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Capturing the competitive advantages of AMT: Design–manufacturing integration as a complementary asset

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Abstract

In this article we describe and test a theory of complementarities between design–manufacturing integration (DMI) and usage of advanced manufacturing technologies (AMT). This study extends prior AMT research by examining the role of complementary assets in explaining how AMT adoption contributes to manufacturing performance. In addition, the study provides a finer-grained analysis of associations between Process and Planning AMT usage and various aspects of manufacturing performance. We analyze data from 224 manufacturing plants in order to test the hypotheses that DMI moderates the relationships between AMT usage and manufacturing performance. Regression analysis results indicate that DMI plays the role of complementary asset to AMT usage when quality, delivery and process flexibility are considered. A complementary role is not observed for cost efficiency and new product flexibility. In fact, the results suggest that combined high levels of DMI and AMT usage can be costly. We discuss the implications of the findings for a contingency theory of AMT success, for future research, and for managerial practice.

Keywords: AMT; Design–manufacturing integration; Contingency theory

1. Introduction

The debate concerning the *real* benefits of advanced manufacturing technologies (AMT) continues. Over the past 30 years, reported anecdotes and cases have touted the benefits and promise of computer controlled manufacturing technologies. However, empirical evidence of these benefits has been surprisingly limited, and highly mixed. In addition, while the benefits offered by automated processing and planning systems seem obvious, the potential that these benefits hold for creating competitive advantages is less clear.

Many researchers highlight the flexibility of AMT, whereby firms can produce wide varieties of products at low volumes without added costs or penalties (e.g., Kaplinsky, 1984; Goldhar and Jelinek, 1985; Adler, 1988; Dean and Snell, 1991, 1996; Gerwin, 1993a; Gerwin and Kolodny, 1992; Parthasarthy and Sethi, 1993; Swamidass and Kotha, 1998; Kotha and Swamidass, 2000). In addition, the ability of AMT to increase manufacturing productivity has been well cited (Ettlie, 1984; Dean and Snell, 1991; Swamidass and Kotha, 1998). Routine tasks can be embedded into AMT hardware and software, thereby reducing direct labor costs, rework costs, and work-in-process inventories

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(Zummato and O'Connor, 1992). Process technologies such as flexible manufacturing systems (FMS) and computer numerically controlled (CNC) machines are thought to reduce product changeover costs and process variability, thereby improving both productivity and product quality. By bringing automation and computational power to decision making, planning technologies such as enterprise resource planning (ERP) systems are thought to lower transaction costs and to produce more efficient production plans. However, empirical studies have reported non-significant or even negative direct associations of AMT adoption to performance (Boyer et al., 1996; Beaumont and Schroeder, 1997; Swamidass and Kotha, 1998; Cagliano and Spina, 2000).

The discrepant findings in the literature suggest the need to identify contingencies that may govern AMT–performance relationships (Swamidass and Kotha, 1998; Cagliano and Spina, 2000; Das and Jayaram, 2003). Prior examinations of AMT–performance moderating factors have mainly addressed infrastructural and demographic variables such as worker empowerment, quality programs, and process type (Dean and Snell, 1991; Safizadeh et al., 1996; Boyer et al., 1997; Swamidass and Kotha, 1998; Das and Jayaram, 2003). In this study, we focus on an important yet neglected factor, design–manufacturing integration (DMI).

We posit that the DMI, the integration of product design and manufacturing process knowledge, is an important complement to AMT usage. We view DMI as a strategic integration process reflected by a certain philosophy and by related practices (Ettlie and Reifeis, 1987; Ettlie and Reza, 1992; Ettlie, 1995). Design–manufacturing integration activities raise an organization's ability to identify and effectively address product–process design interdependencies. Assuming the application of AMT is affected by product specifications and by the host-manufacturing environment, DMI represents a potentially important complementary asset.

General theories describing the roles of integration activities in technical capability-performance relationships have been described, but these theories have not been applied to the AMT–performance link. More specifically, the importance of DMI has been discussed, but empirical studies are scarce, and researchers have called for a refined theory of integration and successful process adoption to explain the details of integration–performance relationships (Ettlie and Reza, 1992). Researchers have studied the effects of DMI on new products (Ettlie, 1995; Zahra and Nielsen, 2002) and NPD project outcomes (Adler, 1995; Fleischer and Liker, 1992; Swink, 1999; Swink and Calantone, 2004), but less attention has been given to broader production benefits of DMI, especially benefits related to AMT implementation.

In total, we examine the effects of DMI on relationships between two types of AMT and five dimensions of manufacturing performance. Researchers have recently emphasized the need to consider a multi-dimensional view of AMT and performance (Kotha and Swamidass, 2000), which in turn presents a richer set of moderating relationships that demand research investigation.

This study extends prior research by offering a more fine-grained empirical analysis, thereby offering evidence that begins to explain how AMT can contribute to manufacturing success. This is an important question as many manufacturing firms have sunk enormous amounts of capital into AMT investments over the last three decades. Prior studies of AMT success have focused on AMT–performance links but have neglected to study AMT's influences on specific dimensions of manufacturing performance.

The second contribution of this study is the development and test of theoretical arguments for the importance of DMI as a strong moderator of AMT–manufacturing performance relationships. In formulating these arguments we draw upon the notion of complementary assets, in which AMT is seen as an easily appropriated asset, and DMI is seen as a specialized complementary asset. We discuss the interplay of these "resources," and evaluate evidence of their interacting effects on the creation of competitive advantages through superior manufacturing performance.

A third contribution from our study derives from our analysis of data gathered at the manufacturing plant level. This level of analysis is important since it is at this level that AMTs are actually deployed.

2. Theory development

2.1. *Manufacturing performance enhancements offered by AMT*

Our treatment of AMT focuses on computer integrated technologies (Brandyberry et al., 1999; Boyer et al., 1997; Swamidass and Kotha, 1998), as opposed to more broad conceptualizations of AMT that include soft technologies such as JIT and progressive human-resource development techniques (Narasimhan et al., 2004; Dean and Snell, 1996). Swamidass and Kotha (1998) stress the need to consider AMT using a multi-dimensional perspective, thus enabling a detailed examination of the perhaps subtle relationships among