Innovation Opportunities Emerging from Responsiveness and Co-located Manufacturing

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Introduction: In this article we study the link between innovations and manufacturing. We focus on a specific part of this relationship, by investigating how responsive manufacturing can foster innovations. We propose that this link is uncharted and undervalued, which can undermine the investment in manufacturing. Responsiveness through co-locating manufacturing with either the market or with the R&D encourages innovation: Customer ideas are more easily communicated, and product and process innovations are more rapidly tested. We develop a system dynamics model of the interaction between responsiveness and innovation based on mechanisms that link manufacturing responsiveness to innovativeness in our empirical observations. Classical learning curve models (Wright 1936), learning and innovation modeling (e.g., Anderson and Parker 2002, Adner and Levinthal 2001, Repenning and Sterman 2002, Rahmandad 2012, Erat and Kavadias 2008, Girotra et al. 2010) are important to the argument that we will present in this paper.

Link between responsive manufacturing and innovations can be demonstrated by recent developments from footwear supply chains. Adidas has been innovating with their future supply chain by investing in a "Speedfactory" to bring shoe manufacturing close to markets (Bain 2017). "Speedfactory" allows far greater responsiveness enabling Adidas to bring new and customized products to market by cutting the time from designer's idea to finished products from months to days. Customization of products and designs will enable capturing ideas from users and testing products fast in markets. This enables faster learning and innovation in materials, technology and designs (Vincent 2017, Shotter and Whipp 2016).

Research method: Our study is an exploratory research to establish the existence and value of the proposed responsiveness-innovation link. We use System Dynamics (SD) model grounded to *empirical observations*. Following examples of previous SD studies (Repenning and Sterman 2002, Gray et al. 2017, van Burg and van Oorschot 2013), we do not begin by identifying factors in our model theoretically, but rather observing how certain types of innovation consistently emerge from specific types of responsiveness. Our empirical observations are gathered from 11 firm cases. We summarized our main empirical observations into four mechanisms that link the responsive manufacturing to innovation generation. 1. Responsiveness and product innovation are linked through specialization, customization and servitization. These innovations are

the product of three types of responsiveness: time-based, market-based and development-based. 2. Reverse margin retreat: local and responsive manufacturing encourages innovation at the low-end of the manufacturer's product portfolio. 3. Process flexibility innovation. Responsive manufacturers invest in finding ways to lower the cost of responsiveness. 4. Innovation for new use cases for capacity. Finding innovative ways to utilize capacity buffers required for responsiveness during low demand periods.

System dynamics modeling: Our system dynamics model extends the current understanding of the link between manufacturing and innovation by exploring the mechanisms how specific types of responsiveness increases the innovative capacity and how the returns of the innovations can create a virtuous cycle of learning effects that have been demonstrated in previous research (see e.g., Anderson and Parker 2002, Rahmandad 2012, Repenning and Sterman 2002). The main modeling for our research questions lies in the Innovation-Responsiveness model. It is accompanied by production and inventory model based on the Sterman (2000, p.801) model.

Testable propositions for responsiveness and innovation link for manufacturer: Simulation is used to capture emerging testable propositions for the responsiveness and innovation link for future research. 1. Innovation returns accumulate over time: "path-dependence", 2. Responsiveness of manufacturing generates innovation returns in product and process development, 3. The higher the returns for innovativeness, the higher the investment in responsiveness, 4. Misclassifying innovative products as functional leads to missed learning opportunities, 5. "Pain before gain" of investments in responsiveness.

Discussion: The contribution of this research is to explore the link between innovation and manufacturing and identify testable propositions through SD modeling and simulation. We propose research questions for future modeling and empirical research to study. We identified mechanisms linking responsiveness to increased innovativeness, and the following performance gains.

The identification of mechanisms linking the innovations and manufacturing responsiveness increases the value of local manufacturing capacity. While utilizing global value chains for enhancing innovation and development capabilities as discussed by Lee and Schmidt (2017) is a valuable source of development capacities in global value chain networks, the responsiveness-innovation link we have explored focuses on the local level. These different viewpoints are complements. The value of enhancing innovation depends on the industry and the life-cycle of current technology as was proposed by our model. For decision making perspective our modeling of innovation-responsiveness link suggests that the decision maker should include innovation and learning aspects to the capacity location decision. This proposition is in-line with previous research on the learning effects and capability building (Anderson and Parker 2002, Rahmandad 2012, Repenning and Sterman 2002, Repenning 2001, Repenning and Sterman 2001).

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