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CHALLENGE OF OPEN PLATFORMS TO MASS CUSTOMIZATION CAPABILITIES

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Abstract: *Mass customization has long been a successful strategy for firms to offer customized products at near mass production efficiency. To tackle the inherent complexity and cost tradeoff involved mass customization firms need three key capabilities: solution space development, robust process design, and choice navigation. Recently, strategies that rely on open platforms and business models have emerged to challenge the value proposition of mass customization firms and the relevance of their current capabilities to execute a mass customization strategy. This paper conducts a conceptual analysis of this challenge and puts forward propositions of their implications to mass customization firms and their key capabilities.*
Key Words: ***Mass Customization, Platforms, Key Capabilities, Open Platforms***

1. INTRODUCTION

1.1. Background and motivation

Mass customization (MC) [1]–[6] has been a key *competitive strategy* for manufacturers to address the squeeze of delivering products tailored to customer-specific needs efficiently enough to scale up the business productively. To execute the strategy and address the squeeze successfully, MC firms need several key internal capabilities: solution space development, robust process design, and choice navigation [7]–[9]. These capabilities have allowed MC firms to strive closer to an idealistic goal of providing customers anything they want, anytime, anywhere, and any way they want it – and do it profitably [10]. These capabilities and success factors of MC have been covered in prior research along many research streams, see e.g. [11]–[20].

In all practicality this is an unattainable goal for any one firm and rather an ideal to strive for. Profitability requirement compromises the implied promise of MC, i.e. offering infinite variety to choose from. Even if offering infinite variety would be possible customers probably would not be willing to pay high enough a price for a MC firm to recoup the necessarily high cost of developing such capabilities. Hence, MC firms have relied on a compromise, striking at some specific, limited range of customer needs they subsequently develop sufficient internal capabilities to serve, upon customer requests. This compromise allows to offer customization within that range and while keeping the costs in check.

The ideal of MC, of giving the customers anything they may want, could be achieved also by offering infinite variety of products instead of having the capability to respond to any customer request (as per MC), costs notwithstanding. While variety is not customization, infinite variety would cater to the same implied promise: each customer can find a solution that perfectly matches their needs. Instead of specifying the perfect solution to be delivered in advance, the issue becomes finding that perfect solution from all those on offer. This also is, in its fullest meaning, an unattainable goal. A compromise, as in MC, is nevertheless possible – and a one that may challenge the competitive position of MC firms in the market and the relevance of their key capabilities. This challenge comes from open platforms and open business models.

Recent years have seen the rise of platform economy and platform firms. Platform firms act as intermediaries between customers and 3rd party producers and facilitate the direct interaction between the two. Unlike MC firms that develop internal capabilities to serve their customer and co-create value for them, platform firms move the bulk of value creation outside the firm to external 3rd parties that they orchestrate, kind of both inverting and opening the firm [21]. Platform firms are therefore inherently open. Moreover, their key competitive advantage stems from this openness and the network effects it fosters. The more 3rd party producers join the platform, the more valuable it is perceived by both existing and prospective customers. This leads to more customers joining the platform and increases the likelihood they stay on it. The more customers there are, the more 3rd party producers will join the platform. This positive feedback loop, a network effect, feeds the increase of value from the size of the network. Eventually, network value trumps any value the platform firm may independently offer to the customers see e.g., [22].

The advantage platform firms enjoy from the large number of external 3rd party producers is two-fold. Firstly, it gives the platform scale in value creation while moving the costs of production to 3rd parties [21], [23]. This scale benefit enables platform firms to cater to the "mass" in mass customization. Secondly, some platform firms offer a huge assortment and variety of offerings via their platform, through their large scale of 3rd party producers. When their number is sufficiently large, the platform firm offering caters to the "customization" in mass customization. It should be noted that many platform firms only offer very narrow offerings (like Uber offering just the simple service of getting from place A to place B). Nevertheless, many platforms seem to offer very wide variety of offerings (like Uber Eats, Amazon, or Google Andoid and its apps). Therefore, it seems platform firms move both the "mass" and the "customization" outside the firm, to external 3rd parties, and at the same time also externalize the majority of the costs involved that underlie the reason idealistic definition of MC is, indeed, idealistic and not 'practical'. Platform firms with open platforms therefore pose a competitive challenge to the value proposition of MC firms and the relevance of their internal MC capabilities to deliver on that proposition. This paper conceptually analyzes the implications of this challenge to MC firms and their key capabilities.

1.2. Research design

This paper uses theory adaptation approach [24] as its research design, see Figure 1. In theory adaptation, the scope or perspective of an existing theory (so called *domain theory*) is changed by informing it with other theories or perspectives (so called *method theories*). Theories here should be understood broadly, for example as literature fields or streams of research. More specifically, this paper informs and revises literature on MC key capabilities (domain theory) by exploring how MC capabilities identified in prior literature should potentially be adapted to address the challenges and opportunities presented by open platforms and platform economy firms to traditional MC firms (as motivated in the Introduction). As its method theories, this study uses literature on open platforms and openness in platform economy as well as literature on openness in its varied forms within mass customization and product configuration literatures.

Open platforms and openness in platforms literatures were chosen as the method theories for the following reasons. Platform economy poses the competitive challenge to MC firms, and some authors even argue that platforms beat products everytime [23]. While MC firms typically employ modular product platforms, the challenge to MC firms from platform firms, as understood here, comes from their openness to external 3rd parties and their role in value creation, at large scale. Hence, literature on open platforms should be studied to determine if and how MC capabilities should be adapted to meet the threats or benefit from the opportunities.

Literature on openness within mass customization and product configuration research is used as method theories as they are close to the domain theory of MC capabilities and therefore discussion of openness within them could inform how to adapt MC capabilities. Further, product configuration and configurators have long been key factors in supporting the choice navigation MC capability [11] and there is some budding research on openness within product configuration, see e.g. [25]–[27]. Current MC capability literature is mostly focused on internal capabilities of the firm and largely does not discuss openness. Therefore incorporating the viewpoint of openness from within MC and product configuration literatures to MC capabilities is justfified.

Through theory adaptation, this paper presents propositions for MC key capabilities should be adapted to take into account openness and the challenges and opportunities of open platforms.

The rest of the paper is structured as follows. Next, the domain theory of MC and MC capability literature are reviewed and summarized. This is followed by a summary review of the method theoeries, literature on open platforms and openness within MC and product configuration literature. Next, as a result of this analysis, adapted implications for MC key capabilities are presented. This is done for solution space development, robust process design, and choice navigation support first separately before introducing a new key capability for MC firms that open their product architecture for external actors, governance of external 3rd parties. Discussion and conclusions end the paper.

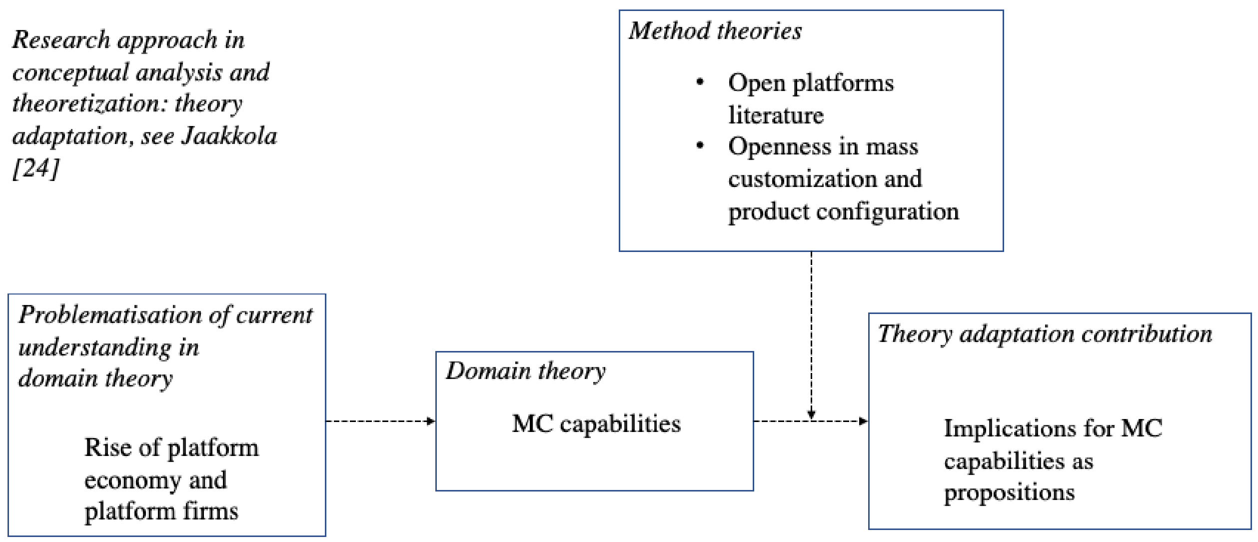

Figure 1. *Research approach, following [24]*

2. DOMAIN THEORY REVIEW

2.1. Mass customization

As discussed earlier, the idealistic view to MC sees it as an approach to provide customers anything they want, any time, anywhere, and any way they want it – and do it profitably [10] – but in practice this is not possible. The profitability requirement of the idealistic view compromises the other goals, or at least restricts their attainment to within a 'pre-determined envelope of variety' [10]. As such, MC falls somewhere in the 'middle ground' between mass production (MP) and craft production (CP) of one-of-a-kind, bespoke products, with both the MC firm and its customers having to make some tradeoffs compared to the two other approaches.

All that being said, an exact and universally accepted definition and scope of even 'practical' MC has been elusive. Kaplan and Haenlein [28], for example, limit MC only to the domain of manufactured physical products, goods, and exclude e.g., services from MC. They see service MC to be tautological as all services, by their nature, involve the customer in their production process. In this sense, MC services would not increase customer involvement or customization similarly as MC does in relation to comparable mass-produced goods. Their other argument for excluding services from MC definition is that it would be misleading. Kaplan and Haenlein [28] argue that while improving the cost-efficiency of individualized services is certainly possible this is different to increasing the customization of low-cost mass produced goods. Service MC would be approaching the aforementioned 'middle ground' from the opposite direction of CP (instead of MP) as addressing a MP mass market at comparable cost and other tradeoffs with a MC approach. While the bulk of MC research is focused on physical products [3], [11], [4], [29], [5], [30] instead of services, excluding them from the field of MC seems too limiting, especially in the light of the emergence of servitization in the past 15 years or so that has in part been fueled with digitalization. Moreover, there is ample literature related to moving to the 'middle-ground' of MC from the direction of CP as well and that CP firms face many similar challenges and acquire similar capabilities as firms that move to MC from direction of MP [31], [11]. And further, many cases reported as MC are not MP products but rather complex, industrial equipment sold at business-to-business markets that often comprise also of services and digital components see e.g., [32].

What then is the 'common ground'? What constitutes MC? While, like seen from above, some points for discussion remain some definitional boundaries and denominators of MC have been identified in literature [33], [4], [29]. First, MC is an approach that aims to provide the customers an offering, product or service, that minimizes the trade-off between the ideal fit with customers' individual needs and what can be provided in practice. Second, the aforementioned trade-off necessitates that the MC provides offerings within a pre-determined range or envelope of variety [10] or fixed solution space [33], [29]. No creative design tasks are done in response to individual customers (although sometimes such can be combined with MC, in engineer-to-order ETO approaches, see e.g., [34]). This envelope of variety is typically based on a modularized design of the offering [4], [29] based on a product family and/or product platform [35], [36]. And third, the offering is provided in response to a particular customer's needs and order [29]. In manufacturing context this means the product is not made, fabricated until the customer has made an order. Or in other words, even though parts and sub-assemblies may have been prepared in advance (and typically are) and irrespective of particular customers, the final steps in the assembly or manufacturing process are taken in response to an individual customer order. This third requirement, i.e., point of customer involvement, is a common dimension for classifying the level of MC a company partakes in MC typologies [37], [3].

2.2. Mass customization capabilities

To successfully offer mass customized solutions, a company needs to have several key capabilities in place. For example, Salvador et al. [8] argue that there are three generic MC capabilities. First, *solution space development* that consists of modules or components that can be mixed and matched in response to a specific range of possible individual customer requests – and only within that range of diverging customer needs. Second, a *robust process design* that is capable of delivering individually customized solutions efficiently. And finally, *choice navigation support* for customers to help them identify the combination of modules most suitable to their needs while minimizing the complexity and burden of choosing from potentially numerous options. How a MC firm may acquire and implement such capabilities is dependent on several things and is by no means uniform among different firms [3], [8]. The following will go through these capabilities in more detail, largely following Piller [7] and Salvador et al. [8].

Solution space development MC capability refers to two separate issues. First, the MC firm must be able to identify the set of customers' needs along which they diverge the most [9]. Whereas as a mass production firm aims to find those needs that are shared by as many potential customers as possible, a MC firm must also be able to identify a broader, more varied range of customer needs that customers value. From that range, the firm must decide and define the range of needs it will develop capabilities to fulfill – and only those needs. This range and its boundaries, i.e. solution space, is to remain fixed and stable over a period of time. Second, a MC firm must develop a product design and architecture from which it can derive and deliver customer-specific product individuals. This design is typically modular. No design or re-invention of modules is to be done in response to individual customer requests. To sum, solution space development addresses what customer needs the firm intends to serve and with what kind of products it intends to fulfill the needs.

Robust process design MC capability, in turn, refers to the ability of a MC firm to reuse existing resources in the organization or its value-chain to fulfill and deliver solutions customized to customer needs within the solution space. While a mass production firm typically has few processes aimed at standard quality and output with scale efficiency through repetition of process steps at large volume, a MC firm must incorporate more flexibility and variety into its production and delivery processes. On the other hand, compared to craft production firms that may customize and invent both the products and process steps required to make them, a MC firm should still operate based on pre-defined ways, reusing and recombining process designs and resources. Flexible automation and process modularity can help. If solution space development defined a finite range of variety of what needs the firm caters to and what the firm can offer, then robust process design deals with how this is to be done and delivered.

A MC firm needs to have a good choice navigation capability to be able to support customers in finding the best possible solution to their individual needs from within the solution space. Choosing from even a large assortment of mass-produced final products is easier than building a customized product by making large number of choices from myriad and often inter-dependent options as is typically the case for MC products. This burden and complexity of choice, and the subsequent uncertainty in evaluating between the options –let alone potential other 'final' product individuals– in MC has been called 'mass confusion' [38], [39]. Mitigating these costs and concerns with choice navigation support is therefore a key MC capability. Choice navigation capability helps customers to find the best possible solution from within the solution space the firm has on offer.

To sum, traditional MC products typically are based on a modular product architecture design. The design remains frozen, ‘closed’ to changes and external inputs, for a period of time until a new, discrete 'generation' of the product is needed. This time is necessary as otherwise the firm cannot capture scale benefits from the modularity [40]. Furthermore, design of MC product architecture is a more costly and complex task than for a regular mass product. Reaping the benefits from the MC product could therefore take more time than for mass products (while at the same time designs of MC products could resist changes in customer needs, and therefore remain viable, longer). Moreover, building the choice navigation capability for MC requires that the customization possibilities the product design enables are captured and embedded in dedicated organizational capabilities and IT systems [11], [41]. This is no mean knowledge engineering feat even when the product architecture is fixed [11]. The stability in the solution space is also beneficial to build the robust processes needed in delivering individually customized products. Product design therefore has been thought of as a separate –and separable– phase followed by production, sales and transfer of ownership to the customer [42]. The underlying assumption is that the customer problem at the time is understood and represented completely and the task of the design is to identify the optimal solution [43].

3. METHOD THEORIES

3.1. Open platforms

Platform openness is discussed in varied ways in current literature. One perspective is the consideration of external (to the firm) actors that may partake in typically mutually beneficial interactions or relationships with the platform firm or other actors on the platform. These external actors can be users or customers, suppliers of components or modules, complementors who develop or producers complements that support the core of the platform, and other 3rd parties, see e.g. [44]–[51]. In other words, platforms may be open toward actors other than the owner of platform, i.e., the platform firm. This openness may manifest as granted access (who gets 'in') to the platform and the level of authority or discretion the actors have to act or transact on the platform (what are they allowed to do) [44], [48], [52].

In an internal product platform, the actors are the sub-units of one firm and they are controlled via managerial hierarchy [51], [53]. The platform owner may source standard modules or components from open markets, while keeping assembly in their own hands. When such otherwise closed platforms involve external actors, they usually supply components or subassemblies to the platform owner or the final product assembler (another external actor itself). Such platforms have been called supply-chain platforms [53], [54]. In them, the controlling relationships are contractual and the delivered components or subassemblies are expected to adhere to the specifications defined by the platform owner. The platform owner selectively opens these interfaces only to known external actors with whom they have negotiated contractual relationships. Any leeway for external actors is limited and does not alter the overall architecture of the product platform or what kind of product individuals can be made or derived from the product architecture. Those are pre-determined by the platform owner and fully known [53], [54].

Next step in increasing platform openness toward external actors is represented by industry or external platforms [53]–[55]. In them, the platform owner typically designs a foundation–often a product or set of technologies–upon which external actors can develop complements on, i.e. complementary products, services, or technologies. The overall technological architecture follows the traditional idea of a stable core and variety coming from peripheral components from modularity. The interfaces are shared openly to any willing external actors [53], [54]. The actors are not necessarily known to the platform owner nor are they in the owner's control, beyond the bounds possibly defined in some standard terms and conditions or licensing terms the platform owner has shared [47], [56]. In addition to the external actors being ex ante unknown, the openness and freedom they have over the development of their complements means that the scope of what product individuals can be derived from the combinations of core and peripheral components becomes unknown and somewhat unbounded [46]. This potential of unknown and even large crowds to create innovative complements has been called *generativity* [57], [58]. When greatly enlargened innovation scope from generativity is coupled with scale benefits achieved via network effects, the results are platform giants like Apple, Google, Microsoft, to name a few.

Another form of platform openness is resource openness [45], [48], [51], [56], [59]. Note that in the above, the implicit assumption was that at least the platform core is kept in-house, as proprietary, and that any additions or changes to it are to be done solely by the platform owner. The core may be opened, however, by forfeiting related intellectual property rights (IPR) [48], [56]. The motivation to do so is to benefit from external contributions to the development of the core while possibly retaining some control and/or means for value capture in other ways than direct platform core sales.

A distinct form of openness is also evident especially in those platform contexts where modules and their interfaces are digital. This has interesting implications for design, production, delivery, and use of product individuals derived from such platforms. The design of a physical product platform and its architecture is a time-consuming and expensive task. Therefore this design has been frozen to allow the firm time to recoup the costs involved [40] during latter stages of the product lifecycle. There really is little that meaningfully separates design from production in software [40] – both in terms of time lag or even the cognitive task. For software the design largely is the product. Copies can be reproduced and transferred instantly. When digital technology is part of physical products, the software can be changed very flexibly and fast, also after the initial product individual may have been produced and delivered to the customer. Therefore the 'bounds' of the product individual are more open [40], [46], or at least part of its functionality remains potentially *open-ended* at time of sale or sales specification (even if it were fully specified at the time).

Digital modules or components, especially if software, are also much more *product agnostic* than physical components [46], [60], [61], i.e. design of software components requires little product specific knowledge and its use or instantiation is not tied to specific product. All the potential uses of a software component are not known or even knowable at design time, again adding to the open-ended nature of especially digital products. Physical components are nested in fixed part-of design hierarchies. The place and function (uses) of a component are known, whereas for digital componets these are more loosely coupled and layered [61]. This *open-ended nature* of digital components, both in terms of their 'flexible' position in (m)any product architecture(s) and their use, is especially powerful boon for (re)combinatory innovation [61] – and even more so when components are contributed by large uncoordinated crowds of external developers, which fosters aforementioned generativity [57], [58]. Therefore, for digital products and components their design and uses are more open-ended [43], both in terms of the time they take place and their role and uses in a product architecture, than for physical components.

3.2. Openness in mass customization and product configuration

Openness has been discussed in a few within MC and product configuration literature. Offering configurable products has been an important and successful way to implement MC and product configurators an equally important way to achieve necessary choice navigation capability [11], and is therefore discussed here in more detail.

MC in itself and 'by design' is open to inputs from external parties. Production and delivery of any product individual that is to be delivered according to customer specifications has to incorporate external inputs within the processes. As discussed earlier, MC firms limit the possible inputs within designed boundaries – but give customers freedom to choose within those customization possibilities. The bounds and possiblities are therefore fixed at design stage, while the specifications of the product individual then during sales specification [9], [11], [27], [62]. There is flexibility within the designed bounds, but they themselves are rigid and fixed. Many of the MC typologies use the point of where standard (fixed) activitities end and customer-specific (flexible) activies begin as the basis for categorizing MC firms, see e.g. [3], [37], [63]–[66].

Some firms are offering some mix or combination of above discussed configurable products and possibility for adding options designed and engineered according to customer orders that fall outside the predefined range ingrained in the design of the product architecture. This latter part is often called engineering-to-order (ETO) [67]. While ETO caters to customers needs outside the predefined customization scope, it is an internal process of the firm. There is some work also within product configuration to build configurator systems supporting configuration that can combine both predefined and unforeseen customer requirements, see e.g. [27], [68], [69].

Sales configuration, the process of defining the customer-specific product invidual to be produced, is often done in cooperation with the customer and a sales person or even by customers themselves [11], being therefore open to parties external to the firm. Usually, this process is done by a single person. However, in some contexts, this person may need to incorporate the needs of a larger group into the configuration, often with suboptimal results [25]. Felfernig et al. [25] propose building configurators supporting configuration decisions made by groups to tackle this issue. They also see this to be important for building the configuration knowledge bases, often done by individuals or small teams of knowledge engineers. Further, Piller et al. , [39] explored co-design communities of customers as a way to alleviate choice navigation mass confusion. Piller and Walcher [70] studied how crowds of users can be empowered with specific toolkits to create large number of varied designs that can be utilised by the firm in many ways. Some of their cases presented toolkits that limited the possible designs within some pre-determined bounds while others were more open-ended.

4. IMPLICATIONS FOR MASS CUSTOMIZATION CAPABILITIES

4.1. Solution space development

Open platform firms benefit from the generativity of large crowds of external complementors. For MC firms this the biggest threat and opportunity when a part of the modular product architecture can be decoupled in a manner that both preserves a stable core and interface toward external and even at design time unknown complements, and those complements potentially provide a relatively large proportion of the variety and features of the the overall offering (when compared with the internal stable core and possible complements).

This kind of decoupling arguably a more likely case when the external complements are either software or service modules. Software is inherently modular. Service modularity has gained interest in recent years and is also inherently decoupled from both physical and software architecture (when services are implemented by human labor). Further, this is more an opportunity if MC approach is cosmetic [71], i.e. majority of the solution and its delivery is standard and internal, and the cosmetic variety can be opened to external actors, in both design and delivery or just design. Conversely, if a significant portion of the modular product architecture is closely coupled and complex, and that portion provides a large proportion of the features customers value, then openness is less a competitive threat or opportunity for MC firms. A hybrid of these two 'extremes' are likely to present more complexity to the management of the solution architecture than at either 'ends'.

A key solutions space development capability for MC firms is to match the solution space to customers needs and their variety [9]. Open platforms can bypass this when the external actors bear both the risk of designing complements that customers do not value and the associated costs. When the crowd of external actors is large the customers are still likely to find complements that they value via the platform. The large crowd is also more likely to be able to keep up with changing customers needs than any one firm.

Proposition 1: *Open platforms are more a competitive threat (or opening their platform for complementors an opportunity) for MC firms when a part of the modular solution architecture can be loosely decoupled and the larger portion of the features customers value that part delivers. This decoupling is more likely when the decoupled part is software and/or services. The decoupled part is more likely to represent a large portion of the features customers value when it is software or the MC approach is originally cosmetic.*

Proposition 2: *Conversely, open platforms are less a competitive threat (or opening their platform for complementors an opportunity) for MC firms when their modular solution architecture is tightly coupled and the larger portion of the features customers value the physical portion of the architecture represents. Tight coupling is, self-evidently, more likely the deeper the MC approach is.*

Proposition 3: *If MC firm is to benefit from openness in solution space development they need to develop capabilities for modular product architecture design that enables designing external complements that provide features that customers value but that are as decoupled as possible from the internal core and complements. This implies decisions on what in the product architecture is to remain fixed, with pre-determined customization range, and what is to be varied and open-ended, and potentially opened for external actor contributions.*

4.2. Robust process design

A major benefit for open platforms is their ability to flexibly scale production with external resources, and to do it at large scale. As open platforms are typically loosely coupled at product architecture level, it allows also organizational decoupling, with those parts that provide variety (designed and) delivered by external actors, and the stable and fixed core internally by the firm. For the reasons discussed previously, the external and open modules or complements are more likely to be software or services. The delivery of both differs from manufacturing of physical products in ways that are relevant for our discussion. For software, the production of instances from the design is largely instant and flawless, when compared to physical product manufacture. For service, the key distinction is that service delivery capacity is perishable see e.g., [72], or in other words service processes begin only in response to customer requests. Therefore for any MC solution delivery that includes service modules by external actors involves a process handover to actors outside the firm and its direct hierarchical control. Such handovers increase complexity to the process management and potential risk for its robustness. On the other hand, scaling up the process may be easier outside the firm boundaries. For MC solutions that comprise potentially physical products, software, and services there are potentially complex domain handovers and overlaps between them, due to the different ways the domains are designed and delivered.

Continuous and more open-ended changes of the solution space with openness also have implications for robust process design. How can the MC firm keep its process design up to date with the changes in the solution space? Digital and software modules also allow the more flexible and open-ended updates of the already delivered product individuals. The MC firm should develop the capabilities for this.

Proposition 4: *MC firms need to develop capabilities to manage the domain overlaps and handovers that occur during operation and delivery of specific customer solutions over the customer relationship.*

Proposition 5: *MC firms need to develop capabilities to quickly reflect changes in solution space designs to the different domains and their delivery organizations, whether internal or external to the firm, all the way to customer-specific solution individuals.*

4.3. Choice navigation

Traditional choice navigation support for MC has relied on a solution space design that has been frozen and potential limitations for e.g. delivery times that have stemmed from the robust process designed to deliver the solutions. MC firms have then implemented choice navigation support, for example configurators, that encompass all this knowledge to support customers in finding the best possible fit with their needs. If the solution space is opened for external actor designed modules that can further be included and removed continuosly, choice navigation support needs to keep up – also continously.

Sourcing so called configuration knowledge about newly introduced modules from their external designers could potentially be difficult, especially at scale, when they are uncoordinated and even unknown. Even if such modules would be more loosely coupled within the architecture and therefore less likely to introduce undesirable or unworkable module combinations, mass confusion problem will remain. If the open modules are introduced at large scale, this will likely make the issue more severe. This applies both at the initial choice navigation instant when the customer specifies the product individual for the first time and also during the entire customer relationship.

A further complication could arise from the faster and perhaps less transparent updates and changes to software or service modules in general, and especially in an already delivery product individual. Especially software modules can change at a fast pace, unexpectedly, and even unbeknownst to the customers. Therefore, the customers may be subject to even more custom confusion when their solution and its performance and behavior may be in continuous flux. Even if updates and changes would be to the open, external components, the problems the changes introduce could be attributed to the MC firm acting in kind of a system integrator role.

Proposition 6*: MC firms need to develop choice navigation capabilities to alleviate the custom confusion that may arise from the continuous change of features, performance, and behavior of solutions already delivered to the customer.*

Proposition 7*: MC firms need to develop choice navigation capabilities to help customers find best fitting solution modules from among those developed by external third parties.*

Proposition 8*: MC firms need to manage updating and building of choice navigation knowledge and capability as a continous process, instead of a one-time 'batch-like' process that followed the initial design of the product architure.*

4.4. Governance of external 3rd parties

If MC firms are to open their solution space design and/or the robust process required to delivery them to external actors, they will need a new key capability: governance of 3rd party actors that are outside their direct organizational or even contractual control. To do this at scale and continuously also means contracts negotiated one-to-one often are not efficient enough. Rather, the relationships need to be managed at 'arms'-length distance' with take-it-or-leave-it terms and regulations. Digital open platforms manage their complementors with so called boundary resources that are tools and regulations that help both to foster third party contributions on the platform and to govern their actions on it, see e.g. , [47], [56], [73]–[75].

MC firms could look into developing boundary resources for fostering design and development of modules, testing their technical compatibility with existing architecture, and collection of information that would support choice navigation decisions involving the added modules. In some sense, opening the solution space for 3rd parties may mean the MC firms makes a tradeoff between managing technical complexity and complexity of governance. Designing an internal product architecture and subsequent robust process is a complex and challenging task. Designing a core that possibly has less technical interdependencies but with variety coming from uncoordinated extenral actors may not be any less complex and challenging. The challenge will be more on the governance side. Further, for an MC firm that has prided itself with providing the customers with everything and anything they want, giving out even some of the value creation to external actors may prove a difficult cultural challenge as well.

Proposition 9*: MC firms need to develop boundary resources both to foster design and development of desirable modules by external actors, and to their governance at arms' length distance.*

5. DISCUSSION AND CONCLUSIONS

Mass customization has been a successful strategy to offer customers products that are customized to their individual needs and do it at near mass production efficiency. Both the value proposition of mass customization and the key capabilities firms need to execute the strategy have been recently challenged by open platform firms that move and foster a large bulk of their value creation outside the firm to external actors.

This paper contributes to mass customization literature by conducting conceptual theory adaptation study. The paper analyses literature on open platforms and openness in mass customization and product configuration literature to put forth propositions for implications for key mass customization capabilities are to be adapted to benefit from openness, and how those are potentially challenged by competition from open platforms.

The propositions are beneficial for managers of mass customization firms that may be concerned by the competitive threat from open platforms, or that are looking to benefit from openness and external actor contributions as part of the MC offering. They may guide the development of their capabilities for such endeavors.

This is a conceptual study and therefore its findings are not directly empirically supported. Empirical work from case studies of mass customization firms that have explored varied ways of openness are an interesting avenue for future research to amend this limitation. What could be the hybrid forms between fully internal mass customization platforms and those with fixed, standard core and variety coming from crowds of external actors is an interesting angle too, especially for mass customization firms looking to tip their toes with openness. Can you do it step-wise or is it an either-or proposition? Are the complex industrial equipment mass customizers most safe from competitive threat of open platforms, due to their inherent complexity and low volumes? Further inquiries into hybrid approaches of mass customization and openness could look into how the different domains of physical products, software, and services can be ‘configured’ in terms of how open they are, when a part of a mass customized solution space.

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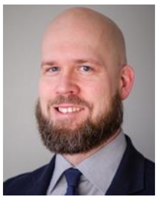

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