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Lean and agile manufacturing: external and internal drivers and performance outcomes

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Abstract

Purpose – Lean and agile manufacturing are two initiatives that are used by manufacturing plant managers to improve operations capabilities. The purpose of this paper is to investigate internal and external factors that drive the choice of lean and agile operations capabilities and their respective impact on operational performance.

Design/methodology/approach – Lean and agile manufacturing are each conceptualized as a second-order factor and measured through a bundle of distinct practices. The competitive intensity of industry and the competitive strategy are modeled as potential external and internal drivers, respectively, and the impact on quality, delivery, cost, and flexibility performance is analyzed using structural equations modeling. The model is tested with data from the high performance manufacturing project comprising a total of 211 plants from three industries and seven countries.

Findings – The results indicate that lean and agile manufacturing differ in terms of drivers and outcomes. The choice of a cost-leadership strategy fully mediates the impact of the competitive intensity of industry as a driver of lean manufacturing, while agile manufacturing is directly affected by both internal and external drivers, i.e. a differentiation strategy as well as the competitive intensity of industry. Agile manufacturing is found to be negatively associated with a cost-leadership strategy, emphasizing the difference between lean and agile manufacturing. The major differences in performance outcomes are related to cost and flexibility, such that lean manufacturing has a significant impact on cost performance (whereas agile manufacturing has not), and that agile manufacturing has a stronger relationship with volume as well as product mix flexibility than does lean manufacturing.

Research limitations/implications – Cross-sectional data from three industries and seven countries are used, and it would be interesting to test this model for more industries and countries.

Practical implications – The results provide insights into the factors that influence the choice of lean or agile manufacturing for improving operations, and the results that can be obtained.

Originality/value – To the authors' knowledge, this is the first large-scale empirical survey of leanness and agility simultaneously, using data from manufacturing firms in Europe, Asia, and North America. The model incorporates a wide perspective on factors related to lean and agile manufacturing, to be able to identify similarities and differences.

Keywords Lean production, Agile production, Operations management

Paper type Research paper

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Introduction

In order to cope with increasing competitive intensity, manufacturing companies attempt to improve their manufacturing operations by addressing specific needs.

Depending on the analysis of the requirements of the marketplace, the firm may choose different paths of improvement, for example lean and agile manufacturing. Different improvement programs cultivate different capabilities over time, but managers have tended to view such programs as solutions to specific problems rather than as stepping-stones in an intended direction (Hayes and Pisano, 1994). If a company should be able to use such improvement programs effectively to address the gap between the market requirements and the current manufacturing capabilities, the content and process of alternatives must be clear and concise, so that managers really understand what to apply when and what the possible outcome could be. However, there is a lack of clarity in the extant literature as to what constitutes leanness and agility, how these differ, and when to employ which (Narasimhan *et al.*, 2006). This paper addresses this gap through a broad and large-scale empirical survey.

Shah and Ward (2003, 2007) stated that lean production is a multi-dimensional approach that encompasses a wide variety of management practices, while Brown and Bessant (2003) found that there is no firm agreement as to the exact nature of what constitutes agile manufacturing. In addition, combinatorial and complementary forms of lean and agile have been proposed. Katayama and Bennett (1999) regarded the simultaneous achievement of leanness and agility as a requirement for long-term competitiveness, associating leanness with resource efficiency and high performance, and agility with capabilities addressing customer requirements.

The purpose of this paper is to investigate lean and agile manufacturing in terms of internal and external drivers and the impact on performance. As a result, we aim to obtain guidelines that show under what circumstances or production situations certain operations capabilities should be pursued and how this affects operational performance. We hope that this study will add some clarity to the similarities and differences between leanness and agility. We develop second-order factors to measure lean and agile capabilities, each consisting of a bundle of interrelated yet distinct practices. MacDuffie (1995), Shah and Ward (2003, 2007), Ketokivi and Schroeder (2004) and Peng *et al.* (2008) advocated the use of bundles of practices to better capture the width of multidimensional concepts. We review and contrast literature on both lean and agile to find discriminating characteristics. These objectives relate to the following research questions:

RQ1. Are there external and internal drivers of lean and agile capabilities, and if so, how do these influence the choice of lean and agile manufacturing?

RQ2. What are the effects on operational performance; are there differences between lean and agile manufacturing, and if so, what are the differences?

Thus, the aim of this paper is to explore and analyze the differences between lean and agile manufacturing.

The paper is organized as follows. First, we review literature on leanness and agility. Second, the research model is developed from the literature and the hypotheses are discussed. The research method, utilizing data from the third round of the global high-performance manufacturing (HPM) project, is described. The results in terms of measurement models of lean and agile manufacturing and a structural equations model linking these to drivers and performance outcomes are presented. The concluding section of this paper discusses the implications of the research findings for research and practice.

Literature review

In order to improve operations capabilities, manufacturing plant managers use different initiatives. Lean manufacturing and agile manufacturing are two such initiatives that have received much attention in recent years. *Webster's Dictionary* makes a clear distinction, defining lean as "containing little fat" and agile as "nimble" (Aitken *et al.*, 2002). In the operations management area, some authors argue that agile and lean are subsets of each other (Kidd, 1994; Shah and Ward, 2003). Other authors view them as putting different emphasis on the same set of dimensions (Narasimhan *et al.*, 2006). Yet other authors view them as paradigmatically different, referring to the concept of "leagility" (Naylor *et al.*, 1999; Mason-Jones *et al.*, 2000; van Hoek, 2000; Aitken *et al.*, 2002; Childerhouse *et al.*, 2002; Bruce *et al.*, 2004; Krishnamurthy and Yauch, 2007). The definitions by Naylor *et al.* (1999) serve to contrast the concepts: lean requires elimination of all forms of waste, including time, and it requires the implementation of a level schedule, while agile requires the use of market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place. Leagility advocators argue that leanness should be emphasized for make-to-stock operations, while agility is recommended for make-to-order operations, and that the two should be combined in assemble-to-order operations, such that leanness is used upstream of the customer order decoupling point for operations that are forecast-driven and agility downstream for the operations that are customer order-driven.

When looking at the characteristics associated with lean and agile, there is some overlap of some characteristics that are viewed as ingredients in both lean and agile manufacturing, such as waste elimination, setup time reduction, continuous improvement, 5S and other quality improvement tools. To develop measures of leanness and agility of a manufacturing system, the very basics of the concept need to be disentangled (Narasimhan *et al.*, 2006). Narasimhan *et al.* (2006) reviewed recent literature on leanness and agility, and propose the following definitions:

> Production is lean if it is accomplished with minimal waste due to unneeded operations, inefficient operations, or excessive buffering in operations.

while:

> Production is agile if it efficiently changes operating states in response to uncertain and changing demands placed upon it.

We are therefore looking for characteristics that can be associated with one but not with the other, and focus on leanness and agility as operations capabilities related to practices and routines.

Lean manufacturing

The source of the term lean production can be traced to the International Motor Vehicle Program (IMVP), and was first used by Krafcik (1988) and Holweg (2007). However, the just-in-time (JIT) system or Toyota production system (TPS) was the forerunner of lean manufacturing, with the works by Taiichi Ohno, Shigeo Shingo, and Yasuhiro Monden as notable markers of the rise of JIT/TPS/lean in the 1980s (Schonberger, 2007). Later, Womack *et al.* (1990) reported on the results from the IMVP study and offered lean manufacturing as a synonym for the practices pioneered by Toyota; the concepts and techniques under the lean label were the same as those of JIT a decade earlier

(Schonberger, 2007). Womack and Jones (1996) provided five lean principles: value, the value stream, flow, pull, and perfection, described in the following way:

(1) value is defined by the ultimate customer;
(2) the value stream is the set of all the specific activities required to bring a specific product through the internal value chain;
(3) flow is about making the value-creating steps flow;
(4) pull refers to using a pull schedule; and
(5) perfection is concerned with making improvement a continuous effort.

Lewis (2000) used these core principles while studying the performance of three case firms. He found that the success of lean production is dependent upon contextual factors such as type of market, dominant technology, and supply chain structure. Furthermore, he noticed a trade-off between lean production and innovation, such that the more successfully a firm applies lean principles, the less it will engage in general innovative activity. Naylor *et al.* (1999) described lean manufacturing as developing a value stream to eliminate all waste, including time, and to ensure a level schedule. A level schedule means that the manufacturing process must be kept away from volatility, protected from uncertainty and variation. This makes high-capacity utilization possible, thus leading to lower manufacturing costs. Lean manufacturing in this sense is a program aimed mainly at increasing the efficiency of operations.

Agile manufacturing

Agile, as a concept in manufacturing, was coined by a group of researchers at Iaccoca Institute, Lehigh University, in 1991, to describe the practices observed and considered as important aspects of manufacturing (Iacocca Institute, 1991a, b; DeVor *et al.*, 1997). An agile manufacturing system is a system that is capable of operating profitably in a competitive environment of continually and unpredictably changing customer opportunities as defined by Goldman *et al.* (1995). Similarly, Gunasekaran (1998) defined agile manufacturing as the capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services. To be able to respond effectively to changing customer needs in a volatile marketplace means being able to handle variety and introduce new products quickly. Highly customized products are regarded as a key component in an agile manufacturing system (Kidd, 1994). Sharifi and Zhang (2001) viewed agility as comprising of two main factors: responding to changes in proper ways and due time, and exploiting changes and taking advantage of changes as opportunities. Sharifi and Zhang (1999, 2001) identified high rate of new product introductions as well as quick introduction of new products as key properties of an agile manufacturing system. Tsourveloudis and Valavanis (2002) regarded the main capabilities of an agile production system as the ease with which the system can change between products, and the ability to introduce new products without investments.

Research framework and hypotheses

In this research, we posit that there may be both external forces and internal forces driving an organization to embark on a particular route to improving the operations characteristics. Increasing competition makes the manufacturing firm act in some way to strengthen its competitive position. The response to competitive pressure may differ between firms; some may want to improve their lean capabilities whereas others may choose to improve their agility. The competitive strategy of the firm, be it cost leadership or differentiation, may also influence the choice of operations characteristics. The choice of a lean or agile improvement program would also depend on the performance effects that can be expected. If there are differences, the choice would be related to the areas of operational performance that need to be strengthened. On the other hand, if the effects on individual performance measures are similar, it would lead to the conclusion that lean and agile have more similarities than differences, and that the differences do not significantly affect performance.

The research framework is shown in Figure 1. Competitive intensity of industry and competitive strategy are modeled as drivers (external and internal, respectively) of lean and agile manufacturing. Competitive intensity of industry is modeled as both a direct (external) driver and an indirect driver via the competitive strategy of the plant. Thus, competitive strategy is modeled as having a possible mediating effect on the choice of improvement manufacturing, in terms of cost, quality, delivery, and flexibility. The competitive strategy should typically be developed before the choice of improvement program is made, to guide this decision process, and can be viewed as the internal interpretation of the key properties that manufacturing require, addressing the competitive intensity of industry.

Competitive intensity of industry as an external driver

Increased global competition forces manufacturing companies to take action, both in terms of operational performance as well as strategic positioning. Companies need continuously to improve their operations to stay competitive. There are many pressures that threaten manufacturing performance, such as global competition, advances in manufacturing technology, and advances in information technology (Yusuf and Adeleye, 2002), and the degree of competition is a key environmental variable (Kim and Lim, 1988). Katayama and Bennett (1996) identified competitive pressure as the driver for a lean production response through cost reductions, facilitating price competition to expand market share. In response to competitive pressures, Vokurka and Fliedner (1998) suggested that world-class firms strive to achieve agility. Sharifi and Zhang (1999, 2001) identified intensified competitive pressure as a driver of agility. Yusuf and Adeleye (2002) viewed agility as a response to the ever-changing requirements of sophisticated consumers and products under persistently changing competitive and success factors, and Vázquez-Bustelo *et al.* (2007) proposed that turbulent environments influence the adoption of agile manufacturing. Thus, both lean and agile manufacturing can be seen as responses to increasing competitive intensity in the industry.

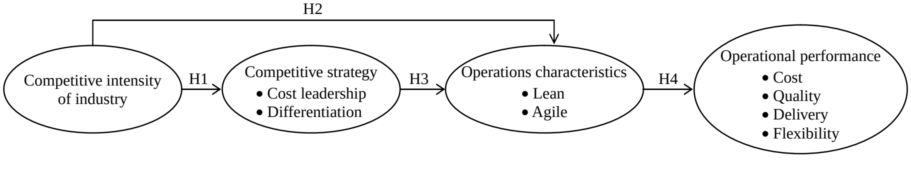


Figure 1.
The research model of the relationships among operations capabilities, drivers, and performance

Competitive strategy as an internal driver

Business-level competitive strategies are organizational attempts to reconcile goals with the realities of their environments (Scherer, 1980) and a way for companies to actively choose their route to competitiveness (Porter, 1985). Competitive strategy discusses how an organization chooses to compete in a market, particularly the issue of positioning the company relative to competitors with the aim to establish a profitable and sustainable position. The notion of strategic choice recognizes that organizations may address competition differently based on the strategic orientation of management. The most well-known typology for competitive strategy is probably that of Porter (1985), distinguishing among three major routes to competitiveness: cost leadership, differentiation, and focus. Adopting a cost-leadership strategy means that the company takes the competition head on, offering a product that is equivalent to those offered by competitors, but more efficiently than competitors. Cost leaders would emphasize cost reduction and firms strive to become the low-cost producer. Efforts are focused on cost control in order that above-average returns may be forthcoming even at low prices (Porter, 1980; Kotha and Orne, 1989). By streamlining their operations and their entire organization to become extremely cost efficient, they are able to offer a lower price. Low price is typically the order-winning competitive priority. The second route is differentiation where the rationale is to avoid direct competition by differentiating the products and/or services offered to deliver higher customer value, making it possible to charge a premium price. The form of differentiation can typically be style or quality according to Porter (1980). The objective is to create a product or service that is, or is perceived to be, unique by customers (Kotha and Orne, 1989). A price policy with a greater unitary profit margin could be practiced (Santos, 2000). Thus, differentiation is clearly a different competitive strategy from cost leadership. Third, the focus strategy is targeted towards one or more market segments of the company's markets. Kotha and Orne (1989) indicate that the strategic target can be either industry-wide or for a particular segment only. Within a focus strategy, the firm can choose either a cost leadership or a differentiation approach (Porter, 1985; Kotha and Orne, 1989; Santos, 2000; Ward and Duray, 2000). Business units may employ the two basic strategies with a broad or restricted scope in order to develop and attain competitive advantages within their competitive environment (Porter, 1980). If these advantages are focused on a few segments of the market, no general competitive advantage is attained (Santos, 2000).

The three strategies can fundamentally be reduced to two, since the company must choose between cost leadership or differentiation strategies even in a focus strategy. Thus, there are two competitive strategy choices; Kotha and Orne (1989), Santos (2000) and Ward and Duray (2000). Kotha and Orne (1989) state that: "The two fundamental types of competitive advantage a firm can possess in its pursuit of uniqueness are: lower cost and/or differentiation." According to Santos (2000, pp. 613-4), the focus strategy implies that the company must focus "on one of the two previous strategies". By competitive strategy Ward and Duray (2000, p. 124) refer to "the broad dimensions that a business uses as a basis of advantage, e.g. price vs differentiation". In theory, these two competitive strategies seem to be able to relate well to leanness and agility, respectively, which makes them interesting for our model.

Other typologies have been presented over the years (Cannon and St John, 2004; Prajogo and Sohal, 2006). For example, Miles and Snow (1978) classified organizations into four different groups (defenders, prospectors, analyzers, and reactors) based upon the choice of products and markets, and Treacy and Wiersema (1993) discriminated between strategies aiming for operational excellence, customer intimacy, and product leadership.

Hypotheses for the drivers of lean and agile manufacturing

Based on the literature, we expect that both cost leadership and differentiation can be the strategic choice of a firm in response to an increasing competitive intensity of industry. Thus, we formulate the following two hypotheses:

H1a. There is a positive relationship between competitive intensity of industry and cost leadership as a competitive strategy.

H1b. There is a positive relationship between competitive intensity of industry and differentiation as a competitive strategy.

Furthermore, also based on the literature, we expect that both lean and agile manufacturing can be responses of a firm to increasing competitive intensity of industry. Thus, we formulate the following two hypotheses:

H2a. There is a positive relationship between competitive intensity of industry and lean manufacturing.

H2b. There is a positive relationship between competitive intensity of industry and agile manufacturing.

When relating the competitive strategy to the pursuit of leanness and/or agility, we formulate four hypotheses relating to each combination of competitive strategy versus lean and agile operations characteristics. From the literature, we see that lean manufacturing can be associated with a cost-leadership strategy, whereas agile manufacturing can be associated with a differentiation strategy. As for the other two combinations, there are no clear theoretical relationships, wherefore it is important to explore these relationships:

H3a. There is a positive relationship between cost-leadership strategy and lean manufacturing.

H3b. There is a positive relationship between differentiation strategy and agile manufacturing.

H3c. There is no relationship between cost-leadership strategy and agile manufacturing.

H3d. There is no relationship between differentiation strategy and lean manufacturing.

Measures of operational performance

Cost, quality, delivery, and flexibility are typically considered to be the main manufacturing-related competitive priorities (Narasimhan *et al.*, 2006). Naylor *et al.* (1999) rated the importance of quality and lead time equally for lean and agile, whereas cost is a key metric for lean and service is a key metric for agile; by service they mean support and flexibility. Hill and Hill (2009), Berry *et al.* (1991) and Menda and Dilts

(1997) viewed quality in terms of conformance to specifications and on-time delivery as market qualifiers for any type of product, whereas cost is typically a dominating order winner in high-volume, low-variability environments, and flexibility dominates low-volume, one-of-a-kind production. Aitken *et al.* (2002) argued that both agility and leanness demand high levels of product quality, and they also require minimum total customer lead times. Prince and Kay (2003) made a distinction between lean and agile related priorities. They associated consistent quality, cost, and dependable deliveries with leanness, whereas fast delivery, rapid volume change, and rapid product mix change were associated with agility. Narasimhan *et al.* (2006) empirically investigated leanness and agility using cluster analysis, and found that lean performers were better on cost performance, while agile firms performed better on quality, delivery, and flexibility. Thus, in general, good quality and delivery performance is assumed to be achievable in both lean and agile environments, while cost is predominantly associated with leanness and flexibility with agility. Therefore, it is important to use individual measures of operational performance, rather than combining them into one construct, since lean and agile manufacturing are expected to affect these measures differently.

Hypotheses for the performance outcomes of lean and agile manufacturing

Based on the literature, we expect that there is a significant positive impact on quality and delivery (speed and dependability) performance for both lean and agile. We further expect that lean manufacturing will have a significant positive impact on cost performance but not on flexibility, while agile manufacturing will have the reverse effect, i.e. a significant positive impact on flexibility (volume and product mix) but not on cost performance. Thus, we can postulate the following hypotheses:

- *H4a-d.* There is a positive relationship between lean manufacturing and (a) cost, (b) quality, (c) delivery speed, and (d) delivery reliability performance.
- *H4e-f.* There is no relationship between lean manufacturing and (e) product mix flexibility and (f) volume flexibility performance.
- *H4g.* There is no relationship between agile manufacturing and cost performance.
- *H4h-l.* There is a positive relationship between agile manufacturing and (h) quality, (i) delivery speed, (j) delivery reliability, (k) product mix flexibility, and (l) volume flexibility performance.

Description of data and research instrument

The data used for empirical analysis of the framework were collected as part of the third round of the HPM research project. The first round of the HPM project began in 1989 with an aim of understanding the emergence of Japanese manufacturing practices in the USA. The second round began in 1996 and involved 165 plants in five countries: Germany, Italy, Japan, the UK, and the USA (Schroeder and Flynn, 2001). The third round of the HPM project was conducted in 2005 and collected data on a variety of manufacturing practices and performance. The third round HPM database contains data from 211 plants in the USA, Germany, Sweden, Finland, Austria, Japan, and South Korea. In each country, plants were selected from three industries: electronics, machinery, and automobile suppliers. A stratified design was used to randomly select an approximately equal number of plants in each country and each industry. The selected plants were contacted by a member of the HPM research team to participate in the study. In return for participating, each plant was provided with a detailed profile of its own manufacturing operations and benchmark data in its industry. With this approach, the third round of the HPM project yielded a response rate of 65 percent, calculated as the percent of the plants contacted by the research team that returned the surveys (Peng *et al.*, 2008). The response rates by country varied from 35 to 80 percent. The HPM project is being administrated from the University of Minnesota and data collection is conducted by independent research groups in each participating country. The HPM code book is maintained in English. All questionnaires are translated into each language and back translated to ensure interpretative consistency. The authors belong to the HPM research team and have been actively involved in collecting data.

The unit of analysis is the manufacturing plant. As noted by Forza (2002), it is not possible for a plant itself to produce answers to a questionnaire, this has to be done by human respondents. Data were collected using 12 different questionnaires directed to managers, supervisors and direct labor. Most questions were answered by multiple informants, ensuring reliability of answers and to allow informants to address their particular areas of expertise. This also helped to reduce common method variance and potential common method bias. The informants for each item used in this research are specified in Appendix 1. To conduct plant level analysis, we aggregated individual informant responses to the plant level by taking the average of within-plant responses (Peng *et al.*, 2008).

In the HPM project both objective measures and perceptual measures are used. In this research, only perceptual measures are used. Although perceptual measures are subjective, these kinds of measures are frequent in the literature, often due to the difficulties in collecting comparable and objective data about the performance of manufacturing systems. Ketokivi and Schroeder (2004) conclude that perceptual measures are viable alternatives in large sample studies as long as rigorous examinations of reliability are performed. MacDuffie (1995) suggested bundles of practices to better capture the width of multidimensional concepts. Likewise, Ketokivi and Schroeder (2004) promote multidimensional measures to improve the reliability of measures.

Table I provides a description of the sample. Plants are evenly distributed across the seven countries and three industries. The sample represents a mix of small and large plants with a median size of 379 employees. The average plant in the sample is 34 years old and manages nine different product families. In general, the sample exhibits high variety and seems appropriate for examining the research questions in this study.

Model operationalisation

Competitive intensity of industry

The competitive intensity of industry was captured using four items (see Appendix 1 for details). The respondents were asked to indicate on a seven-point Likert scale ranging from "strongly disagree" to "strongly agree" on a number of assertions. To verify the measurement of the competitive intensity of industry, Cronbach's reliability α was calculated for the construct. The result indicated adequate internal consistency since the Cronbach's α for the four indicators was 0.700.

Country	Electronics	Number of plants Industry Machinery	Auto suppliers	Total
Austria	10	8	4	22
Finland	14	6	10	30
Germany	9	13	19	41
Japan	10	11	13	34
South Korea	10	10	11	31
Sweden	7	10	7	24
USA	9	11	9	29
Total	69	69	73	211
Median (mean) plant size – total number of hourly and salaried personnel employed				379 (936)
Median (mean) plant age – years				34 (40)
Median (mean) number of product families in the plant				9 (72)

Table I.
Description of sample

Competitive strategy measures

In order to measure cost leadership and differentiation, we use two items for each competitive strategy (see Appendix 1 for details). The respondents were asked to indicate, on a five-point Likert scale ranging from "absolutely crucial" to "least important," the importance of certain market and manufacturing goals. Our measures of competitive strategy are related to the market and manufacturing goals of the plant, that reflect the strategic intent of the plant. To assess the unidimensionality of the measures of competitive strategy a confirmatory factor analysis (CFA) was conducted. The results are reported in Table II, showing the items having high within-factor loading (>0.83) as well as low cross-factor loadings indicating that the measures are consistent and separate.

Lean and agile characteristics

In this research, we are searching for discriminating characteristics that are associated with either lean or agile manufacturing, but not with the other. The characteristics that are captured here as being distinctly used for lean operations and that differ from agile operations, are:

- repetitive production;
- daily schedule adherence; and
- flow-oriented layout, representing three interrelated yet distinct practices.

Indicator	Competitive strategy Cost leadership	Differentiation
Low price	*0.854*	0.044
Low-manufacturing unit cost	*0.856*	−0.004
Ability to rapidly change over products on short notice	−0.071	*0.845*
Ability to vary volume of products produced on short notice	0.113	*0.835*

Notes: Please identify the importance of each goal above. Identify the goal as absolutely crucial only if it helps "win the order" from the customer in the marketplace relative the competition. Rate the other goals according to their relative importance; $n = 211$; five-point Likert scale from "absolutely crucial" to "least important"

Table II.
Competitive strategy (as indicated by market and manufacturing goals), standardized factor loadings after CFA

The key characteristics that distinguish agile from lean are that an agile manufacturing system is highly capable of developing new products and providing customization opportunities in an efficient manner. We include three constructs in our composite measure of agile manufacturing:

(1) high-customization capability;
(2) efficient variety handling; and
(3) new product agility, representing three inter-related yet distinct practices.

These aspects are summarized in Table III, with reference to sources in the literature (see Appendix 1 for details).

A CFA was conducted to assess the unidimensionality of the measurement model of the operations characteristics. The results are reported in Table IV, including standardized factor loadings and Cronbach's reliability α. These six constructs are consistent and separate, with respect to the distinct differences between factor loadings for factors within a construct and those between constructs. To verify the reliability of the operations capabilities (second order constructs), all items attributed to lean or agile

Program	Characteristics	Source and description
Lean		
	Repetitive production	Womack and Jones (1996): pull, take time Naylor *et al.* (1999): level schedule Aitken *et al.* (2002): pull material flow Shah and Ward (2007): pull system
	Daily schedule adherence	Womack and Jones (1996): make exactly what the customer wants just when the customer wants it Lewis (2000): exactly when needed Shah and Ward (2003): pace of customer demand
	Flow-oriented layout	Womack and Jones (1996): flow Lewis (2000): flow directly towards the customer Aitken *et al.* (2002): pre-defined processes Shah and Ward (2003): streamlined system Shah and Ward (2007): equipment layout for continuous flow
Agile		
	High-customization capability	Kidd (1994): highly customized products Goldman *et al.* (1995): quick understanding of the unique requirements of each individual customer and rapidly providing it Gunasekaran (1998): customer-designed products Sharifi and Zhang (2001): product model configuration flexibility Aitken *et al.* (2002): customer-specified design
	Efficient variety handling	Vokurka and Fliedner (1998): broad range of products Sharifi and Zhang (2001): providing a wide range of choices Tsourveloudis and Valavanis (2002): the ease of changes between products
	New product agility	Sharifi and Zhang (1999, 2001): high rate and quick introduction of new products Tsourveloudis and Valavanis (2002): introduce new products without investments Aitken *et al.* (2002): design and deliver products quickly

Table III.
Selected differentiating characteristics of lean and agile manufacturing

Table IV. Lean and agile characteristics, factors, standardized factor loadings, and reliability measures after CFA

	Lean characteristics ($\alpha = 0.811$)			Agile characteristics ($\alpha = 0.727$)		
	Repetitive production ($\alpha = 0.884$)	Daily schedule adherence ($\alpha = 0.862$)	Flow-oriented layout ($\alpha = 0.702$)	High-customization capability ($\alpha = 0.743$)	Efficient variety handling ($\alpha = 0.644$)	New product agility ($\alpha = 0.670$)
RPR1	*0.907*	0.019	0.024	−0.055	−0.070	−0.023
RPR4	*0.897*	0.024	0.086	−0.086	−0.044	−0.025
RPR3	*0.815*	0.129	0.027	0.033	−0.086	−0.077
RPR2	*0.745*	0.123	0.126	−0.230	0.063	0.028
DSA4	−0.011	*0.888*	0.148	0.066	0.025	0.025
DSA2	0.194	*0.837*	0.146	0.128	0.045	−0.020
DSA1	0.315	*0.822*	0.150	−0.001	0.128	−0.076
DSA3	−0.112	*0.745*	0.154	−0.200	0.133	0.044
FOL2	−0.035	0.007	*0.736*	0.174	−0.227	0.057
FOL3	0.046	0.292	*0.697*	−0.039	0.292	−0.021
FOL1	0.205	0.198	*0.688*	−0.058	0.361	0.039
FOL4	0.120	0.219	*0.638*	0.077	0.170	−0.080
HCC1	−0.091	−0.070	0.131	*0.820*	−0.017	0.081
HCC2	0.018	0.028	0.050	*0.794*	0.290	0.064
HCC3	−0.234	0.053	−0.027	*0.678*	0.224	0.152
EVH1	−0.147	0.055	−0.005	0.276	*0.742*	0.051
EVH3	−0.152	0.149	0.173	0.324	*0.706*	−0.084
EVH2	0.096	0.094	0.219	−0.017	*0.646*	0.234
NPA1	−0.206	0.081	0.113	0.146	0.060	*0.772*
NPA3	−0.051	−0.075	−0.030	−0.039	0.010	*0.767*
NPA2	0.153	−0.005	−0.082	0.178	0.103	*0.744*
Eigenvalue	3.24	2.98	2.16	2.14	1.97	1.86
Variance explained (%)	15.4	14.2	10.3	10.2	9.4	8.9

Note: $n = 211$

manufacturing were grouped and then the Cronbach's reliability α was calculated for the whole group. These results are also presented in Table IV. The tests indicate that the second order constructs are consistent with $\alpha = 0.811$ and $\alpha = 0.727$, respectively. The correlation coefficient between the two operations capability constructs is 0.132 ($p = 0.116$), indicating that our measures for agile and lean indeed are different.

Operational performance measures

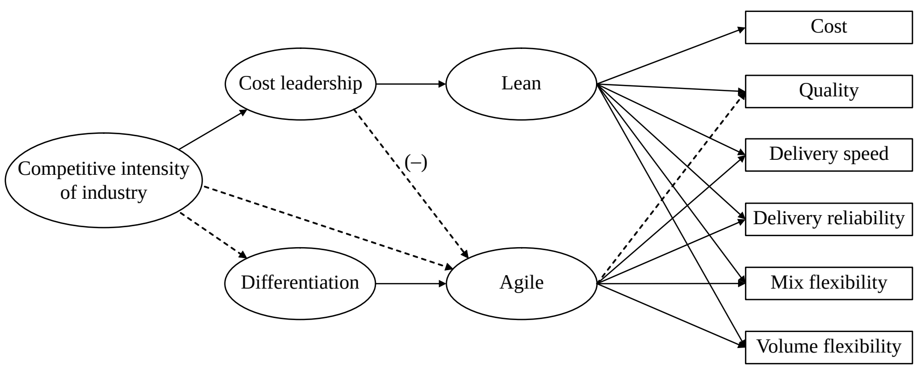
We measure performance in terms of quality conformance (to specifications), delivery speed, delivery dependability, cost, volume flexibility, and product mix flexibility, i.e. the typical manufacturing-related competitive priorities; (Peng *et al.*, 2008). To measure operational performance, the respondents marked on a five-point scale how their plant compared to the competition in its industry along these performance measures (Appendix 1). These measures are used as single items, to be able to identify potential differences between the two delivery measures and the two flexibility measures. Even though there may be multiple dimensions to quality (the eight dimensions by Garvin, 1987), conformance to specifications is the only one for which manufacturing has the prime responsibility (Hill and Hill, 2009, p. 86).

Results

To test the research model, a structural equation modeling approach was used. All structural equations modeling analyses were conducted using AMOS 5.0, within SPSS 13.0. The correlation matrix of all variables is presented in Appendix 2.

First, the overall model fit is evaluated by χ^2/df (normed χ^2) and root mean square error of approximation (RMSEA). Both measures assess how well an a priori model reproduces the sample data. The proposed structural model (combined measurement and path model) fits well as indicated by the model fit statistics: RMSEA = 0.063, $\chi^2/\text{df} = 1.836$, while the suggested cutoff points are RMSEA < 0.08 and $\chi^2/\text{df} < 3$ (Hair *et al.*, 1995). Next the individual paths of the model are evaluated. The results are shown in Figure 2 and Table V.

H1 proposed that high levels of competitiveness in industry would influence manufacturers in formulating a response in terms of a competitive strategy. This hypothesis is fully supported since the standardized estimates are 0.532 ($p < 0.001$)



Notes: Solid lines depict 1% significance level and dotted lines depict 5% significance level

Figure 2.
Structural equations model

Paths	Standardized path coefficient	p-value
H1a. Competitive intensity of industry → cost leadership	0.532	< 0.001
H1b. Competitive intensity of industry → differentiation	0.214	0.041
H2a. Competitive intensity of industry → lean	−0.172	0.206
H2b. Competitive intensity of industry → agile	0.267	0.049
H3a. Cost leadership → lean	0.412	0.007
H3b. Differentiation → agile	0.504	< 0.001
H3c. Cost leadership → agile	−0.317	0.026
H3d. Differentiation → lean	0.106	0.382
H4a. Lean → cost	0.512	< 0.001
H4b. Lean → quality	0.403	< 0.001
H4c. Lean → delivery speed	0.522	< 0.001
H4d. Lean → delivery reliability	0.653	< 0.001
H4e. Lean → product mix flexibility	0.263	< 0.001
H4f. Lean → volume flexibility	0.431	< 0.001
H4g. Agile → cost	0.149	0.106
H4h. Agile → quality	0.194	0.038
H4i. Agile → delivery speed	0.395	< 0.001
H4j. Agile → delivery reliability	0.330	< 0.001
H4k. Agile → product mix flexibility	0.519	< 0.001
H4l. Agile → volume flexibility	0.534	< 0.001

Notes: Fit indices: $\chi^2 = 991.63$; df = 540; χ^2/df = 1.836; RMSEA = 0.063

Table V. Results of the hypothesized paths in the model

and 0.214 (0.041) for cost leadership and differentiation, respectively. Thus, the competitive intensity of the industry can influence firms to go in two directions, pursuing a cost-leadership strategy or a differentiation strategy. Both paths are significant, wherefore a company has a choice of competitive strategy when the competitive pressures are high.

H2 stated that there is a positive relationship between the competitive intensity of the industry and operations capabilities. *H2a* is not supported, since the path to lean is not significant. Lean manufacturing capabilities are not directly affected by the competitive intensity of the industry. *H2b*, on the other hand, is supported (p-value of 0.049 and a standardized estimate of 0.267). Agile manufacturing can thus be regarded as a direct response to high-competitive intensity of the industry, while lean manufacturing is not.

H3a-d test the relationships between competitive strategy as an internal driver and operations capabilities. Of these four hypotheses, three are supported. It is interesting to note the significant ($p = 0.026$) and negative (−0.317) relationship between cost leadership and agile manufacturing. Thus, cost leadership is negatively associated with agile manufacturing, implying that firms with a cost-leadership strategy do not choose (and even avoid) agile operations characteristics. Instead, the choice is lean manufacturing. For firms pursuing a differentiation strategy, agile manufacturing is the choice, while lean is not significantly related to differentiation (the path coefficient is close to zero). Since, the relationships from the two competitive strategies to the two sets of operations characteristics are distinctly and significantly different, it is evident that lean manufacturing is the choice for firms with a cost-leadership strategy, and that agile manufacturing is the choice for firms with a differentiation strategy. This is further supported by the negative path from cost leadership to agile manufacturing, strongly suggesting that agile is not a choice for cost leaders.

In the model, it is also possible to analyze the indirect effects of the competitive intensity of industry on operations characteristics via the choice of competitive strategy. Alternatively stated, we can analyze whether the choice of competitive strategy has a mediating effect on the choice of lean and agile manufacturing. There are significant indirect paths from the competitive intensity of the industry to operations characteristics via the competitive strategy. In the case of cost leadership, the competitive strategy fully mediates the relationship between competitive intensity and the choice of lean manufacturing. This implies that lean manufacturing follows as the significant choice for a cost-leadership strategy. Thus, a cost-leadership strategy is pivotal for the choice of lean manufacturing, since there is no direct effect from the external driver to lean. In other words, lean manufacturing is the active choice for a cost leader. For the differentiation strategy, there are both direct and indirect significant paths from competitive intensity to agile manufacturing, indicating a strong relationship, and that the choice of a differentiation strategy partially mediates the choice of agile manufacturing. Thus, agile manufacturing is driven both directly by the competitive intensity of the industry and indirectly via the differentiation strategy, indicating that a differentiation strategy works in alignment with agile manufacturing capabilities.

H4 concerns how the different operations characteristics relate to several operational performance dimensions. Ten of the 12 hypotheses are supported; the only exception being product mix and volume flexibility performance that are both positively impacted by lean manufacturing. However, agile manufacturing shows a stronger relationship to both flexibility dimensions than does lean. It is interesting to note that cost performance is not significantly affected by agile manufacturing. The impact on quality (conformance to specifications) is significantly stronger for lean manufacturing than for agile, which was not expected, since we assumed equal impact. Thus, these results suggest that it is easier to attain conformance quality in lean systems. An explanation can be that lean is typically associated with a stable manufacturing environment that allows for a well-developed quality assurance system including statistical process control that supports consistent quality in conformance with specifications.

These results support the view that there are differences between lean and agile manufacturing, that they are driven by different competitive strategies, and that they affect operational performance in different ways. Thus, the decision on operations characteristics is important with respect to the desired outcome.

Discussion

In this research, we have investigated lean and agile manufacturing to test whether their respective drivers and performance outcomes differ. We have found that discriminating constructs for lean and agile manufacturing can be developed, i.e. lean and agile manufacturing do indeed foster some distinctly different operations capabilities. It is evident that the drivers for leanness and agility differ, while the impact on performance measures shows both some similarities and some differences.

We find strong empirical alignment between certain combinations of competitive strategy, operations capabilities and main performance outcomes. A cost-leadership strategy is well aligned with lean manufacturing operations capabilities and cost performance, while a differentiation strategy is well aligned with agile manufacturing operations capabilities and flexibility performance.

The external driver considered here, the competitive intensity of industry, shows that the existence of high-competitive pressure leads firms in two directions in terms of competitive strategy. We find that both cost leadership and differentiation are responses to such competitive circumstances. Firms that perceive a more intense competitive environment pursue cost reduction or agility enhancement practices or both simultaneously. The competitive strategy as an internal factor drives the choice of lean and agile manufacturing, and has a mediating effect on the relationship between the competitive intensity of the industry and operations capabilities. A cost-leadership strategy fully mediates the choice of lean manufacturing, whereas a differentiation strategy only partially mediates the choice of agile manufacturing, since there is a direct effect on agility from the competitive intensity of the industry. Thus, lean and agile manufacturing improvement practices are driven by both internal and external factors, either directly or indirectly. The model allows firms to pursue lean and agile manufacturing simultaneously, but the empirical results suggest that a firm chooses one of these, with respect to the significant negative path from cost-leadership strategy to agile manufacturing.

The major differences in performance outcomes are related to cost and flexibility, such that lean manufacturing has a significant impact on cost performance (whereas agile manufacturing does not), and that agile manufacturing has stronger path coefficients leading to volume as well as product mix flexibility than lean manufacturing (even though lean significantly impacts flexibility). Both lean and agile initiatives significantly affect quality conformance, delivery speed and delivery reliability. Our results concerning the impact of lean and agile initiatives on operational performance can be compared with those of Narasimhan *et al.* (2006), even though they used a different data set (a sample of US-based firms) and a different methodology for analyzing the data (cluster analysis). However, there are some striking similarities between the two studies. The main results concerning cost and flexibility performance are very similar, in that leanness has a significantly stronger impact on cost and that agility has a stronger impact on flexibility measures. However, there are some minor differences between the two studies concerning the impact on quality and delivery performance. Our results show that lean initiatives have a higher impact on quality performance, while Narasimhan *et al.* (2006) actually found that agility has a slightly higher impact on quality performance. Furthermore, we found that the impact on delivery speed and reliability is very similar for lean and agile, while Narasimhan *et al.* (2006) found that agility has a higher positive impact on delivery performance. The differences in the results concerning quality and delivery are minor, and can possibly be related to the differences in the samples. This could mean that non-US firms to a larger extent associate lean-related improvement initiatives (than agile initiatives) with quality conformance, delivery speed, and delivery reliability.

The managerial implications include the insights concerning drivers and performance outcomes of lean and agile manufacturing. First, this research strongly supports the view that competitive intensity in the industry is an external driver for choosing a competitive strategy and a manufacturing improvement initiative. Thus, if competition is intense it becomes important for the firm to distinguish itself from the competition, by either pursuing a cost-leadership strategy or a differentiation strategy. If the firm is striving for cost leadership, then lean manufacturing is the appropriate improvement initiative, significantly affecting cost performance. In this situation, agile manufacturing is not the choice, with respect to the significant negative path from cost leadership to agile manufacturing. Thus, a cost-leadership strategy is best supported by a lean improvement initiative. It should be noted that lean manufacturing has a significant and positive impact on all performance measures, wherefore lean performers appear to have developed capabilities that emphasize cost efficiency, quality, and delivery as well as flexibility. Thus, within the context of repetitive production, daily schedule adherence, and flow-oriented layout, even product mix and volume flexibility are positively and significantly impacted. Consequently, a firm may well expect to attain improvement along many operational performance measures if applying lean principles properly. For firms with a differentiation strategy, agile manufacturing provides a better fit as an improvement initiative, with a stronger significant impact on flexibility performance, in addition to significant and positive impacts on delivery and quality performance. Thus, agile manufacturing is the appropriate choice if a differentiation strategy is used. There is no significant positive impact on cost performance, but cost efficiency is usually not a priority for companies that are able to charge a premium price. Instead, agile performers have developed capabilities that emphasize flexibility but also delivery speed and reliability as well as quality conformance; capabilities that are more useful in a differentiation strategy. With respect to the effect on performance measures, lean is advocated if the firm needs to improve cost efficiency, while agile is advocated if improvements in flexibility are needed. If both cost efficiency and flexibility performance are vital to the firm (for example, while pursuing a combination of lower cost and differentiation strategy), these results suggest that a combination of lean and agile is relevant. Even though lean has a significant and positive impact on all operations performance measures, agility provides an even stronger impact on the flexibility dimensions. However, the negative sign on the path between cost-leadership strategy and agile characteristics suggests that it may not be trivial to combine these successfully.

There are some limitations to this research. We have identified several practices and routines that are associated with either leanness or agility. However, there may be other practices or routines that can be related to leanness or to agility. We use cross-sectional data from three industries and it could be interesting to do cross-industry analysis as well as test this model for other industries. Further research can consider other external drivers (as compared to competitive intensity of industry) as well as other models for competitive strategy. Still, we hope that this study will contribute to the understanding of lean and agile manufacturing, and how these are related to competitive intensity of industry, competitive strategy, and operational performance, by adding a broad perspective in a large-scale empirical study.

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(The Appendix follows overleaf.)

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Appendix 1

Variable	Item
The competitive intensity of industry. Informants: PE, PM, PS	
CI1	We are in a highly competitive industry
CI2	Our competitive pressures are extremely high
CI3	Competitive moves in our market are slow and deliberate, with long time gaps between different companies' reactions (reverse coded)
CI4	We don't pay much attention to our competitors (reverse coded)
Seven-point Likert scale from "strongly agree" to "strongly disagree"	
Competitive strategy, as indicated by market and manufacturing goals. Informants: PE, PM, PS	
Please identify the importance of each goal below. Identify the goal as absolutely crucial only if it helps "win the order" from the customer in the marketplace relative the competition. Rate the other goals according to their relative importance	
CS1	Low price
CS2	Low manufacturing unit cost
CS3	Ability to rapidly change over product on short notice
CS4	Ability to vary volume of product produced on short notice
Five-point Likert scale from "absolutely crucial" to "least important"	
Operational performance items. Informant: PM	
Please indicate how your plant compares to its competition in your industry	
OP1	Unit cost of manufacturing
OP2	Quality conformance to product specification
OP3	On time delivery performance
OP4	Fast delivery
OP5	Flexibility to change product mix
OP6	Flexibility to change volume
Five-point scale: "superior", "better than average", "average", "equivalent to competition", "poor, low end of industry"	
Indicators of operations characteristics	
Daily schedule adherence (DSA). Informants: IM, PC, SP	
DSA1	We usually meet the production schedule each day
DSA2	We usually complete our daily schedule as planned
DSA3	We cannot adhere to our schedule on a daily basis(reverse coded)
DSA4	It seems like we are always behind schedule (reverse coded)
Flow oriented layout (FOL). Informants: IM, PC, SP	
FOL1	We have laid the shop floor so that processes and machines are in close proximity to each other
FOL2	We have organized our plant floor into manufacturing cells
FOL3	Our processes are located close together, so that material handling and part storage are minimized
FOL4	We have located our machines to support just-in-time production flow
Repetitive production (RPR). Informants: IM, PC, SP	
RPR1	Our master schedule repeats the same mix of products, from hour to hour and day to day
RPR2	The master schedule is level-loaded in our plant, from day to day
RPR3	A fixed sequence of items is repeated throughout our master schedule
RPR4	We use a repetitive master schedule from day to day

(*continued*)

Table AI.
Questionnaire constructs and items

Variable	Item
High customization capability (HCC). Informants: PD, PE, PS	
HCC1	We are highly capable of large-scale product customization
HCC2	We can customize while maintaining high volume
HCC3	Our capability for responding quickly to customization requirements is very high
Efficient variety handling (EVH). Informants: PD, PE, PS	
EVH1	We can easily add significant product variety without increasing cost
EVH2	Our setup costs, changing from one product to another, are very low
EVH3	We can add product variety without sacrificing quality
New product agility (NPA). Informants: PD, PE, PS	
NPA1	Compared with our industry, we introduce new products more slowly (reverse coded)
NPA2	We achieve a competitive advantage by introducing new products more quickly than our competitors
NPA3	We are never the first in our industry to introduce a new product (reverse coded)
Seven-point Likert scale from "strongly agree" to "strongly disagree"	

Notes: Informants: IM, inventory manager; PC, production control manager; PD, member of product development team; PE, process engineer; PM, plant manager; PS, plant superintendent; SP, supervisor

Table AI.

Appendix 2. Correlation matrix

Table AII.

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	CI1	–																
2	CI2	0.630**	–															
3	CI3	0.289**	0.181*	–														
4	CI4	0.395**	0.359**	0.375**	–													
5	CS1	0.337**	0.343**	0.190*	0.127	–												
6	CS2	0.347**	0.381**	0.087	0.187*	0.506**	–											
7	CS3	0.077	0.078	−0.025	0.054	−0.069	−0.117	–										
8	CS4	0.117	0.207**	0.195**	0.062	0.063	0.019	0.411**	–									
9	DSA1	0.122	0.13	0.102	0.195**	0.133	0.266**	0.01	0.005	–								
10	DSA2	0.065	0.098	0.038	0.221**	0.071	0.192**	−0.002	−0.001	0.786**	–							
11	DSA3	0.249**	0.054	0.182*	0.285**	0.077	0.157*	−0.092	−0.012	0.549**	0.488**	–						
12	DSA4	0.115	0.128	0.057	0.228**	0.088	0.220**	−0.057	0.048	0.712**	0.731**	0.615**	–					
13	FOL1	0.128	0.215**	0.112	0.127	0.039	0.174*	0.093	0.1	0.383**	0.323**	0.260**	0.276**	–				
14	FOL2	0.026	0.061	−0.046	0.077	−0.176*	−0.009	0.048	−0.048	0.094	0.133	0.095	0.146	0.314**	–			
15	FOL3	0.054	0.168*	−0.064	0.07	−0.048	0.06	0.04	0.035	0.393**	0.354**	0.352**	0.378**	0.645**	0.269**	–		
16	FOL4	0.058	0.145	0.043	0.071	−0.098	0.043	0.034	−0.067	0.318**	0.280**	0.278**	0.255**	0.367**	0.295**	0.458**	–	
17	RPR1	−0.151*	−0.007	0.038	0.024	0.149*	0.158*	0.021	0.007	0.254**	0.118	−0.001	0.048	0.147*	0.001	0.052	0.121	–
18	RPR2	−0.119	−0.088	0.121	0.013	0.007	0.118	−0.074	−0.163*	0.292**	0.186*	0.108	0.047	0.160*	0.001	0.116	0.199**	0.610**
19	RPR3	−0.150*	−0.059	−0.067	−0.044	0.166*	0.176*	0.019	−0.005	0.279**	0.222**	0.044	0.109	0.185*	0.053	0.051	0.08	0.754**
20	RPR4	−0.124	−0.012	0.046	−0.023	0.165*	0.194**	0.013	−0.04	0.275**	0.177*	−0.039	0.001	0.204**	−0.026	0.06	0.157*	0.808**
21	HCC1	−0.011	0.062	−0.121	−0.053	−0.093	−0.149*	0.153*	0.056	−0.089	0.004	−0.167*	0.007	−0.014	0.116	0.088	0.06	−0.156*
22	HCC2	0.08	0.118	−0.105	0.042	−0.019	−0.045	0.206**	0.116	0.064	0.127	−0.076	0.052	0.082	0.04	0.087	0.144	−0.076
23	HCC3	0.065	0.051	−0.076	−0.044	−0.055	−0.106	0.121	0.163*	−0.043	0.083	−0.047	0.092	−0.035	0.027	0.018	0.055	−0.273**
24	EVH1	0.102	0.097	0.01	0.044	−0.127	−0.112	0.208**	0.173*	0.073	0.078	0.118	0.107	0.195**	0.018	0.189*	0.121	−0.161*
25	EVH2	0.137	0.128	0.119	0.098	−0.008	0.083	0.183*	0.058	0.234**	0.219**	0.153*	0.187*	0.370**	0.089	0.335**	0.163*	0.004
26	EVH3	0.171*	0.177*	0.078	0.220**	−0.027	0.026	0.201**	0.088	0.147*	0.173*	0.203**	0.201**	0.331**	0.034	0.280**	0.265**	−0.199**
27	NPA1	−0.012	−0.034	0.136	0.032	−0.159*	−0.134	0.007	0.046	−0.061	0.002	0.13	0.119	0.012	0.11	0.099	0.038	−0.205**
28	NPA2	−0.03	−0.019	0.194**	0.224**	−0.148*	−0.106	0.087	0.056	0	0.024	−0.027	−0.018	0.028	0.044	−0.072	−0.069	0.051
29	NPA3	−0.098	−0.11	0.246**	0.082	−0.138	−0.077	0.002	−0.064	−0.124	−0.102	−0.02	−0.071	−0.015	−0.081	−0.064	−0.084	−0.086
30	OP1	0.035	0.034	0.101	0.236**	0.025	0.193**	0.122	0.148*	0.270**	0.260**	0.113	0.192**	0.290**	0.107	0.200**	0.06	0.144
31	OP2	0.065	0.007	0.035	0.191*	−0.068	0.129	0.150*	−0.038	0.210**	0.249**	0.200**	0.103	0.116	0.201**	0.12	0.162*	−0.064
32	OP4	−0.052	−0.073	0.161*	0.104	−0.144	0.03	0.170*	0.237**	0.157*	0.154*	0.025	0.180*	0.214**	0.104	0.147*	0.062	0.06
33	OP3	−0.079	−0.081	0.061	0.139	−0.006	0.105	0.091	0.107	0.261**	0.290**	0.118	0.233**	0.254**	0.143	0.247**	0.176*	0.105
34	OP5	0.062	0.019	0.076	0.04	−0.094	0.033	0.228**	0.125	0.084	0.063	−0.029	0.038	0.173*	0.247**	0.174*	0.163*	−0.053
35	OP6	0.166*	0.164*	0.201**	0.217**	0.061	0.13	0.196**	0.339**	0.150*	0.119	0.13	0.165*	0.316**	0.197**	0.240**	0.197**	0.035

(continued)

	Variable	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	CI1																	
2	CI2																	
3	CI3																	
4	CI4																	
5	CS1																	
6	CS2																	
7	CS3																	
8	CS4																	
9	DSA1																	
10	DSA2																	
11	DSA3																	
12	DSA4																	
13	FOL1																	
14	FOL2																	
15	FOL3																	
16	FOL4																	
17	RPR1																	
18	RPR2	–																
19	RPR3	0.472**	–															
20	RPR4	0.622**	0.635**	–														
21	HCC1	−0.225**	−0.128	−0.174*	–													
22	HCC2	−0.13	−0.012	−.107	0.563**	–												
23	HCC3	−0.308**	−0.186*	−0.252**	0.473**	0.420**	–											
24	EVH1	−0.188*	−0.094	−0.225**	0.190*	0.406**	0.325**	–										
25	EVH2	0.126	0.003	0.037	0.103	0.161*	0.208**	0.324**	–									
26	EVH3	−0.123	−0.148*	−0.160*	0.255**	0.401**	0.321**	0.528**	0.344**	–								
27	NPA1	−0.126	−0.230**	−0.218**	0.190*	0.180*	0.312**	0.225**	0.218**	0.101	–							
28	NPA2	−0.004	−0.032	0.023	0.166*	0.245**	0.192**	0.186*	0.165*	0.066	0.435**	–						
29	NPA3	−0.048	−0.092	−0.067	0.067	0.029	0.027	0.031	0.075	−0.029	0.401**	0.361**	–					
30	OP1	0.233**	0.185*	0.192**	0.042	0.051	0.017	0.026	0.156*	0.05	0.081	0.103	0.045	–				
31	OP2	0.002	0.04	−0.088	0.038	0.061	0.13	0.128	0.182*	0.13	0.083	0.103	0.186*	0.323**	–			
32	OP4	0.055	0.037	0.085	0.06	0.133	0.164*	0.08	0.112	0.147*	0.061	0.036	0.150*	0.229**	0.258**	–		
33	OP3	0.157*	0.164*	0.136	0.084	0.222**	0.206**	0.103	0.156*	0.111	0.126	0.097	0.041	0.343**	0.377**	0.592**	–	
34	OP5	−0.099	−0.026	−0.021	0.233**	0.213**	0.173*	0.153*	0.169*	0.105	0.147*	0.186*	0.05	0.220**	0.164*	0.336**	0.239**	–
35	OP6	−0.061	0.047	0.054	0.149*	0.179*	0.157*	0.157*	0.150*	0.145	0.211**	0.136	0.071	0.296**	0.169*	0.419**	0.386**	0.547**

Notes: *Correlation is significant at the 0.05 level (two-tailed); **correlation is significant at the 0.01 level (two-tailed)

Table AII.