internet-based long-tail retail arrangements intend to let heterogeneous customer groups obtain product and service modules that reflect more closely individual tastes and preferences, and thus enable increased precision with which demand is met (Brynjolfsson et al., 2006). Personalisation technologies also play an important role, such as Amazon's collaborative filtering and recommendation system, and Netflix's algorithmic tool for movie preference rankings. These developments thus lead to our eighth, and final, proposition.

*Proposition 8: Changes in IT are expected to increase the preciseness with which modularised products and services can meet heterogeneous buyer preferences, which will lead to an increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.*

Similar to Figure 1 for the firm, Figure 2 summarises the four cornerstones and propositions to analyse modularisation from the perspective of the individual consumer, and illustrates the connections between four economic issues, theory bases, and the role of IT that we suggest play a role in developments from integration to modularisation, as they are relevant to the demand-side. A key point of our framework is that considering both the supply- and demand-sides promises a fuller picture for explaining and predicting

the conditions under which there will likely be an increase in inter-firm modularisation of information-based products and services with a subsequent increase in vertical de-integration.

**Figure 2** Four cornerstones of product modularisation and vertical de-integration (consumer perspective, demand-side)



#### 4 Discussion and conclusions

This paper develops a framework for explaining and predicting the conditions under which there will more likely be an increase in inter-firm modularisation of information-based products and services and a subsequent increase in vertical de-integration. Our developed framework joins the perspective of the firm (see Figure 1) with the perspective of the individual consumer (see Figure 2) to explain and predict an increase in product modularisation and vertical de-integration as a result of recent and expected developments in IT.

In addition to extending and joining extant consumer and organisational economics theory, the current paper's developed framework is intended for practitioner use. In particular, this framework highlights important supply-side and demand-side trade-offs for decision makers to consider. For example, a positive effect from the perspective of the supply-side in terms of savings and advantages from modularisation and specialisation can correspond with a negative effect for the demand-side in the form of

additional required efforts and costs. In order to determine the net effect, decision makers should consider developments with respect to all eight propositions provided here simultaneously.

In summary, this paper presents a *value-based approach* that joins supply-side and demand-side factors to explain and predict the *differential* diffusion of product modularisation and vertical de-integration across industries. We suggest that current developments towards modularisation often coincide with changes in IT capabilities and interface standards and are thus particularly applicable to information-based products and services that are often offered via web-based platforms.

The current paper identifies four distinct issues considered in both organisational and consumer economics, namely: transaction-related efforts, commitment-related contractual risks, measurement-related contractual risks, and impacts on the value of products and services. We propose that the combination of each of the issues and their resulting impacts on modularisation from the perspectives of *both* the firm and the consumer play important roles in shaping the overall developments in a particular market.

This paper should prove fruitful for not only empirical testing of the corresponding eight falsifiable hypotheses of our theory-based propositions, but also could be extended by applying formal modelling and possibly simulation techniques in order to improve our understanding about the multitude of interactions and resulting developments of IT and the impacts on inter-firm modularisation of information-based products and services.

In summary, this paper contributes to both management theory and practice in the context of management information systems. It provides a number of theory-driven propositions that appear promising for further analysis, formal modelling, and empirical testing. We suggest that both explanatory and predictive powers are improved in maintaining a *value-based approach* that joins supply-and demand-side factors. We anticipate that the next generation of research examining IT change and organisational governance will continue to contribute significantly to the advancement and integration of organisation and consumer economics.

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