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Mass customization in an endogenous-timing game with vertical differentiation ☆

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ABSTRACT

We study mass customization in a duopoly game in which the firms' products have different qualities. Whether customization choices are made simultaneously or sequentially is endogenously determined. Specifically, the customization stage of the game involves two periods. Each firm either selects its product type in period 1 or postpones this decision to period 2. We show that customization by one or both firms occurs only if the quality difference is sufficiently large. Flexibility of timing in the customization stage sometimes enables the firms to achieve an outcome that is Pareto superior to that if they were constrained to simultaneous customization choices. Although the high quality firm is more likely to customize, in some circumstances the low quality firm can obtain an advantage by becoming the first and only firm to adopt customization.

1. Introduction

Mass customization (MC) is the use of flexible manufacturing systems to produce individually tailored products without significantly compromising cost efficiency. This concept was first coined in Davis (1987). As a business strategy, MC gathered remarkable momentum in the early 2000s when the technological advances in information technology facilitated the transfer of customer-provided specifications to manufacturing (Piller, 2002).

Today, mass customization is offered by many producers in a wide variety of industries.[1] The best example of effective MC is the production facility at Dell Corporation. When a customer wants to buy a computer system, he/she goes to Dell's website and selects from a variety of options for memory size, processor speed, hard disk size, software, and other peripherals. Dell produces a computer system per customer's specifications and delivers it within three to five business days in most cases (Kraemer et al., 2000). Table 1 reports major MC adopters in five product categories.[2]

Research on mass customization has mostly been descriptive, with a vast majority of publications being surveys and case studies (Franke and Piller, 2004; Ives and Piccoli, 2003; Lihra et al., 2008).[3] No generalizable quantitative research has been conducted thus far, as no large-scale microeconomic data is available, owing partially to protection of commercial information by producers. Another possible reason for the void of empirical research on MC is the small size of theoretical literature. As theory oftentimes generates interests and provides insights for empirical analysis, more theoretical studies of MC are warranted. The present paper adds to the small but growing literature (reviewed in Section 1.3) applying game-theoretical models to study mass customization.

1.1. Our model and results

Observations from the descriptive literature on MC, casual empiricism, and Table 1 allow us to make the following two generalizations about customization. First, the firms that have adopted MC generally produce high quality products. Second, MC adoptions by firms within an industry tend to be sequential in time (usually years apart). Despite these salient features of the MC phenomena, the existing theoretical studies have mainly focused on symmetric firms and ignored both inherent differences in product quality and the timing of adoption.

We believe that it is important to build theoretical models that can explain the above observed features in order to provide a solid foundation for future empirical work on MC. In our recent paper (Loginova and Wang, 2011) we modeled firms of different qualities and provided an

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[1] For latest examples, see http://www.mass-customization.de/ edited by Frank Piller.
[2] This table is compiled from several case studies (e.g., Berger et al., 2005; Moser et al., 2006) and company histories available online.
[3] Kumar et al. (2007) found 1124 MC publications in 365 outlets and concluded that MC is a mature field with major presence in the areas of operations research, management science, and operations management.

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Table 1
Examples of mass customization and adoption dates.

Product category	Company	Adoption date
Footwear	NikeID (http://www.nikeid.com/)	1998
	mi adidas (http://www.miadidas.com/)	2000
	Converse (http://www.converse.com/)	2004
	Reebok (http://www.reebok.com/)	2005
Apparel	Interactive Custom Clothes Company (http://www.ic3d.com/)	1996
	Levi Strauss (http://www.levi.com)	1999
	Land's End (http://www.landsend.com/)	2001
Watches	Timissimo (http://www.timissimo.com/)	1998
	121 Time (http://www.121time.com/)	2003
Messenger bags	Timbuk2 (http://www.timbuk2.com/)	2000
	Seagull (http://www.seagullbags.com/)	2003
Computers	Hewlett-Packard (http://www.hp.com/)	1995
	Dell (http://www.dell.com/)	1997

explanation for the first feature. The present paper takes a step further by introducing the endogeneity of timing into customization.[4]

We consider an industry in which products are characterized by variety (horizontal attribute) and quality (vertical attribute). Consumers are heterogenous in two dimensions. Specifically, each consumer has a most preferred variety and a quality valuation. There are two firms that are located at the end points of the variety space. The firms are asymmetrical due to having different qualities. Customization provides ideal varieties for consumers but does not affect qualities. The model has two stages, the customization stage followed by the pricing stage. The customization stage unfolds in two periods. Each firm either selects its product type – standard or customized – in period 1 or postpones this decision to period 2. Thus, whether customization choices are made simultaneously or sequentially is endogenously determined.[5]

The two-period approach to model the customization stage is, of course, an abstraction from reality. Although other (more complicated) strategies may be considered by firms, we believe that our simple approach is rich enough to capture the essence of endogenous timing. Moreover, it allows us to conveniently apply the results of Hamilton and Slutsky (1993) (discussed in Section 1.2).

Our equilibrium analysis shows that the difference in the firms' qualities and flexibility of timing in the customization stage play important roles in determining the equilibrium outcome. In particular, no firm will customize if the quality difference is small, regardless of the fixed cost of customization. Intuitively, customization by one or both firms makes their products less differentiated, thus intensifying price competition. The smaller the quality difference is, the tougher the price competition. For sufficiently large quality differences, customization by one or both firms may occur. Because the high quality firm benefits more from customization than the low quality firm, the high quality firm is more likely to customize.

Introducing endogenous timing yields new insights. Sequential product type selections can arise in equilibrium. This corroborates the second feature of MC adoptions mentioned above. More importantly, the timing of customization is a strategic tool for the firms. It sometimes enables the firms to achieve an outcome that is Pareto superior to that if they were to make their customization decisions simultaneously. While in the model of Loginova and Wang (2011) without endogenous timing the low quality firm never customizes alone, in the present model it can obtain an advantage by becoming the first and only firm to customize in some circumstances. For example, Timbuk2 is known for the successful customization of its messenger bags and backpacks. However, Tumi, whose products are of superior quality to those of Timbuk2, is not known for customization. As another example, Apple produces high quality products, yet it does not offer customization.

1.2. Why endogenous timing?

Industrial organization economists have long recognized the importance of endogenous timing in many economic activities. In the technology adoption literature, the pioneering empirical works of Griliches (1957) and Mansfield (1968) indicated that new technologies are usually diffused over time. Many subsequent theoretical works modeled the timing of technology adoption, including seminal papers by Reinganum (1981, 1983) and Fudenberg and Tirole (1985). Endogenous entry is another example that has sprung a sizable literature (Anderson and Engers, 1994; Lane, 1980; Prescott and Visscher, 1977). One of the main focuses of this literature has been on the order of entry by firms and the subsequent competition. Our paper shares features with both literatures. The customization stage can be thought of as a game of product (standard, customized) adoption. In contrast to the technology adoption literature, our paper explicitly models the subsequent price competition, as is done in the endogenous entry literature.

Another area of application of endogenous timing is price and quantity choices in an oligopoly. The standard models of Cournot, Bertrand and Stackelberg take firms' order of moves as exogenously given. A natural question to ask is which order of moves – simultaneous or sequential – should be assumed in a particular situation. Hamilton and Slutsky (1993, p.59) take the view that "When players have flexibility in the timing of their moves, whether they play a simultaneous or sequential move game should not be exogenously imposed, but should be determined in a larger extended game." These authors were the first to introduce a game-theoretic model in which the determination of simultaneity versus sequentiality of moves is endogenous (Hamilton and Slutsky, 1990, 1993). Several subsequent studies have applied their model to standard price or quantity duopoly games, e.g., Sadanand and Sadanand (1996), Matsumura (1999), and Amir and Stepanova (2006). Other applications of the Hamilton and Slutsky model include games of accumulation (Romano and Yildirim, 2005) and international competition (Lu, 2006; Syropoulos, 1994). The game structure of the customization stage in our paper also follows Hamilton and Slutsky (1993). In essence, we associate the abstract choices in Hamilton and Slutsky (1993) with product type choices. Of course, our paper is also about the subsequent competition in the pricing stage of the game. The nature of competition in this stage is an important part of our model.

Insofar as mass customization is a new technology, its adoption should follow patterns similar to those of other technologies.[6] Accordingly, endogenous timing should be an important part in the analysis of customization choices. As MC technology becomes available in a particular industry, some firms choose to adopt it right away, while others choose to wait and may never adopt at all. For example, Nike started customization in 1998, while Adidas did not offer customization until 2000 (Moser et al., 2006). In the computer industry, many companies including Dell, Gateway, and HP offer customization, but Apple does not.

1.3. Theoretical literature on MC

Other than Loginova and Wang (2011), the paper on customization that is closest to the present study is Syam et al. (2005). These authors also model consumer preferences in a two-dimensional space. Both dimensions correspond to horizontal attributes of the

[4] As noted in Section 3, the game studied in the present paper includes the game in Loginova and Wang (2011) as a proper subgame.

[5] As far as modeling goes, the main difference between the present paper and Loginova and Wang (2011) is that the customization stage in the latter involves a single period in which the firms simultaneously decide whether to customize their products.

[6] Dinlersoz and Pereira (2007) report adoptions of e-commerce and observed that some firms moved first, while others followed, either quickly or with some delay.