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Moving towards the incomplete: A research agenda for the development of future products in the digital economy

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Abstract

Pervasive digital technologies are advancing at an exponential rate, changing the nature of products and services as we know them. Firms could now serve context through the delivery of digitally enabled offerings. Serving context requires the product to be designed as incomplete, allowing the consumers to complete the offering in context through the application of their own resources. An offering may be digitised in such a way that functionality can be added (reprogrammed) even after the product has been transferred to the customer. In that respect, the product will remain "incomplete" through life [1]. An incomplete product can be tailored to the customers' context to obtain a better "fit" with its environment and what the customer wants to achieve. Value co-creation occurs in context; empowering the consumer with the ability to dynamically reconfigure the offering the benefit is potentially increased. Incomplete products skew the trade-off between standardisation and personalisation. In the case of the iPhone®, the boundary of standardisation is drawn at the hardware level where as the boundary for personalisation is drawn at the digital app layer, allowing firms to derive scale economies whilst the customer is achieves high levels of personalisation. This paper proposes threeareas need a completely need study. First, it explores product and service architectures and the role of modularity within incomplete products. Second, it aims to conceptualize a meaning for indefinite postponement, a new concept enabled by incomplete products and digital technologies. The final area for discussion is transaction boundaries. Roll Royce have shown through their Power by the Hour © that transaction boundaries can be redrawn so that the focus is on outcomes rather than exchange. The concept of incomplete product will have a significant impact on transaction boundaries in the digital economy. As the offering is reconfigured in context, understanding the human resource and how they integrate their own resource into the offering will be key. A number of challenges for service research are proposed that will have significant implications on the development of incomplete products in the connected digital economy.

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Keywords: Incomplete product; Pervasive digital technologies; Value cocreation; Modularity

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1. Introduction

The digital economy is providing firms with new opportunities. One of these is that firms could potentially serve context (value-in-use). Huge strides have been taken to understand how to achieve value-in-use, especially within fields like marketing. Research has shown that consumers evaluate value of the offering against their use and experience of it [2]. This suggests value to the consumer is different to that of a firm. The consumer evaluates value based on use and experiences, yet the firm views value as worth (money) [3]. With this in mind, the consumer will more often than not buy the offering out of the context of use.

Firms have the chance to serve context by developing dynamically reconfigurable offerings. The concept of dynamic reconfigurability has been developed considerably in systems design but as of yet, hasn't been appropriately transferred to the product design and engineering community. Within system design, it has been described as *"the capability to modify their functionalities, adding or removing components and modify interconnections among them"* [4, p.1]. By incorporating this concept into future offerings functionality can be added (reprogrammed) even after the product has been transferred to the customer. In that respect, these products remain 'incomplete' through life [1]. The 'incompleteness' means future offerings will exhibit flexible boundaries (as opposed to 'fixed' boundaries that limit the offerings functionality) allowing them to materialize new affordances based on the context of use [5]. We define incomplete product to be 'a physical product, design with a modular architecture, capable of dynamic reconfigurability allowing for the offering to obtain an optimal fit within the actors dynamic and ever changing context of use where the transaction boundaries are aligned with the context of use.It is suggested an incomplete product exhibits the following characteristics: it can be actuated (controlled); capable of dynamic reconfigurability (through its modular architecture); it is visible; integrates personal data and is part of a system (can be coordinated) [3]. The classic example is the smart phone. When transferred to the customer it only has a few functionalities but through the app store, customers are able to configure the phone to materialize new affordances such as a dictionary or a games platform. The platform is therefore standardized at the point of exchange (economies of scale benefitting the firm) yet highly customizable in context. Empowering the consumer with the configurability means that transaction boundaries must be engineered to context and postponement now becomes indefinite [6] while the offering begins to exhibit characteristics of a service.These are made possible through the products architecture, where modules are capable of dynamic reconfigurability within the consumption space. It is these concepts - postponement, transaction boundaries and product and service architectures - that are seen as key features for the development of incomplete products in the connected digital economy. However, theories and methods in these areas have been developed in a material world where the focus was on standardization and value-in-exchange. The digital economy provides new challenges, which require an extension of these theories to cope in a digital world. The subsequent section proposes that these areas need a completely new study for the development of incomplete products in the connected digital economy where the focus is on value-in-use and outcomes.

2. Literature review

2.1. Product architecture, service architecture and modularity

Product architecture is predominately known as *"the scheme by which the function of a product is allocated to physical components"* [7, p419]. Following the inception of Henderson and Clarks [8] paper on architectural innovations, product architecture research gained momentum.The research community focused heavily on product and process architectures with two main concepts at its core; modularity and integrality.

Recently, a new set of architectural literature in the service community has been growing. An important characterization of services in comparison to products is that they are usually produced and consumed at the same time [9].IfM and IBM [10] have stated that service architectures are one of the most important challenges for the service community, calling for a greater emphasis on understanding and developing them. It is said that the decomposition of service system functions into individual elements is what delivers the overall services of the service system [9]. It is easy to see the similarities between service and product architecture from this definition whilst the concept of interfaces is also similar. Service interfaces include people and information [11], as opposed to physical product interfaces. It can be said that both product and service modules deliver information, albeit through

different mediums. As pervasive digital technologies advance, and products are capable of dynamic reconfigurability in context and on demand, products begin to exhibit characteristics of a service. By viewing a product in a different light, and looking at it from the perspective of the service it provides in context and on demand, then the landscape for product architecture fundamentally changes to incorporate both product and service architectures. We can say that a product, with fixed boundaries, is a rigid service with a low tolerance for variety whereas an incomplete product, with its open and flexible boundaries, has a high tolerance for variety. People could now become a module within a complex product system. People are better at absorbing contextual variety than technology ever could be [3] and so designing a product as incomplete allows the customer to attenuate the variety. With this in mind, product and service architecture literature can learn from each other to develop new architectures for incomplete products with a focus on the service the offering provides in context. Architectural knowledge and capabilities are an important asset to a firm if they are to remain competitive as purposeful change can enable a superior offering and allow for worth to be captured at various points in the system [12]. A firm becoming comfortable with their architecture plays a dangerous game and to remain competitive in a market they need to alter and play with their architectures as technologies advance. In order to develop incomplete products in areas like complex engineered goods, product architectures need a completely new study [3] and modularity needs to play a key role given its adaptable and flexible nature. However, modularity as it stands is not in a position to cope with digital technologies as it is a theory developed in a material world that cannot cope with the unbounded nature of digital innovations[13].It is therefore proposed that modularity theory needs extending to cope with the digital economy while the consumption space and the boundaries of the human resource need to be incorporated into the design of an incomplete offering. As such, it is suggested that product and service architectures become interlinked.

2.2. Indefinite postponement

Mass customization (MC) allows products to be customized prior to the transfer of the product to the customer with firms retaining economies of scale. For example, the car market is known for using product platform modularity to deliver a rangeof different variations of their automobiles across different countries whilst retaining economies of scale [14]. Building upon the MC literature, Ng et al [6] suggest that the current MC school can be classified as tailoring. They put foreword an additional concept that they call platforming, whereby the customization takes place in the consumption space, rather than prior to the exchange. Under this conceptualization, product platforms (e.g., automobiles) are tailored offerings whereas the iPhone ® is a platformed offering as it can be reconfigured within the consumption space. A platform strategy means that postponement becomes indefinite.

Postponement is a strategy most widely found within supply chain management. It is a method of producing a standardized product that can be modified as close to the point of exchange as possible without increasing production costs to efficiently deliver different degrees of customization [15]. Modularity is associated with postponement given its ability to attach and recombine modules on a standard platform [16] and has been shown to be difficult to implement with non-modular structures [17]. As a result, postponement and modularity became important concepts within MC. Postponement takes place up until the point the demand signal enters the system at which point a given set of components are turned into specified end products [18]. The closer the customer order decoupling point (CODP) [19] is to the factory (upstream) the firm benefits from economies of scale and production efficiencies. The closer to the customer (downstream) means the firm will suffer from a lack of production efficiency but, the customer will gain from flexibility during design and manufacture [6,18]. Even with these concepts, the customer remains exogenous and their outcomes are not the focus of enquiry. As such, the consumption space is rarely included in the supply chain. The integrated framework of Yang, Burns and Backhouse [20] states the last point to be distribution, highlighting that the consumption space does not come into the system. They conceptualized the two ends of the framework as pure standardization and pure customization, with the latter being incredibly expensive due to the reduction in standardization and economies of scale. Incomplete products look to skew this trade-off and show that new methods of product design, new business models and advancements in pervasive digital technologies would allow firms to benefit from economies of scale yet allow the consumer to personalize the offering in context. Firms could develop a platform strategy [6] where the customer completes the offering in context. Thus, the final assembly of the product is postponed indefinitely as the offering is

completedthrough digital and additive layer manufacturing (ALM) technologies and the integration of the consumers' resources. Little research has been developed around the concept of 'indefinite postponement' and as such its application is limited beyond known exceptions, such as the iPhone®. The customer will always be the most knowledgeable about the context as the firm is not able to be present in the context of use. Thus designing a product as incomplete means the customer is empowered with the resources to customize the offering to their specific context of use. This fundamentally challenges the institutionalized logic that products are designed and manufactured by the firm and transferred to the customer. The concept of postponement needs to shift when delivering incomplete products to incorporate the consumer into the supply chain when postponement becomes indefinite. We define indefinite postponement as 'a platformingstrategy where the offering is designed as incomplete, empowering the customer with the ability to attenuate variety by completing the offering when required in context and on demand'. As described, the iPhone® has been designed in a way that allows the user to configure the desired affordances through the app store, allowing the consumer to customize the offering to context. For the physical world the challenge has been even more difficult but developments in ALM could change this. Notable characteristics of ALM include little to no increase in costs for small to medium lot sizes because the technology does not require tooling [21,22], it inhibits flexibility for the development of customized parts [23] and it can provide parts that require no assembly time as they are functionally integrated [24]. As more consumers gain access to ALM technologies, firms could begin to sell parts that could be purchased and printed in context. This provides the firm with a new opportunity to serve context and with ALM technologies advancing, it is impossible to ignore the implications it could have. The authors propose that for indefinite postponement to become a reality it is necessary to explore existing and future technologies to understand how they can be implemented within future offerings in such a way that they can be dynamically reconfigured in context and on demand. These types of technologies have become feasible in the connected digital economy and it is now that we need to explore their applications and expand traditional design approaches if we are to develop a world focused on value-in-use.

2.3. Transaction boundaries

Many have questioned existing research about transaction costs, specifically why and where activities terminate, instigating a stream of research that utilized the principles of modularity [25,26,27]. Utilizing modularity theory they were able to articulate where these interfaces were, why they occur and the optimal position of the transaction. As a result, Baldwin [25] redefines transaction to mean a *"mutually agreed upon set of transfers between two or more parties with compensatory payment"* (p.164). It is suggested that transactions should occur when mundane transaction costs (MTC) are lowest [25,27] and this is usually when the item to be transferred can be fully specified. MTC's are lowest at module boundaries where a 'thin crossing point' has been developed, as opposed to a 'thick crossing point' [25] where information, energy and material flows are complex and difficult to count, therefore becoming expensive. Thin crossing points have the potential to create markets, as shown by IBM's system 360, which allowed competitors to develop offerings compatible with IBM computers; something previously not possible [28]. As digital technologies advance, the point of transaction can be placed closer to the consumers' context where new module boundaries are created. Roll Royce Power by the Hour © and the iPhone ®have shown that transaction boundaries can be redrawn closer to the consumption space to focus on outcomes. The theory proposed by Baldwin [25] is enlightening and provides a foundation for understanding where transactions can be placed. It is proposed a platformed offering could enable the development of thin crossing points (to produce low transaction costs) positioned at the boundary of configurable modules, enabling the offering to attenuate variety [5]. By creating module boundaries within context, the firm can be compensated during the use of the offering and open up new markets based within the context of use. This would then allow the firm to serve context (value-in-use). This is possible as modular transaction boundaries can be engineered [25] and can move up and down the production and

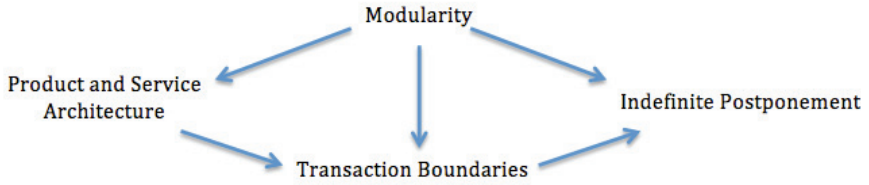

Fig. 1. Conceptual relationships between the concepts.

distribution system [29] as technologies change. The challenge for firms attempting to serve context is one where the transaction boundaries can be drawn within the consumers' context. The focus of the offering would then be on the outcomes desired rather than the exchange value that has proliferated within the mass production era. It is therefore essential that we identify how transaction boundaries can be engineered as close to, if not in, the consumption space. By designing the point of transaction within the consumption space firms will be able to align the compensation they receive with the use of the offering.

3. Discussion

This paper proposes a research agenda for the development of incomplete products in the connected digital economy where firms could now serve context. Four areas have been identified as being key if firms are to achieve this; product and service architectures, indefinite postponement and transaction boundaries. The four areas are seemingly disconnected from one another in the literature, yet through the concept of modularity and an incomplete product they become increasingly related. Figure 1 shows the conceptual links between the areas and is further described below.

Product and service architectures have been seen as separate areas but it has been shown that through the delivery of an incomplete product, the two areas need to become one. An incomplete product shows characteristics of a service in that the affordances are often produced and consumed at the same time. Another key area that brings the two sets of literature together is that the interface between the offering and its reconfigurability is now going to be the customer. The information about the context is delivered by the customer to the offering in order to reconfigure it accordingly, thus the customer (human resource) becomes a module within the overall system. Since the consumption space and the human resource is now an active part of achieving value-in-use, the product architecture needs to incorporate aspects usually associated with service architecture. It is therefore recommended the two areas become inseparable for the design of incomplete products. The way in which the offerings architecture is developed will enable transaction boundaries to be engineered within the consumption space. As proposed by Ng and Wakenshaw [5] a platformed offering, with modules that are reconfigurable in context and on demand, could act as an enabler for introducing transaction boundaries to context. The way in which module boundaries are defined and how they are reconfigured is of interest to those designing the point of transaction. Modularity enables flexibility for product reconfigurability and also creates 'thin crossing points' [25] for one party to compensate another. It is clear the concept of modularity connects the architecture of the offering and the transaction boundaries, thus it is imperative that designers, engineers and those designing the transactions work together from the outset. Finally, the architecture of the offering coupled with the transaction boundaries allows the product to be designed as incomplete, making postponement indefinite. Indefinite postponement means that the human resource becomes essential in the system. It isimportant to understand the boundaries of the human resource; by understanding this resource it will better inform the design of an incomplete product. Without a modular and reconfigurable architecture and modular transaction boundaries engineered to context, the concept of indefinite postponement is not possible. Modularity again acts as a bridge between seemingly disparate areas as it is the reconfigurable modules (associated with the architecture) and the context based modular transaction boundaries (compensation) that allow indefinite postponement to become a reality. Directly related to the dynamic reconfigurability and indefinite postponement are the technologies that enable it. We have seen with the iPhone®that digital technology can be utilized to allow for dynamic reconfigurability in context and on demand. However in the material world an appropriate technology has

not been formally identified. This research proposes that ALM could provide firms with an appropriate technology capable of allowing the consumer to print their own parts in context. However, the exploitation of ALM is under researched, especially within incomplete products, and is therefore lacking any significant empirical research.

It is clear from research compiled in a predominately material world that modularity could aid firms in serving context, yet the digital world provides new challenges for modularity and these need exploring. The design of an incomplete product,where modularity links the offerings architecture, transaction boundaries and level of postponement, allows firms to derive an optimal level of scalability and variety, something previously impossible. These separate domains now become intertwined for the development of future offerings in the connected digital economy where outcomes are aligned to purchase and areenabled by a socio-cyber-material offering.

4. Summary

This paper identifies key research areas needed for future products in the digital economy. Through the advancements of digital technologies, firms are now able to serve context (value-in-use), yet research has been lacking in this area. First, we identified the key areas that need developing in the connected digital economy for firms to be able to develop incomplete products and align the use of the offering with the compensation to the firm.We then articulated the relational links between the concepts using modularity, showing that as an over-arching theme modularity acts as an enabler to the subsequent areas. A modular architecture (incorporating both product and service architectures) capable of dynamic reconfigurability can lead to transaction boundaries being engineered to context with the aggregation of both ultimately leading to postponement being indefinite. Our research agenda proposes that these areas can no longer be treated in silos but must come together for the development of future offerings in the digital economy. We contend that a move from the traditional ‘fixed’ view of product design to an incomplete product offering requires a shift in boundaries to incorporate the consumption space and to utilize the customer as a resource to attenuate variety. We suggest that the process is no longer linear but a system in which each party integrates resources to find an optimal fit between the actor, the offering and their context of use.

This research agenda calls upon designers, engineers, service researchers, economists and operations researchers to come together to embark on a journey of a truly interdisciplinary nature in order to generate empirical studies for incomplete products. It is only empirical studies that will allow this concept to move forward and to identify appropriate methods and tools for the application of an incomplete product. Research into incomplete products is at a very early stage with a variety of questions that need answering. For example, the research community needs to address issues such as: What new architectures can be developed for future offerings in the connected digital economy; what implications does an incomplete product have on a firm’s business model; what implications does indefinite postponement have on the design and delivery of an offering; where can the boundary for transaction be drawn to align the compensation for the offering with its use; what technologies, through the concept of incomplete product, can be exploited to aid firms in serving context (value-in-use); what are the boundaries of the material, digital and human resources in value-creation? The advancement of pervasive digital technology has opened up a whole new area of research for future socio-cyber-physical offerings in the connected digital economy and has considerable implications on the research community as a whole.

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