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Process Management Practices and Performance: Competition and the Moderating Effect of Technological Capabilities

Mary Benner
University of Pennsylvania

Francisco Veloso
Carnegie Mellon University, fveloso@cmu.edu

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Mary Benner
Management Department
The Wharton School
2000 Steinberg Hall-Dietrich Hall
Philadelphia, PA 19104-6370
Tel: +1 215-746-5719
benner@wharton.upenn.edu

Francisco M Veloso**
Department of Engineering and Public Policy
Carnegie Mellon University
5000 Forbes Av.
Pittsburgh, PA 15213
Tel: +1 412 268 4640
fveloso@cmu.edu
and
Universidade Catolica Portuguesa – FCEE
Lisbon, Portugal

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** Corresponding Author

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ABSTRACT

Attention to processes has increased, as thousands of organizations have adopted process-focused practices, including TQM and ISO 9000. Proponents of such programs stress the promise of improved efficiency and profitability. But research has not consistently borne out these prospects. Moreover, the expectation of universal benefits is not consistent with research highlighting the important role of firm-specific capabilities in sustaining competitive advantage. In this paper, we use longitudinal panel data for firms in the auto supplier industry to study two new issues. First, we find that, with the majority of firms within an industry adopting process management practices, late adopters no longer gain financial benefits from these practices. Second, we explore how firm technological capabilities moderate the performance advantages of process management. We find that firms that are very narrowly- or broadly- oriented have fewer opportunities for complementary interactions that arise from process management practices and thus benefit less than those with limited breadth in technologically related activities.

Keywords: operations strategy, technology management, quality management, empirical research methods

INTRODUCTION

A central question in strategy is how firms achieve sustainable competitive advantage. Research is often aimed at assessing whether particular organizational practices can deliver sustainable advantages, especially given that other firms can also adopt similar practices. As Porter (1996) highlights, for example, practices aimed at improving operational effectiveness may benefit adopting firms, but if a firm's competitors can all adopt the same practice, the benefits will be competed away. Firms are then frustrated in their efforts to translate such performance improvements into relative financial performance advantage. If a generic "best practice" is equally beneficial to all potential adopters, it cannot confer lasting benefits (e.g. Lieberman and Montgomery, 1988; Porter and Siggelkow, 2004; Levinthal, 2000).

Research in strategy has increasingly focused on the central role of firm-specific, unique, and inimitable capabilities (e.g. Peteraf, 1993; Barney, 1991), and organizational routines or processes have emerged as critical building blocks in these difficult-to-imitate capabilities (e.g. Teece, Pisano, and Shuen, 1997; Dosi, Nelson and Winter, 2000; Eisenhardt and Martin, 2000). At the same time, enthusiasm for organizational routines and processes has increased in managerial practice. Thousands of firms have embraced the process-focused practices that underlie a progression of popular programs focused on quality improvement, including Total Quality Management (TQM), Business Process Reengineering, the Malcolm Baldrige Award Criteria, and more recently, the ISO 9000 quality certification program and Six Sigma (e.g. Staw and Epstein, 2000; Garvin, 1991, 1995; Cole, 1998; ISO, 2004). While these programs differ in scope and approach, they share a core focus on systematic attention to organizational processes (Benner and Tushman, 2002). This focus on process management involves mapping, incrementally improving, and ultimately adhering to systems of improved processes (Benner and Tushman, 2002).

Proponents of process management practices cite expectations of improved quality and efficiency, leading to increased revenue, reduced costs, and ultimately, higher profits (e.g. Winter, 1994; Garvin, 1995; Hammer and Champy, 1993; Harry and Schroeder, 2000). Correspondingly, empirical research on the performance implications of process management has generally relied on the assumption that process management practices will lead to improved profit and competitive advantage (e.g. Easton and Jarrell, 1998; Corbett, et al, 2005.) However, despite expectations of profit improvements from process management, the findings from such research have been equivocal. While some research demonstrates the anticipated financial advantages (e.g. Easton and Jarrell, 1998; Corbett et al, 2005; Hendricks and Singhal, 1997), other research has not found better business performance associated with process management techniques (e.g. Powell, 1995; Staw and Epstein, 2000; Terziovski et al., 1997; Samson and Terziovski, 1999).

One explanation for these contrasting findings, drawn from the strategic management literature, is that any financial advantages may be competed away as more firms in an industry adopt and achieve similar improvements. Indeed, process management often has been viewed as a generic practice that is easily adopted by firms (e.g. Hammer and Champy, 1993; Harry and Schroeder, 2000; Pande, Neuman, and Cavanagh, 2000). In that case, it will be increasingly difficult to translate efficiency improvements into relative financial performance advantages over time as firms within an industry increasingly adopt identical practices (Porter, 1996; Lieberman and Montgomery, 1988).

However, process management practices may confer lasting benefits if they interact with firm-specific routines and associated capabilities in ways that are difficult to imitate. Since process management implementation is aimed at streamlining processes and the handoffs between processes across an organization, and as processes are central components of firms' capabilities, such practices necessarily affect firms' capabilities. Process management activities are thus a meta-practice that directly affects the potential for firms' capabilities to lead to competitive advantage. Specifically, process management practices can increase the "fit" or complementarities among organizational activities (c.f. Siggelkow, 2002). Thus, the potential for process management to strengthen capabilities will differ across firms, depending on firm-specific characteristics. In line with existing perspectives in manufacturing strategy (White, 1996; Miller and Roth, 1994), some research looking at process management has also begun to recognize that the impact of process management practices may depend on firm characteristics (e.g. Benson et al., 1991; Das et al., 2000; Sousa, 2003; Ettlie, 1997; see also Sousa and Voss, 2002 for a recent review of research on quality improvement). However, research has not provided consistent analyses of how the interaction of process management with firm capabilities affects the financial performance benefits of process management practices.

In this paper, we go beyond prior research, using strategy and organization theory literature to better understand how competitive advantage arises for firms adopting process management practices. We explore two questions that have been missing in previous studies.

First, we ask what happens to the financial performance benefits of firms adopting process management practices as the majority of competitors in an industry embrace similar practices. We argue that as process management practices are ubiquitously implemented in an industry, efficiency improvements are less likely to translate directly into higher profits, as generic process management practices can be imitated (cf. Barney, 1991, Peteraf, 1993), and their benefits competed away (e.g. Porter, 1996). Second, we consider how the financial performance advantages of process management implementation are influenced by firm-specific capabilities. We follow prior work that explores relatedness or coherence in a firm's technological capabilities (e.g. Patel and Pavitt, 2000; Silverman, 1999; Teece, Dosi, Rumelt, and Winter, 1994; Wolter, Veloso, and Steinemann, 2003), and analyze how the breadth or focus of firms' underlying technological capabilities moderate the effects of process management practices on performance. This approach also reflects research in strategy that suggests firms have opportunities to create greater advantage from related businesses (e.g. Rumelt, 1974; Singh and Montgomery, 1987). Process management practices may be one vehicle for creating linkages and synergies across related activities.

We study these ideas using a unique, comprehensive, longitudinal dataset for firms in the auto supply industry. Studying these questions within one industry where process management adoption has become ubiquitous allows us to assess the changes in relative performance advantages over time, while better controlling for industry effects that also influence firm performance. Following previous research on process management (e.g. Benner and Tushman, 2002), we rely on data on firms' ISO 9000 certifications to measure process management adoption. ISO 9000 certification requires a third-party registrar, such as Underwriters'

Laboratories (UL), to verify that an organization documents and adheres to its processes. Thus, these data overcome some of the challenge of assessing whether firms are really undertaking process-focused practices (e.g. Powell, 1995; Easton and Jarrell, 1997; Zbaracki, 1998; Westphal et al., 1997). We assess the moderating role of breadth in firms' underlying technological capabilities with a firm-specific measure of technological coherence from a comprehensive assessment of the technologies used by each auto supply firm.

We estimate models of the impact of process management on firm performance using panel data with firm fixed effects and year controls. This longitudinal approach statistically controls for firm specific unobserved factors correlated with both performance and process management practice adoption that could lead to erroneous inference and might confound our findings. For example, firms that adopt may have systematically different performance levels for reasons unrelated to adoption. Identifying our estimate from the change in performance (more specifically, from the within-firm variation) avoids attributing differences in levels of performance that are independent of adoption to the adoption itself.

The paper proceeds as follows. In section 2, we develop our hypotheses about process management's effects on firms' financial performance. In section 3, we discuss our measures and models. Section 4 presents the results of our empirical tests. In support of our hypotheses, we find that the financial performance benefits of process management disappear as the majority of competitors in an industry adopt similar practices, and further, that the performance benefits of process management are indeed moderated by technological coherence in firm-specific capabilities. This relationship exhibits an inverted U-shape: very narrowly- or very broadlyfocused firms have fewer opportunities to take advantage of the potential for improved internal fit or complementary interactions among related firm activities, while firms with limited breadth in technologically related activities appear to benefit the most from implementing process management practices. We conclude with a discussion of the implications of this work for research and practice, and possible extensions.

HYPOTHESES DEVELOPMENT

Process management practices have gained widespread attention in the last few decades, in both practice and research. Although programs like TQM, ISO 9000, and Six Sigma differ in approach, these programs share an underlying set of practices focused specifically on an organization's processes. The first step in process management involves mapping an organization's processes, that is, the routines for carrying out organizational activities such as manufacturing or new product development (e.g. Dean and Bowen, 1994; Hackman and Wageman, 1995; Hammer and Champy, 1993; ISO, 2004). This is followed by concerted efforts to improve and streamline processes by eliminating wasted steps and coordinating the handoffs between processes across the organization (e.g. Hackman and Wageman, 1995; Anderson, Rungtusanatham, and Schroeder, 1994). The final stage in process management is adherence to systems of improved processes (e.g. Harry and Schroeder, 2000; Heaphy and Gruska, 1995; Mukherjee, Lapre, and Van Wassenhove, 1998; ISO, 2004.)

Process management and firm performance

As these programs have gained popularity in practice, researchers have sought to understand their effects on organizations. The expectation that these programs will lead to financial performance benefits for firms has spurred a large body of research focused on the assessing the performance benefits for firms adopting process management. This literature suggests that process management practices will improve firm performance through two main mechanisms. The first source of performance improvement arises directly from increases in operational efficiencies and resulting cost reductions from implementing process-focused practices (e.g. Westphal, et al, 1997; Corbett, et al, 2005; Sterman, et al, 1997). Even in the absence of proactive efforts to incrementally improve processes, such as in the case of ISO 9000's primary focus on adherence to documented processes, repetition of standard processes is also likely to result in improved efficiency through incremental learning-by-doing (c.f. Levitt and March, 1988; Levinthal and March, 1993; Benner and Tushman, 2003). The second source of performance improvement arises from increases in firms' legitimacy following adoption of process management, leading to access to new markets or customers and increases in revenue (e.g. Westphal, et al, 1997; Corbett et al, 2005; Hendricks and Singhal, 1996; King, Lenox and Terlaak, 2005; Guler, Guillen, and MacPherson, 2002). Existing research further suggests that these benefits of improved efficiency or legitimacy will translate directly into improved profitability (Ittner and Larcker, 1997). Thus, following the predictions of prior research, our first hypothesis is:

Hypothesis 1a: Adoption of process management practices by a firm will result in improved financial performance.

However, despite these expectations of performance benefits, results of studies that assess process management's effects on firm financial performance have been conflicting. While some existing research has shown performance advantages from adopting TQM (Easton and Jarrell, 1998; Wruck and Jensen, 1994), ISO 9000 (Corbett, Montes-Sancho, and Kirsh, 2005), and winning a quality award (Hendricks and Singhal, 1996, 1997, 2001), other studies have not found performance improvements associated with process-focused techniques (e.g. Powell, 1995; Samson and Terzivoski, 1999; Staw and Epstein, 2000). Wayham et al (2002) found a small and fading effect, while Sterman, Repenning, and Kofman (1997) found that the improved yields and reduced waste resulting from TQM did not translate into better financial performance. In a recent review, Sousa and Voss (2002) conclude that the "impact of Quality Management practices on business performance is weak(er) and not always significant." Other research has found financial benefits of TQM adoption, but not from implementation of process-focused techniques (e.g. Samson and Terziovski, 1999; Powell, 1995). In these cases, other elements of the larger package of TQM practices, such as executive commitment or employee empowerment, drove financial performance improvements. These contrasting findings are surprising as it is specifically the attention to processes that is expected to lead to performance improvements.

Some research, following institutional theory (e.g. DiMaggio and Powell, 1983; Zucker, 1986; Zbaracki, 1998), suggests that these equivocal findings arise from differences in the actual practices undertaken by early and late adopters. This research suggests that the benefits of such practices are higher for earlier adopters of process management specifically because later adopters fail to utilize the actual techniques that would generate efficiency benefits (Westphal, et al, 1997).

But performance differences may arise between early and later adopters even if they adopt identical practices. Improvements in legitimacy or operational effectiveness that result from adoption of a generic improvement program are available to all adopting firms (e.g. Porter, 1996; Powell, 1995). As the majority of firms in an industry adopt, it is increasingly difficult to translate absolute improvements in operational effectiveness into sustainable relative financial performance advantages (e.g. Lieberman and Montgomery, 1988; Porter, 1996.) This is an important possibility that has not been explored in prior empirical work on process management. Although the idea that performance benefits are greater for early adopters is not new, our use of the ISO 9000 certification data to assess the effects of process management allows us to specifically explore the explanation that the benefits are competed away. ISO 9000 certifications require an audit by a third-party registrar outside the organization to validate that the organization has undertaken process-focused activities, that is, that the specific processes being certified have been mapped and are being followed. This ensures that the early and later adopters in our study are undertaking comparable activities and allows us to test the explanation that the performance benefits are competed away. Thus, we modify the predictions in H1a with the following:

Hypothesis 1b: Adoption of process management practices by firms within an industry will be associated with performance benefits for early adopters, but lower performance benefits for later adopters.

The moderating role of firm-specific capabilities

But are there conditions under which firms can sustain the performance benefits of practices focused on improving processes? Prior research suggests that sustainable competitive advantage arises as underlying firm activities are coordinated to create unique firm-specific interactions or complementarities (Porter and Siggelkow, 2004). Tighter coordination of organizational activities occurs as these activities are repeated in stable routines or operating procedures (e.g. Hannan and Freeman, 1984). Process management furthers these natural organizational tendencies as it involves techniques specifically aimed at adhering to standard routines, and tightening the coordination between interdependent processes in an organization. For example, an organization focused on improving the efficiency and speed of its manufacturing process is likely to also focus attention on the handoffs or linkages between its product development process upstream and the manufacturing process downstream. Efforts to develop products that can be more easily manufactured results not only in further improvements in manufacturing, but also creates tighter interactions between the two processes. Similarly, process management spurs tighter linkages between other upstream and downstream activities across an organization (e.g. Dean and Bowen, 1994). As an organization utilizes process management practices, that is, as it carries out activities through adherence to standardized processes, and further, improves processes by tightening the coordination between processes, it is likely to achieve greater "fit" between activities (e.g. Siggelkow, 2002). The resulting configuration of interconnected capabilities is increasingly firm-specific and difficult to imitate. Moreover, because these underlying sets of routines and capabilities differ across organizations, the performance implications that arise from the interaction of process management practices with underlying routines are also likely to differ.

In this research, we look at firm capabilities as technological breadth or coherence. In doing so, we follow a growing body of research in strategy that assesses the extent of relatedness in firms' capabilities and resources with measures of technological breadth (Silverman, 1999; Argyres and Silverman, 2004; Miller, 2004). Researchers have argued that technological breadth provides a finer-grained measure of firms' activities and resources than market based measures of relatedness drawn from a firm's participation by SIC codes (e.g Jaffe, 1989; Silverman, 1999). In existing research, the technology categories listed on a firm's patents are frequently used as an indicator of its technological breadth. However, the technology classes in which a firm patents (invents) can understate the full range of its capabilities (Silverman, 1999). Thus, as explained in detail in the methods section, our measure of the breadth of technological capabilities has been carefully constructed by assessing the range of firms' actual activities in a particular industry, automobile suppliers in our case.

Prior work suggests that the extent of coherence or relatedness in a firm's underlying technological capabilities offers differential opportunities for creating firm-specific interactions and complementarities that can lead to competitive advantage (e.g. Hill and Hoskisson, 1987). Evidence from the diversification literature shows that related diversification can result in higher performance than unrelated (e.g. Rumelt, 1974; Singh and Montgomery, 1987; Teece, et al 1994). Related diversifiers are expected be able to better exploit economies of scope, and thus create strategic assets more efficiently than competitors. Because of relatedness of their technological activities, they can more efficiently tap into their core capabilities and generate synergies between business units or segments and thus exhibit a better performance vis-a-vis narrowly focused units and unrelated diversifiers. In the setting we will explore in this paper, the idea is that a firm that does Die Casting would more easily gain more from diversifying to Investment Casting rather than Plastic Injection Molding (see next section for a complete the description of the measure used to implement the concept of technology coherence). The benefits of relatedness arise, in part, because of the greater potential for unique combinations of resources and capabilities as firms coordinate related activities more closely (e.g. Hill and Hoskisson, 1987).

As process management practices provide a mechanism for linking organizational activities, their benefits are likely to be greater in firms that have some opportunities to gain synergies from linking related activities. Thus, we hypothesize that the breadth of a firm's technological capabilities moderates the performance effects of process management utilization. A narrowly focused, technologically coherent firm is unlikely to have many opportunities for unrealized synergies across activities that the application of process management techniques can uncover. Such firms have less to gain from activities that increase coordination and the potential for complementarities between activities. The benefits for firms with narrowly focused technological capabilities are also more likely to arise from generic efficiency improvements rather than from inimitable interactions in activities, and as a result, may also be competed away more easily through imitation (e.g. Porter, 1996; Lieberman and Montgomery, 1988). As a firm increases the breadth of its technological capabilities and, correspondingly, its opportunities to realize synergies from related activities, increased utilization of process management practices can create firm-specific interdependencies that are not easily imitated.

However, firms with high levels of unrelated activities or technological breadth, face less potential for the complementary interactions that arise from tighter coordination of related activities. Moreover, it may be difficult for these firms to implement process management practices across its disparate activities, hindering their ability to reap any value from the potential for better coordination and tighter linkages (e.g. Repenning and Sterman, 2002). Thus,

H*ypothesis* 2: *Technological coherence will moderate the effect of process management on performance, following a curvilinear (inverted U) relationship.*

This means that, increases in performance from process management utilization will be low for very narrow technology capabilities [due to potential for imitation] or very broad [due to lower potential for inimitable combinations in unrelated activities]. Increases in performance from process management utilization will be highest for firms with a broad but not diverse level of technological coherence.

DATA AND MEASURES

Data Construction

We test our hypotheses on a sample of firms from a single industry, the automotive supplier industry in the U.S. during the 1990s. We chose this industry and timeframe for several reasons. First, process management adoption has been ubiquitous in this industry, which allows us to assess how performance benefits of process management is affected as firms within an industry increasingly adopt them. Second, using data from a single industry also helps us better control for heterogeneity and avoid other complications inherent in inter-industry analysis

(Montgomery and Wernerfelt, 1988). Third, we are able to use a unique dataset with detailed, comparable information on technological characteristics for firms in this industry. Finally, we study these questions during a time period where ISO 9000 adoption increasingly became a requirement for participation in the sector; while at the end of the eighties none of the firms had adopted ISO 9000, by the end of our observations, three quarters of the total had adopted. In addition, reporting requirements for financial disclosures of business segment information changed in 1998; we therefore chose the ten-year period from 1988 to 1997 to exclude the effect of these reporting changes. The time period covers approximately one full economic cycle of the automotive industry.

Auto parts firms are defined as firms primarily engaged in manufacturing finished and semi-finished automotive components.[1] To include as many firms as possible in the analysis, a broad list containing over 650 firm names was compiled from multiple sources[2], and this list was then narrowed down to meet the criteria of the industry definition. Data on firm technology was accessed from company annual reports (10-K) filed with the Securities Exchange Commission (SEC), financial data was from COMPUSTAT, and data on ISO 9000 certifications was obtained from McGraw Hill's database of registered companies.

Our data set encompasses only U.S. registered, public companies. As our interest is specifically in the firms participating in the sector, a firm was included in the data if it had at

[1] The definition excludes suppliers of raw materials, tool manufacturers, suppliers of instrumentation and computer services, testing services, software developers, pure R&D companies, pure manufacturers of components for trucks and other transportation equipment, and pure automotive aftermarket firms.

[2] Firms in COMPUSTAT with at least one business segment representing SIC code 3714 (Motor Vehicle Parts & Accessories) and/or business segments having an automotive manufacturer as primary business segment customer; firms listed in the Market Data Book of Automotive News, and firms listed in the Automotive Engineering International Annual Product Sourcing Guide, North America.

least one business segment whose sales to the automobile industry represented a minimum of 50% of its of total sales. The baseline data set includes 89 firms in the ten-year period and covers approximately $120 billion of annual sales.

We use data from the ISO 9000 certification program as the relevant proxy for a firm's commitment to process management practices. While ISO 9000 differs in approach from other process management programs such as TQM and Six Sigma, this measure has several advantages. A challenge with using TQM adoption to represent process management practices is heterogeneity in the actual practices that firms adopt, and the difficulty of assessing whether firms actually undertake any process-focused practices (e.g. Easton and Jarrell, 1998; Zbaracki, 1998). In contrast, ISO 9000 certification requires that firms document and demonstrate adherence to their processes in periodic audits conducted by third-party registrars (such as UL), which increases the likelihood that firms are engaging in systematic attention to underlying processes. In addition, the registrars provide the certification data, which helps overcome the subjectivity of firm self-reports in surveys of quality program adoption (c.f. Easton and Jarrell, 1998). Moreover, the institutional mandate for ISO 9000 adoption, particularly in the auto industry, has been greater than for other quality programs during this period (e.g. Guler, et al, 2002; Terziovski, Power and Sohal, 2003). These pressures for ISO 9000 make the adoption "decision" less endogenous than in the cases of TQM or Six Sigma, which have been more voluntary and thus more biased by self-selection (e.g. Easton and Jarrell, 1998; Corbett et al., 2005). Widespread adoption arising from these pressures also allows us to observe how performance is affected as the majority of firms in an industry adopt.

We used ISO 9000 certification data provided from McGraw-Hill's ISO 9000 Registered Company Database on a CD each quarter. We included a certification in our data if we could verify from location and company information that it was attributable to a firm in our dataset. We used the date listed on the certification, so the first date of adoption of ISO 9000 was represented by the first ISO 9000 certification for that firm. We also cross-checked the data with earlier versions to ensure we had initial dates of each certification rather than renewal dates.

Finally, it is important to recognize that, while financial performance is measured at the corporate level, firms can have multiple ISO certifications, even within the same location. Ideally, one would measure the financial performance of the particular part of a company associated to a given ISO 9000 certification. But, unfortunately, such detailed information does not exist. As a result, we follow an established practice (see Docking and Dowen, 1999; Simmons and White, 1999 and Corbett et al., 2005) and focus on a firm's first certification. For small firms with a unique location, this is not an issue because there is no difference between site certifications and firm performance. But such difference exists for large firms with many sites. However, such disconnect works against finding any effects in our analysis. If a firm has multiple sites being certified separately, a certification of a first location is likely to have a smaller effect in the financial performance of the firm. Thus the effects of certification must be strong in order to be captured by our estimation. This makes our results potentially conservative.

Measures

ISO Adoption. Our primary measure of ISO 9000 adoption is a binary measure for each firm that equals zero until the year the firm receives its first ISO 9000 certification, and equals one thereafter. For example, if a firm became ISO 9000 certified in 1993, its ISO adoption variable would be zero from 1988 until 1992 and one from 1993 to 1997. In addition, we also created an individual firm time trend since adoption. This helps capture the idea that efficiency or legitimacy benefits unfold over time as the organization adheres to documented processes and the market becomes aware of the certification, a result suggested by the recent work of Corbett et al. (2005). This variable is zero until first certification, then takes successive values of 1, 2, 3, etc, for subsequent years. For the firm first adopting in 1993, this variable will be zero until 1992, 1 in 1993, 2 in 1994, 3 in 1995, etc[3].

Firm Performance. We measure financial performance at the firm level. Consistent with prior research, we rely on multiple measures of performance to attain robustness of results. We use two accounting measures, return on assets (ROA) and return on sales (ROS), as well as a market based measure, Tobin's q (the ratio between a firm's market value and the replacement value of its assets).

Technology Coherence. We hypothesize that firm-specific technological capabilities moderate the relationship between ISO 9000 adoption and performance. In particular, we expect the level of focus or diversity in the technological capabilities of a firm to be associated with different benefits from ISO 9000 adoption. We created a measure of coherence in the portfolio of technologies of a firm through a detailed analysis of the firm's technology footprint[4], using a

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[3] We also considered an alternative specification ending the individual trend line 3 or 4 years after adoption. The results were similar. Yet another alternative would be to have both an individual trend and an adoption dummy, enabling two degrees of freedom on the post adoption line. We also considered this, but the results, whenever significant, were no different from having just the linear trend. So we decided to use the simpler model.

[4] The few studies that have analyzed firm technology coherence have used patents (see Silverman, 1999; Breschi et al., 2003; Gambardella and Torrisi, 1998). While this may be appropriate in high tech industries where patents are a critical mechanism of technology appropriation, it is not feasible in the automotive industry, where patents are only of minor importance as a measure of technology resources and capabilities. For a discussion on how patents are used across industries as a mechanism of technology appropriation see Cohen et al., 2000.

methodology developed by Steinemann (2000)[5]. First, we used a 3-level hierarchical classification scheme for technologies used in auto component manufacturing. We consider technologies within a given category to be more related to each other than to technologies in other groups at the same level. We defined relatedness, or group membership, on the basis of similarities in materials, equipment and manufacturing methods. Technical and engineering literature on automotive components served as a guideline for establishing the classification scheme (cf. Steinemann, 2000). The classifications were also validated by experts in the automotive field. The final hierarchy (see appendix) has nine major technology groups (level two in the hierarchy), twenty three subgroups (level three in the hierarchy) and over forty individual technologies. Casting, for example, (a level three subgroup), is part of the metal processing group and involves five different individual technologies. The idea of the classification is that all casting technologies are related, but different from, for example, machining or forming, two other subgroups of the metals processing group.

Second, we use this classification scheme to categorize capabilities for every auto business segment of all firms present in our sample. We classified firm capabilities through a detailed search of firm annual reports and SEC 10-K reports. Whenever a firm reported the presence of a given technology, we labeled its presence in the third level of the hierarchy [6]. So, for example, if a firm uses metal stamping, compression molding, injection molding and manual assembly to manufacture the components it sells, it will have a total of four technologies, two of them in the same level three subgroup – plastics molding, and the other two in different subgroups and groups.

[5] The development of this measure (Steinemann, 2000) was unrelated to understanding the impact of ISO adoption on performance. Thus, the variable is not biased by the underlying objective of the assessment in this paper.
[6] More detail on criteria used in assessment and classification is available in Steinemman (2000) or from the authors.

The resulting dataset allows us to assess whether each of the technologies in the third hierarchical level exists in a business segment for a given firm in a given year. We then use a Herfindahl Concentration Index based on Berry (1975) to construct a measure of technological coherence (the inverse of diversification) for the automotive business segments of every firm. We do this by calculating $HCI = \sum_i S_i^2$ for each firm in a given year, where each S_i is the share of technological competencies at the second hierarchical level (e.g. 121 – Casting or 132 – Molding). For example, a firm with 5 technologies in total, three in metal processing and two in plastics processing would have a coherence level of COH = [(3/5)^2+(2/5)^2] = 0.36+0.16 = 0.52. After calculating an HCI value for each year, we then averaged it over the years to allow us to contrast firms[7]. The resulting variable can vary from one, if the capabilities are all in one of the second hierarchy levels, to close to zero if the competences are distributed across all the groups[8]. Our hypothesis is that firms adopting ISO 9000 that have technology coherence levels, as measured by the HCI, that are either very high (for example, the firm does only injection molding, and the HCI measure would equal one) or very low (for example, the firm has one technology in each of the 23 level-three groups) will benefit less than those in the middle range.

Control Measures[9] We included firm size measured through sales in log form to control both for the effect of size on ISO 9000 adoption and performance. Since high levels of

[7] As data was gathered, it became noticeable that the technology footprint of the firms was quite stable over this period. So, yearly data on technology was collected only back to 1993 and averaged over 1993-1997. Thus the measure becomes firm specific and not firm-year specific.

[8] Though the value never goes to zero, a firm with one competence in each of the 23 groups would have coherence of 1/23.

[9] In cross-sectional models, control variables are used to control for differences between firms. We discuss the cross-sectional interpretations here. In panel data models with firm fixed effects, the fixed effect controls for cross-firm differences, and the interpretation of the control variables changes to within-firm, over time.

investment can have an impact on both process management adoption and performance, we also included a control for capital expenditures for each firm-year. But, since capital expenditures tends to track sales very closely, and since we were mostly concerned with having a large capital investment confounding the effect of the ISO adoption, we represented this control as a dummy that is 1 if the firm invests more than the average of the sector (5% of sales) in capital and zero otherwise[10].

In addition, we created a measure of customer concentration to capture potential concentration effects on performance and ISO 9000 adoption. We calculated customer concentration as the Herfindahl concentration ratio of sales to the three largest buyers of automotive components in the United States, General Motors, Ford and (Daimler) Chrysler. If a firm has sales to only one of the three large automobile manufacturers, rather than evenly distributed among the three, it is presumably more subject to the idiosyncrasies of one customer with respect to pressures to adopt ISO 9000.

We also created measures of diversification in business segments and geography as control variables for firm-level data. Although firms are mostly focused on the automotive sector, some also have activities in other business segments, which could affect firm performance (see for example Montgomery and Wernerfelt, 1988; Chatterjee and Wernerfelt, 1991; Lang and Stulz, 1994). Geographic diversification may also affect firm performance, particularly in the auto industry (Sturgeon and Florida, 1997). We measure business segment and geographic diversification as the inverse of the Herfindahl Concentration Index described above

[10] Alternative definitions for this variable, including running the models without it, were tried and the overall results are unchanged.

for the case of technological coherence, but with S_i representing the share of a firm's sales in business (or geographical) segment i. For business segments we use different 2-digit codes for firms in SIC codes 3300-3999 or different 1-digit SIC codes otherwise. For geography, segments are one of the three largest world markets, North America, Asia and Europe. Diversification is just 1 minus the Index: DIV = 1 – HCI.

++++++++++++++ Table 1 here ++++++++++++

Descriptive Statistics. Descriptive statistics for the variables are presented in Table 1. We carefully assessed the data to eliminate outliers, especially in our performance variables (see appendix with the distributions for the three performance variables in our final sample). In addition, since one of the objectives of the paper is to contrast results across the three performance measures, we eliminated observations if we did not have data for all three performance metrics[11]. This procedure forced the removal of 14 firms from the original sample, as well as the elimination of several firm-year observations. The final baseline dataset includes a panel of 75 firms and a total of 457 observations. The firms in our sample had an average return on sales of 7.8% and an average return on assets of 10.1%. The average market value was 45% above book value. The average level of technological coherence is 0.4, but the values range from 0.1 to 1. As one might expect, Table 1 also shows that our variables are more stable within than across firms.

+++++++++++++++++ Figure 1 here +++++++++++++++++

[11] Allowing for the sample to include observations where performance is available for some of the metrics but not others does not change the overall results.

For the ISO adoption variable, instead of descriptive statistics, the relevant analysis is the evolution in the firm adoption pattern over the period considered in the analysis. Figure 1 presents the survival function for the sample (i.e. those that have not adopted). As shown, the adoption pace is rather slow in the beginning, with the first adoption occurring only in 1990 and a handful of subsequent certifications happening until 1992. After that, the pace of adoption increases rapidly, with 75% certified in 1997, the last year in our analysis.

EMPIRICAL STRATEGY, ANALYSIS AND RESULTS

We are interested in testing the impact of process management (measured by ISO 9000 certification) on firm financial performance. How might we best measure this effect? The simplest approach would be to ask whether firms adopting process management have better performance after accounting for other correlates of performance. Ordinary least squares (OLS) does this, but a major shortcoming of this method is that the group of firms adopting may have systematically different performance from non-adopters for reasons unrelated to process management[12]. Thus, a careful empirical test of these hypotheses must be able to exclude these differences in financial performance between adopters and non-adopters that arise from factors entirely outside of the focus of our study[13]. In particular, measurement of the effect of process management requires a counterfactual, that is, a measure of what would have happened to that firm in the absence of adoption. One way to specify the counterfactual (to control for these differences between adopters and non-adopters) is to employ a matched pairs design, as Corbett

[12] A separate analysis not reported here but available from the authors upon request suggests this is indeed the case.
[13] This might be particularly important if some of this unobserved firm heterogeneity drives adoption (for example, high performance firms adopting early to signal their superiority) because the adoption regressor becomes correlated with the error term, generating a violation of OLS assumptions and potentially biasing the results.

et al (2005) have done in their study of ISO 9000, with particular attention to matching firms based on similarity in performance characteristics prior to adoption. While this may be possible when studying a cross-section of industries, it is a more difficult design to carry out in a single industry where the majority of firms eventually adopt the program. Since answering our research questions requires that we study process management adoption over time in one industry, our approach, in contrast, is to assess how a particular firm's performance changes with its own adoption of process management. That is, we ask how performance changes within firms following adoption, and then relate this to the contemporaneous changes at up-to-then non-adopting firms. A longitudinal panel data design with firm fixed effects and year controls accomplishes this (Hsiao, 1986), while also allowing the use of our full sample of firm-year data.[14]

We then use the following model to test hypothesis 1a:

(1) $$Performance_{it} = \beta_0 ISO\_adoption_{it} + \beta_1 \ln\_sales_{it} + \beta_2 capex_{it} + \beta_3 div\_geo_{it} + \\ + \beta_4 div\_seg_{it} + \beta_5 cust\_cc_{it} + \sum_{k=1}^{9} \gamma_k .year\_dummies_k + \alpha_i + \varepsilon_{it}$$

The dependent variable $Performance_{it}$ is the financial performance of firm *i* at time *t*, measured as return on assets (ROA), return on sales (ROS) and Tobin's q. The independent variables are ISO 9000 adoption, a set of control variables that may influence firm performance, as described in section 0, as well as year dummies to capture annual idiosyncratic shocks that can affect the performance of all firms (e.g. overall economic conditions). As explained above, the

[14] In addition, we ran a Hausman test which rejected the hypothesis of the alternative random effects model.

model also includes firm fixed effects (α_i) to control for unobserved firm heterogeneity[15]. We ran these models in STATA, using the xtreg (fe) command.

+++++++++++++++ Table 2 Here +++++++++++++++

The results from the base model (1) are presented in Table 2[16]. In columns (1)-(3), the adoption variable is zero until the year of the first certification of the firm and one from there onwards; the three columns correspond to the performance metrics. Hypothesis 1a, that adoption of ISO 9000 improves the performance of the average firm is supported for only for the Tobin's q metric. On the right hand side of Table 2, we use the individual firm trend since adoption, our alternative definition of ISO adoption to test the same hypothesis. In this case, and over time, certification has a significant effect on firm performance as measured by Tobin's q, (as in the previous result), as well as on ROA, but still not on ROS. Overall, the estimates offer limited support for H1a. But they show very clearly that the stock value of a firm increases with ISO 9000 certification. This suggests a higher *expected* stream of future profits for adopting than for the non-adopters. This may reflect stockholder expectations arising from the increased legitimacy resulting from ISO 9000 adoption, regardless of whether or not a given firm will realize these expected benefits.

[15] Despite the use of fixed effects, bias could still occur if firms adopted ISO 9000 as a reaction to poor performance. In this case, ISO 9000 certification might be just one of several (unmeasured) activities undertaken by a firm to try to improve performance, and we would tend to overestimate the performance impacts of ISO 9000. To explore this, we ran a hazard model assessing the determinants of ISO 9000 adoption. These results, not reported, but available from the authors, show that firms that are doing better financially are more likely to adopt. This suggests that concerns that poor performance drives adoption is not a problem for our data.
[16] We ran the same model but with adoption values lagged one year and the results are similar to the ones reported.

Next we test hypothesis 1b, that early adopters will benefit more from adopting process management techniques. For this analysis, we divided earlier and later adopters according to the year when the majority (greater than 50%) of the firms in the industry became ISO 9000 certified. Our logic is that firms have potential to gain some advantage from process management as a distinctive characteristic until most of its competitors have adopted. As Figure 1 shows, by 1995, less than 40% of the firms in our sample had been certified, while in 1996 over 60% had adopted. Thus, we use 1995 as the cutoff. We created a dummy variable equal to one for earlier adopters (that is, firms that adopted in or before 1995) and equal to zero otherwise. We then included an interaction between the earlier adopter dummy variable and our ISO 9000 adoption variable in the regression model described in equation (1). Since we use a fixed effects model, the direct effect is absorbed by the firm fixed effect; only the interaction remains in the final regression.

+++++++++++++++ Table 3 Here +++++++++++++++

We present the results in Table 3. Columns (1)-(3), with adoption as a 0-1 variable show that there is a benefit to early adopters of ISO 9000 when compared to the remaining group: The performance of the average firm that adopted ISO 9000 in or before 1995 is better than before it was first certified, and the result is significant for any of the performance measures. Moreover, the interaction term that singles out the early adopters captures all of the significance effect arising from adoption. The baseline adoption regressor is not significant for any of the performance metrics. We obtain similar results using the individual firm trend over time used to capture the lasting effect of ISO adoption (shown in Columns (4)-(6) in Table 3). Performance benefits are driven by the early adopters, with the exception of Tobin's q, where there is no difference between adopters before and after 1995. These findings lend broad support for hypothesis 1b. It is the distinctiveness of ISO 9000 adoption early on, when relatively few firms have ISO 9000 certifications, that drives the performance differences. As other competing firms also adopt, the unique advantage of adoption is lost. We also tested our results using 1994 instead of 1995 as the cutoff for early adopters. Results were mostly consistent with those obtained for 1995 (see notes in Table 3 for details).

Hypothesis 2 concerns the moderating effect of a firm's technology characteristics on the performance impact of process management adoption. Specifically, we hypothesize that this moderating effect has an inverted U shape: Both very focused and very diverse firms are less likely to benefit from the adoption of process management techniques when compared to those in the middle range. To understand how firm technological capabilities interact with ISO 9000 adoption, we use the technology coherence metric described in *Measures* section. To test the inverted U hypothesis, we modified equation (1) to include a technology coherence regressor as well as the square of the coherence term (to capture the inverted U shape). We then interacted both with ISO adoption to single out the moderating role. Again, in our fixed effects model, the main effects are captured by the firm fixed effect and only the interaction terms remain. The new regression equation (2) is then:

$$
\begin{aligned}
Perform_{it} &= \beta_0 ISO\_adoption_{it} + \beta_{01} Tech\_Coh_i * ISO\_adoption_{it} + \beta_{02} Tech\_Coh_i^{\,2} * ISO\_adoption_{it} + \\
&+ \beta_1 \ln\_sales_{it} + \beta_2 capex_{it} + \beta_3 div\_geo_{it} + \beta_4 div\_seg_{it} + \beta_5 cust\_cc_{it} + \sum_{k=1}^{9} \gamma_k . year\_dummies_k + \alpha_i + \varepsilon_{it}
\end{aligned}
$$

In addition to the new specification, the evaluation of the impact of technology coherence also requires narrowing our sample of firms. The technology coherence data is only available for firms' auto industry segments, yet our performance measures are at the firm-level. This could be misleading since several companies also have segments outside the auto industry, that also influence firm performance. For this evaluation, we restricted the sample to firms for which the auto segment represented more than 75% of total firm sales[17]. The new sample includes 65 firms and 403 observations.

+++++++++++++++ Table 4 Here +++++++++++++++

Table 4 presents the results of our analysis, again using the two definitions of ISO 9000 adoption. For both ROA or ROS as the performance measure, the coefficients on the technology coherence interaction term are positive, and negative on the squared interaction term. This suggests indeed that firms with average levels of technology coherence have the best prospects for performance improvement upon adoption of ISO 9000. Moreover, since the main effect observed in the ISO adoption coefficient is negative, results suggest that firms with both low and high coherence may actually be penalized when they adopt ISO 9000. The results are similar using both definitions of adoption. The impact is also reasonably within range in terms of the coherence variable and the magnitude of the impact. For Columns 1 and 2, the maximum impact on performance is reached for ISO adopters with a technology coherence levels between 0.55 and 0.6, values within one standard deviation of the 0.41 average for the variable. To have an idea of the magnitude of the impact, a more focused firm, for example with a technology coherence level of 0.2 (one standard deviation below the average) would benefit from ISO adoption in terms of ROS in 0.029 less than an adopting firm with technology coherence 0.6.

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[17] To test robustness, we also ran the same models only with firms where the auto segment represents 100% of the sales and overall results are similar, though significance levels are smaller in some cases due to fewer observations.

Given that the mean level of ROS is 0.078, these differences are relevant. The impacts in ROA are similar (slightly larger, as is the average of this variable).

In addition, neither result holds for the Tobin's q measure. This suggests that while the market might anticipate benefits from ISO 9000 adoption (in the earlier result), it may not recognize that a firm's technology characteristics impact its ability to leverage process management adoption. Overall, hypothesis 2 is supported. First, technological capabilities do moderate the impact of process management techniques on firm performance and second, firms that are highly focused or diversified technologically are less likely to benefit from these techniques. Nevertheless, the differences in accounting return measures and market based measures suggest that stockholders and the market might not recognize these differences.[18]

DISCUSSION AND CONCLUSIONS

We extend existing research studying process management by exploring two questions that have been missing in prior studies. Drawing on literature in strategic management, we first explore how the expected performance benefits of process management practices may be competed away as most firms in an industry adopt. Second, we explore the firm-specific conditions under which these practices might lead to sustainable performance advantages.

We hypothesized and confirmed that while performance advantages accrue for earlier adopters in an industry, they are competed away over time for later adopters. We further argued,

[18] Our hypothesis 2 results are also robust to the distinction between earlier and later adopters. We ran alternative specifications, interacting the technology coherence term (and its square) with the early adoption dummy. The strong results for technology coherence are not explained by earlier adoption (i.e. interactions were not significant while main effects were).

however, that process management practices are not simply generic improvement practices; instead, they directly affect the linkages and fit among firms' activities. Thus, the effects of process management practices likely depend on differences in underlying capabilities. We hypothesized that the extent of coherence or relatedness in firms' underlying technologies would influence the performance benefits of process management utilization. Very narrow firms with only one or a few technologies will have limited opportunities for linking related activities in unique, valuable, firm-specific combinations. Thus, we expect benefits for these firms to be less sustainable, as they are unlikely to lead to inimitable capabilities. As a firm increases the breadth of its technological capabilities, process management practices may help increase the fit among related activities, and may result in firm-specific complementarities and interactions between interdependent processes that are hard to imitate. However, as a firm's technologies become highly unrelated, the potential for complementary interactions that arises from relatedness is reduced; in addition it may be more difficult and costly to implement process management in disparate areas. Our results confirm this hypothesis. Specifically, firms with medium level of technology diversity, i.e. companies with a broad but not very diverse set of technologies systematically show gains from ISO 9000 adoption.

This study contributes to both the process management and strategy literature streams. Although strategy scholars have suggested that the advantages from adoption of best practices like process management will be competed away (e.g. Porter, 1996; Levinthal, 2000; Lieberman and Montgomery, 1988), such ideas have not been empirically tested with detailed panel data on process management practices. Similarly, work in strategic management has developed ideas about how relatedness or fit in firm capabilities affects sustainable advantage (e.g. Siggelkow, 2002), but again such research has not used widespread adoption of process management – with its focus on integrating firm activities - to test these ideas. By integrating these insights from strategy literature with data on process management adoption, we also help explain conflicting results in prior process management literature. We provide deeper insights into the conditions under which some firms are likely benefit more from such practices. Our study of a large-sample longitudinal panel of firms in one industry also makes an important empirical contribution. Instead of cross sections or broad control groups, we are able to study a comparable and competing set of firms in a sector over time during a period when process management adoption became ubiquitous. These features of our empirical design help control for unobserved heterogeneity (and thus selection issues), often overlooked in previous studies. We use a unique dataset that includes objective third-party data on firms' process-focused activities and performance (helping to overcome the subjectivity of self-report survey data), in addition to firm-specific detail on technological capabilities.

This research also contributes to management practice. Managers have often been frustrated in their efforts to translate efficiency gains into expected financial performance advantages. Our findings suggest that although relative performance benefits from process management may become illusive as the majority of firms in an industry adopt, creating sustainable advantage from such techniques may be possible if firms use them to link related activities in unique, inimitable ways. Properly used, such practices may be a way for firms to integrate knowledge while mitigating its imitability (e.g. Coff et al., 2004).

Our study has limitations. Our results strongly show that performance advantages are lower for later adopters, suggesting that the potential for benefits disappears as the majority of firms in an industry adopt these practices. The time frame available in our data limits our ability to directly test whether the advantages for earlier adopters dissipate beyond the periods included in our study. Moreover, while we demonstrate that firms with some relatedness in their portfolio of technologies benefit the most from process management adoption, we again do not have a sufficient timeframe to test whether these advantages are sustainable over a longer period. Our findings provide a first step toward answering deeper questions about the conditions under which process management advantages are sustainable, but future research could consider these questions over an even longer period.

Future work should also explore these questions in multiple industries. While the auto supply industry is ideal for studying the competitive effects of increasing process management use within an industry, the generality of our findings for other contexts is not clear. In industries where adoption of these practices has been slower and less widespread, it may be that firms are able to gain and sustain financial advantages from efficiency improvements. In particular, our findings may be more applicable to mature industries, characterized by a focus on incremental change and pressures for efficiency improvement. Prior research has also suggested that process management practices are most beneficial in stable or incrementally changing environments, and may be detrimental in a changing or turbulent environment (e.g. Sitkin et al., 1994; Sutcliffe et al., 2000; Benner and Tushman, 2003). Process management's focus on incremental learning and local search may inhibit more dramatic innovation and change required to adapt in changing environments (e.g. Sitkin et al., 1994; Levinthal and March, 1993; Benner and Tushman, 2002).

A tighter fit in systems of activities, spurred by process management practices, while appropriate for performance improvements in stable environments, can also heighten inertia and maladaptive response in the face of environmental change (Levinthal, 1997; Hannan and Freeman, 1984). Thus, while managers may gain from using these practices to seamlessly coordinate related activities in mature environments, they must also exercise caution in undertaking these practices in changing environments.

Table 1: Descriptive Statistics and Correlations for Variables

Variable	Firms	Obs	Mean	Overall S. D.	Within S. D.
Return on Sales (ROS)	75	457	0.078	0.043	0.024
Return on Assets (ROA)	75	457	0.101	0.0550	0.038
Tobin's q	75	457	1.452	0.631	0.361
Log of Sales	75	457	2.744	0.785	0.136
Capital Expenditures	75	457	0.469	0.499	0.345
Segment Diversification	75	457	0.232	0.267	0.054
Geographic Diversification	75	457	0.725	0.297	0.086
Customer Concentration	75	457	0.143	0.183	0.073
Technological Coherence	65	403	0.406	0.217	-

Variable	ROS	ROA	Tobin q	LgSales	Capex	SegDiv	GeoDiv	CstCC
ROS	1.00							
ROA	0.83	1.00						
Tobins q	0.63	0.59	1.00					
Lg of Sales	0.01	-0.08	-0.06	1.00				
Cap.Expend.	0.22	0.08	0.07	-0.11	1.00			
Seg.Diversif.	-0.05	-0.11	-0.07	0.58	-0.13	1.00		
Geog.Divers.	-0.05	0.07	-0.05	-0.64	0.02	-0.31	1.00	
Cust. Conc.	-0.16	-0.07	-0.13	-0.24	0.10	-0.21	0.33	1.00
Tech Coher.	0.22	0.15	0.16	-0.46	0.13	-0.31	0.30	0.13

Note: since we are using a panel data, the correlation table might not be a good predictor of the regression relations, as it is likely driven by the cross firm variation, rather the within variation. But it is included as complementary information about the nature of our data

Figure 1: Survivor Function – Share of non-adopters

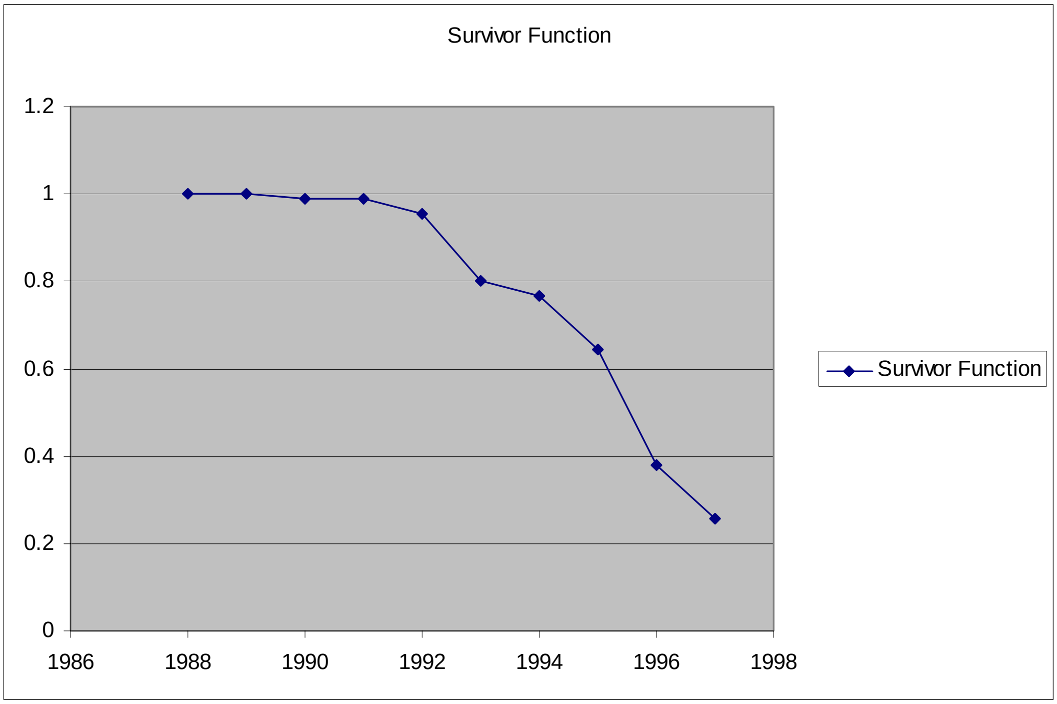

Table 2: Impact of Adoption on Firm performance – Firm Fixed Effects Model

Definition of Adoption:	Adoption 0-1			Firm Trend after Adoption		
Dependent Variable:	ROS	ROA	Tobin's q	ROS	ROA	Tobin's q
	1	2	3	4	5	6
Adoption	0.0019 (0.41)	0.0002 (0.979)	0.1435 (0.03)**	0.0029 (0.12)	0.0068 (0.02)**	0.1339 (0.00)***
Log of Sales	0.0082 (0.71)	0.0157 (0.374)	-0.2706 (0.09)*	0.0110 (0.34)	0.0241 (0.17)	-0.1599 (0.31)
Capital Expenditures	0.0118 (0.3)	-0.0948 (0.12)	0.2620 (0.64)	0.0146 (0.71)	-0.0873 (0.15)	0.3765 (0.49)
Customer Concentration	-0.0083 (0.51)	-0.0112 (0.659)	-0.0408 (0.86)	-0.0062 (0.7)	-0.0050 (0.84)	0.0370 (0.87)
Segment Diversification	-0.0194 (0.89)	-0.0406 (0.227)	0.0130 (0.97)	-0.0205 (0.35)	-0.0441 (0.19)	-0.0325 (0.91)
Geographic Diversification	0.0050 (0.34)	0.0232 (0.306)	0.3016 (0.14)	0.0049 (0.74)	0.0233 (0.3)	0.2945 (0.14)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	457	457	457	457	457	457
Groups	75	75	75	75	75	75
F Statistic Value	4.27 (0.00)***	4.56 (0.00)***	8.01 (0.03)**	4.45 (0.00)***	5.00 (0.00)***	10.03 (0.00)***

p-values in parenthesis; * Significant at 10%; ** Significant at 5%; *** Significant at 1%

Table 3: Impact of Early ISO Adoption+ – Firm Fixed Effects Model

Definition of Adoption:	Adoption: 0-1			Firm Trend after Adoption		
Dependent Variable:	ROS	ROA	Tobin's q	ROS	ROA	Tobin's q
	1	2	3	4	5	6
Adoption	-0.0077 (0.25)	-0.0183 (0.08)*	-0.0519 (0.58)	-0.0050 (0.31)	-0.0099 (0.19)	0.075 (0.27)
Adoption*Until_95	0.0154 (0.05)*	0.0296 (0.01)***	0.3125 (0.00)***	0.0077 (0.08)*	0.0164 (0.02)**	0.0575 (0.35)
Log of Sales	0.0105 (0.36)	0.0202 (0.25)	-0.2230 (0.16)	0.0110 (0.96)	0.0241 (0.17)	-0.1600 (0.31)
Capital Expenditures	0.0091 (0.82)	-0.1000 (0.10)	0.2076 (0.71)	0.0095 (0.24)	-0.0979 (0.11)	0.3393 (0.53)
Customer Concentration	-0.0052 (0.75)	-0.0053 (0.84)	0.0219 (0.92)	-0.0056 (0.34)	-0.0035 (0.89)	0.0421 (0.85)
Segment Diversification	-0.0210 (0.33)	-0.0438 (0.19)	-0.0202 (0.95)	-0.0208 (0.96)	-0.0447 (0.18)	-0.0346 (0.91)
Geographic Diversification	0.0070 (0.63)	0.0269 (0.23)	0.3415 (0.09)*	0.0059 (0.4)	0.0252 (0.26)	0.3013 (0.13)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	457	457	457	457	457	457
Groups	75	75	75	75	75	75
F Statistic Value	4.29 (0.00)***	4.73 (0.00)***	8.19 (0.00)***	4.38 (0.00)***	5.01 (0.00)***	9. 45 (0.00)***

p-values in parenthesis; * Significant at 10%; ** Significant at 5%; *** Significant at 1%
+ The magnitude and significance of the relevant coefficients are very similar if the cut-off year is 1994; exceptions are on the right hand since of the table, with the firm trend adoption variable: the significance level of the Adoption*Until _94 interaction disappears for ROS and the main trend coefficient for TOBIN becomes significant.

Table 4: ISO Adoption and Technology Coherence – Firm Fixed Effects Model

Dependent Variable:	ROS	ROA	Tobin's q	ROS	ROA	Tobin's q
Adoption Variable:	0-1 Adoption			Firm Trend after Adoption		
	1	2	3	4	5	6
Adoption	-0.0523 (0.00)***	-0.0657 (0.01)***	0.2255 (0.32)	-0.0236 (0.00)***	-0.0245 (0.04)**	0.1901 (0.09)*
Adoption* Tech Coh	0.2282 (0.00)***	0.2892 (0.001)***	0.0660 (0.95)	0.1306 (0.00)***	0.1640 (0.01)***	-0.2680 (0.64)
Adoption* Tech Coh Square	-0.1945 (0.00)***	-0.2520 (0.01)***	-0.7198 (0.46)	-0.1219 (0.00)***	-0.1623 (0.02)**	0.2109 (0.74)
Log of Sales	0.0011 (0.93)	0.0066 (0.71)	-0.3568 (0.04)**	0.0069 (0.55)	0.0218 (0.22)	-0.2532 (0.13)
Capital Expenditures	-0.0029 (0.39)	-0.0056 (0.29)	0.0072 (0.86)	-0.0028 (0.40)	-0.0052 (0.31)	0.0150 (0.76)
Customer Concentration	-0.0171 (0.27)	-0.0248 (0.31)	-0.0362 (0.88)	-0.0130 (0.40)	-0.0143 (0.55)	0.0518 (0.82)
Segment Diversification	-0.0033 (0.89)	-0.0123 (0.73)	0.1574 (0.65)	-0.0041 (0.86)	-0.0158 (0.66)	0.0398 (0.91)
Geographic Diversification	-0.0031 (0.82)	0.0116 (0.56)	0.3154 (0.12)	0.0017 (0.90)	0.0171 (0.41)	0.3157 (0.10)*
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	403	403	403	403	403	403
Groups	65	65	65	65	65	65
F Statistic Value	6.09 (0.00)***	5. 34 (0.00)***	8.44 (0.00)***	6.32 (0.00)***	5.88 (0.00)***	9. 78 (0.00)***

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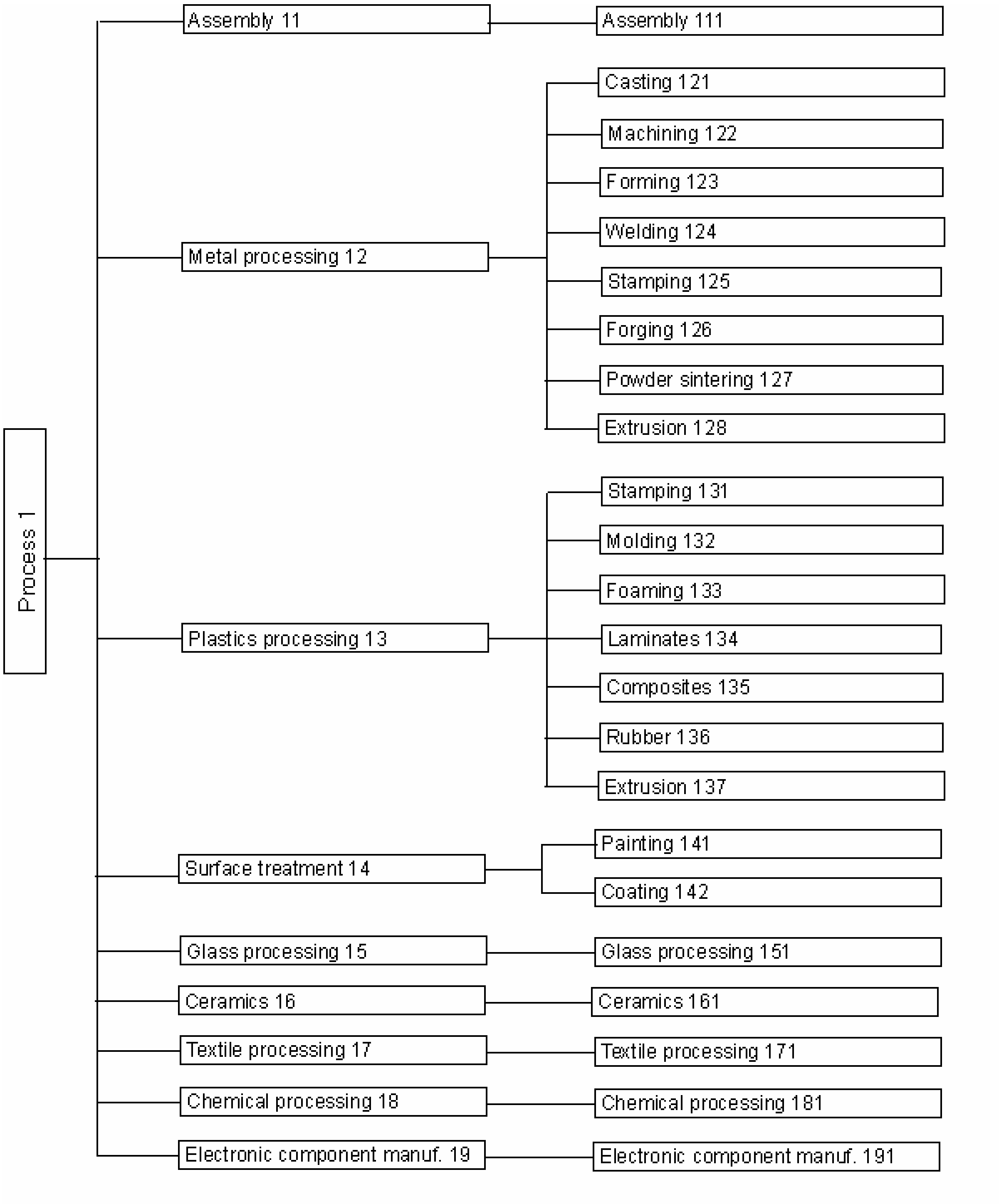
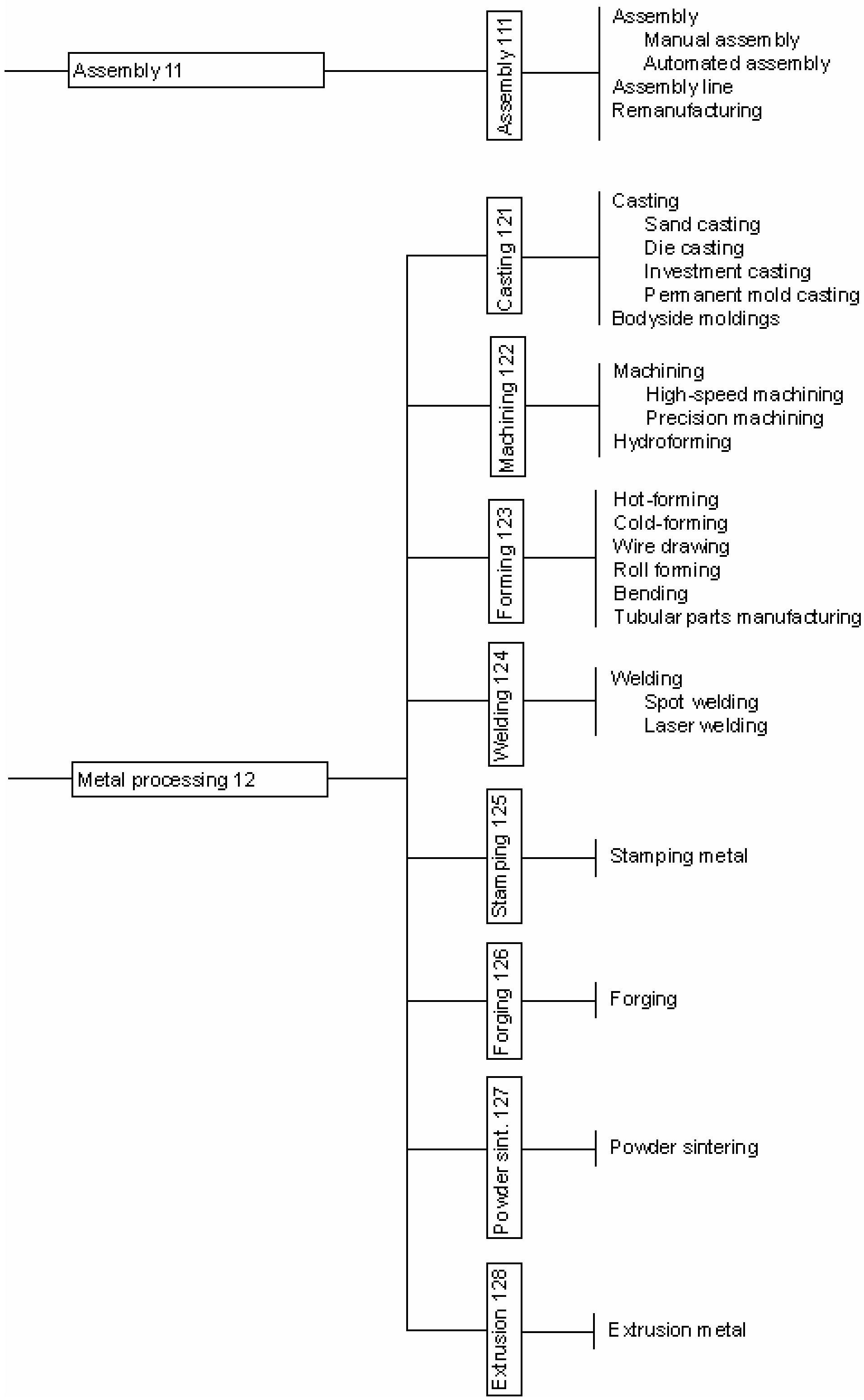
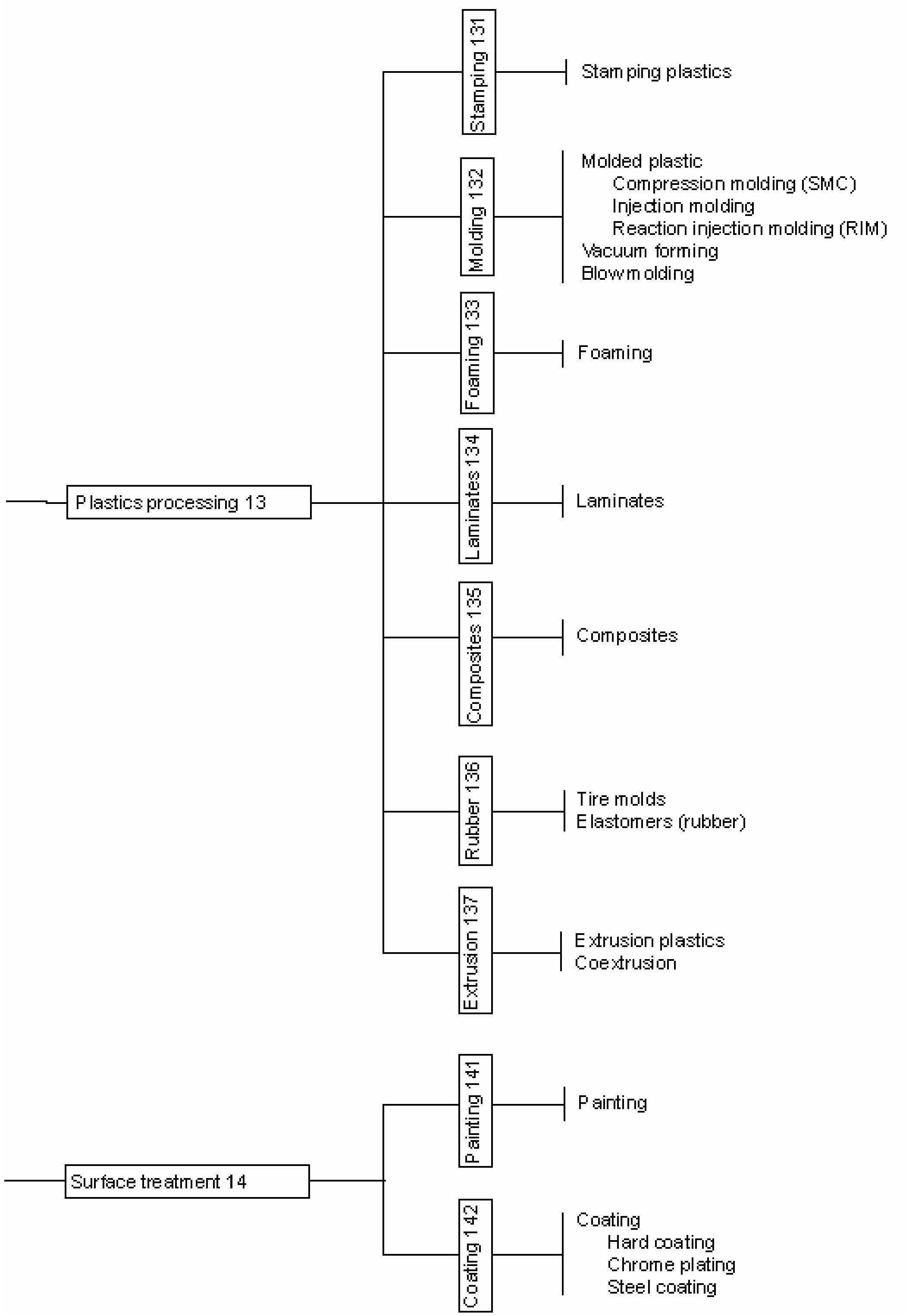
Appendix A: Process hierarchical classification scheme




Assembly 11
Assembly 111
Assembly
Manual assembly
Automated assembly
Assembly line
Remanufacturing
Metal processing 12
Casting 121
Casting
Sand casting
Die casting
Investment casting
Permanent mold casting
Bodyside moldings
Machining 122
Machining
High-speed machining
Precision machining
Hydroforming
Forming 123
Hot-forming
Cold-forming
Wire drawing
Roll forming
Bending
Tubular parts manufacturing
Welding 124
Welding
Spot welding
Laser welding
Stamping 125
Stamping metal
Forging 126
Forging
Powder sint. 127
Powder sintering
Extrusion 128
Extrusion metal


Plastics processing 13
Stamping 131
Stamping plastics
Molding 132
Molded plastic
Compression molding (SMC)
Injection molding
Reaction injection molding (RIM)
Vacuum forming
Blow molding
Foaming 133
Foaming
Laminates 134
Laminates
Composites 135
Composites
Rubber 136
Tire molds
Elastomers (rubber)
Extrusion 137
Extrusion plastics
Coextrusion
Surface treatment 14
Painting 141
Painting
Coating 142
Coating
Hard coating
Chrome plating
Steel coating

Appendix B: Histograms of dependent variables.