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Competence and capability in quality in the high-tech sector: an international comparison

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Abstract

Purpose – The purpose of this paper is to compare Chinese high-tech firms with other international firms in terms of quality capability and competence.
Design/methodology/approach – This study uses data from the GMRG fourth round survey and provides a method for differentiating and empirically measuring quality competence and capability using a sample of 343 plants in 17 countries in the high-tech manufacturing sector.
Findings – It is shown that the theory of performance frontiers can be used to explain differences in levels of investment in quality management, as well as competence and capability, in plants across regions with varying levels of economic development. Further, it is shown that plants in China provide an example of a special case in that they do not display the same characteristics as plants in other emerging economies.
Research limitations/implications – The study is limited to the high-tech sector and is also constrained by the countries in which the GMRG data has been gathered.
Practical implications – Investment in quality management methods may not always result in discernible variance in quality indicators. In this study this has been shown to be the case in plants in the industrialized world, highlighting the importance of developing a requisite proficiency in innovation. For the plants in China leverage may lie in focussing on how and where resources are being invested, and how quality management is actually valued within a plant.
Social implications – The study indicates that although some economies in the world may experience rapid growth this also needs to be tempered by a requisite investment in building human capability.
Originality/value – The evidence indicates that the plants in China in this study do not possess similar levels of quality competence and capability, and struggle to make investment in quality management alter outcomes.

Keywords Capabilities, Quality management, Global operations management
Paper type Research paper

Introduction

Investment in quality improvement programs being linked to improved firm performance has been established through an extensive body of research in the operations management literature (Nair, 2006). As investment in quality-related initiatives expands evidence suggests that plant managers should expect to be able to develop systems capable of delivering significant improvements in plant performance (Ittner, 1994; Waldman, 1994; Flynn *et al.*, 1995; Powell, 1995; Schroeder *et al.*, 2005). At the same time the capability to institutionalize quality through the adoption of quality management methods is often problematic (Beer, 2003). This problem in fact provides one of the ongoing opportunities for research in this area (Schroeder *et al.*, 2005), and is further reinforced by the recognition of the importance of contingencies in this context (Sousa and Voss, 2001).

This paper addresses the problem of embedding quality capability and competency in international plant operations by assessing differences based on the extent of

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economic development of the country where plant operations are located (Sousa and Voss, 2008). Of particular relevance is the theory of performance frontiers and the diminishing returns associated with investments in operations infrastructure as economic development matures (Schmenner and Swink, 1998; Rosenzweig and Roth, 2004). Using this theory, as investment in structure (physical assets) is accompanied by investment in infrastructure (methods and systems), and both mature over time, it is proposed that operations and asset frontiers will converge and limit incremental investment returns (Vastag, 2000). An important associated theme has been the relationship between different manufacturing capabilities and competencies, the trade-offs (or otherwise) between them, and firm performance (Rosenzweig and Easton, 2009; Swink and Hegarty, 1998; Vickery *et al.*, 1993, 1994). When further returns on investment in structure and infrastructure are subject to natural limits in mature economic environments it is proposed that choices may need to be made between competing priorities (Boyer and Lewis, 2002; Rosenzweig and Roth, 2004). In other words competence stabilizes and the ability to further build capability is limited with the likely outcome being that competitive forces have diffused technologies and methods widely, and improvements in firm performance may also stabilize or plateau as a result (Vastag, 2000).

China is classed as an emerging economy with the highest growth rate in GDP globally (Chinability, 2011). This rate of development offers significant opportunity for manufacturers, while at the same time creating challenges for plant managers. Not least of these is to establish and sustain acceptable levels of product quality. For Chinese manufacturers in many sectors this has proved to be problematic (Zhu and Sarkis, 2004; Lin and Johnson, 2004). This paper aims to examine the development of quality-related competence and capability at a plant level internationally in the high-tech manufacturing industry. In particular, the purpose is to understand better some of the similarities and differences between quality competence and capability in Chinese plants and those in other industrialized and emerging economies.

The contribution of this paper is threefold. First, a simple method for differentiating between and measuring manufacturing competence and capability based on current performance, and improvement in performance outcomes over time, is proposed and applied to the specific competitive dimension of quality. In this study definitions of competence and capability from other management disciplines are used to clarify and simplify these concepts. In essence competence is distilled into "what we can do now," and capability into "performance improvement over time."

Second, the study uses the theory of performance frontiers to explain different levels of competence and capability in manufacturing plants based on the extent of economic development of the country in which they are located. It is demonstrated that plants in industrialized economies can be expected (on average) to be more competent (better in terms of "what we can do now") in the management of quality than those in emerging economies. At the same time, however, capability (or potential for improvement over time) in quality management in the emerging economy plants is shown to be on a par with those in the developed economies – at least in terms of management of quality within the plant. This is explained using the theory of performance frontiers and the expected diminishing returns plants in industrialized economies are subject to as asset and operations frontiers converge.

Third, it is also demonstrated that the plants in this study from China exhibit a unique set of characteristics that do not match either the emerging or industrialized economy groups. While there is evidence of substantial investment in quality

management methods in the Chinese plants there is evidence that they do not get a return on this investment consistent with that reported by the other emerging economy plants. The implications and explanation of these findings also provide further opportunities for research.

Theoretical foundation

Manufacturing competence and capability

The clarification of the differences between terms often used interchangeably in the operations strategy literature (e.g. manufacturing competence, capability, competitive priorities, etc.) has been identified as an important area where clarification of definitions would be of benefit (Swink and Hegarty, 1998; Vickery *et al.*, 1993, 1994). This debate has roots in the critical appraisal of the theory of production competence as proposed by Cleveland *et al.* (1989). In this study competence was defined as being a "capability" the value to the firm of which was contingent on strategic choice. As such competence was relative and case specific to the competitive priorities of the firm. Vickery *et al.* (1993, 1994) then questioned both the content and the execution of this research, proposing that a more important link in determining "competence" was that between performance and strategic choice.

Building on the earlier work of Vickery *et al.* (1993, 1994) where competence (in a manufacturing context) was defined as linking plant performance with firm strategy, Swink and Hegarty differentiate capability as "[…] a fundamental proficiency in manufacturing" (p. 375). In this sense they attempt to differentiate the two concepts relative to the strategic objectives of a firm. Competence represents the extent to which the performance of the firm supports strategy, with capability being the means (the operational strengths of the firm) by which competence is maintained.

As a result of this they propose that "capabilities" need to be isolated from both the concept of competence, and from the competitive priorities firms can pursue, and develop two distinct types of capability – growth and steady state. They differentiate between the two types of capabilities thus:

> Steady state capabilities can be measured at any given point in time and are indicated by superior manufacturing outcomes. Growth capabilities are indicated by changes in manufacturing outcomes over time or by the development of new steady state capabilities (Swink and Hegarty, 1998).

This concept of differentiating capabilities and/or competencies based on dynamic characteristics and improvement through time resonates conceptually with similar concepts and definitions from the human resources and strategic management literatures (Kamoche, 1996; Wright *et al.*, 1994, 2001). In the human resource management literature human competence is associated with being able to replicate a base level of performance, whereas capability is defined as being able to learn, and to improve performance, by developing "adaptive capabilities" (Lado and Wilson, 1994). In the strategy literature the distinction is articulated through the concept of "dynamic capabilities" (Teece and Pisano, 1994; Teece, 2007; Winter, 2003) and specifically defined as:

> […] the management capability to effectively coordinate and redeploy internal and external competences […] it refers to the shifting character of the environment; (and) the key role of strategic management in appropriately adapting, integrating, and re-configuring internal and external organizational skills, resources, and functional competences toward a changing environment (Teece and Pisano, 1994).

An alternate interpretation of this definition in a manufacturing context (reflecting the model also proposed in the HRM literature) is that competence represents what you can do, while capability is what you have the potential to do (Zhang *et al.*, 2003), and that capability builds on a base level of competence. In operations, competence therefore can be assessed as residing in repeatable processes and capability in the potential to be able to improve process performance. As Teece would suggest:

> […] private wealth creation in regimes of rapid technological change depends in large measure on honing internal technological, organizational, and managerial processes inside the firm (Teece *et al.*, 1997).

The important point emanating from this debate is that a simple proxy for competence and capability (on any performance dimension in operations), is to use improvement over time as the point of difference. Using "quality" as the performance dimension of interest, competence could therefore be assessed by measuring (say) reject rates at a point in time, while capability could be assessed through the change in reject rates over a set time period. In this way measuring competence captures what can be done and provides a base level of performance. The incorporation of change over time (capability) provides the ability to measure improvement potential (aka dynamic capability/learning ability) as well as responsiveness to a changing environment.

Performance frontiers, manufacturing competence and capability

The concept of a performance frontier was articulated in the context of operations management by Schmenner and Swink (1998) building on similar concepts from economic theory (Samuelson, 1947). In economics a production frontier is "[…] the maximum output that can be produced from any given set of inputs, given technical considerations" (Schmenner and Swink, 1998; Samuelson, 1947). In order to complete the analogy with operations management of this economic definition "output" takes the form of criteria used to measure performance in manufacturing, and "technical considerations" equate to methods, machinery, process and systems choices available to a plant manager. In the context of these choices the performance frontier is the theoretical feasible performance maximum (Schmenner and Swink, 1998). Such frontiers have been identified as physical realities constraining the capability of a production system (Swink *et al.*, 2006), and have been defined in terms of operations thus: "[…] frontiers are formed by choices in plant design and investment as well as by choices in plant operation" (Schmenner and Swink, 1998).

A performance frontier is determined by investment in assets over time, either tangible (structural) or intangible (infrastructural) (see Skinner, 1969). Conceptually there are two frontiers relevant to investment in operations, the asset frontier and the operating frontier (Vastag, 2000). The asset frontier is affected by "[…] investments that would show up in the fixed asset portion of the balance sheet" (Schmenner and Swink, 1998, p. 108), while the operating frontier is "altered by changes in choices that can be made, given the set of assets that the plant management is dealt" (Schmenner and Swink, 1998, p. 108).

In the context of the management of quality, investments impacting the operating frontier will be infrastructural in nature (Skinner, 1969) and include methods-based programs such as TQM, Six Sigma and ISO 9000. Investment in these programs has the purpose of building competence and capability in operations with the objective to improve plant performance (Vickery *et al.*, 1993; Rosenzweig and Easton, 2009). If the relationship between investment and performance, however, is moderated by the relative position of operations and asset frontiers, predicting return on investment

from one plant to another may be problematic. Further, there is evidence suggesting that extent of economic development also moderates this relative position, as well as the proximity to the theoretical maximum performance available to a specific plant (Power *et al.*, 2010).

The performance frontier for a plant in an industrialized economy is likely to be the result of extensive investment in physical assets over time culminating in learning gained from experience in the use of those assets. In such a case it is likely that the operating and asset frontiers will converge. This could result in significant levels of competence in leveraging methods and processes, but it also would limit further extension of manufacturing performance over time (capability building), and/or create pressure to trade-off or choose between competitive priorities (Schmenner and Swink, 1998). The opposite would be the case for firms in countries with lower levels of industrialization, with levels of competence and capability being lower (older technologies combined with less asset investment). At the same time, however, the options for investment in developing capabilities should be greater due to an expected substantial gap between the asset and operating frontiers (Vastag, 2000).

The concept of performance frontiers limiting return on investment in both tangible and intangible assets therefore has important implications for the preceding discussion regarding manufacturing competence and capability. These natural limits should be reflected in relative levels of competence and capability, as well as in the relative returns expected from investment in establishing competence and building capabilities over time.

Quality management in the Chinese context

The importance of understanding the specifics of the local context in managing quality performance in China is a theme that has been identified in a number of earlier studies. In implementing TQM in state run enterprises culture change has been identified as a critical pre-cursor of effective deployment (Jenner *et al.*, 1998), and implementation of quality programs in this sector has been shown to be highly variable (Li *et al.*, 2003). In general the commitment of senior managers has also been identified to be critical, a factor that was also found to be significant in two other rapidly developing economies – India and Mexico (Rao and Raghunathan, 1997). Management of operations was found to be highly developed in plants situated in the Shanghai area, however, not with the same level of sophistication in communication and collaboration with trading partners (Pyke *et al.*, 2000). Other studies from the turn of the millennium suggest that the influence of culture in adoption of employee involvement and TQM programs in China is critical (Pun, 2001) leading to the statement that:

> Successful adoption of EI/TQM practices lies largely on the management of cultural dynamics and organizational complexities in Chinese enterprises (Pun, 2001).

A further insight into the realities of quality management in Chinese enterprises is given by two studies using the Malcolm Baldridge quality criteria to assess breadth and depth of implementation (Lau *et al.*, 2004), and organizational context in services (Zhao *et al.*, 2004). In the former, although some of the commonly held wisdom regarding the strategic value of TQM compared to inspection-based quality control was supported, it was also observed that:

> […] most Chinese firms still lack a full understanding of strategic quality management although a higher percentage of them claim that they are total quality management companies (Lau *et al.*, 2004).

In the second study further development of the system into one with a strong strategic focus was shown to be more closely associated with the perceived importance of quality to the firm (Zhao *et al.*, 2004). The results from both studies indicate that organizational context appears to be an important emerging theme in explaining the adoption and application of quality management (and similar methodologies) in China.

Understanding the dynamics of quality management, competence and capability and the relationship with plant performance in China is an area of research still offering significant opportunity. The expectation for further growth in the manufacturing sector in China is especially relevant given that:

> […] when sales revenues (gross output) that are earned by the manufacturing sector are used to measure the size of output, China will grow to outrank the United States as early as 2008. If, however, the value added of the manufacturing sector is used to measure relative size, China will not outrank the United States until 2013. Furthermore, when output is measured using real (inflation-adjusted) "1997 US dollars," then the manufacturing value added in China will not exceed that of the United States until after 2020 (GlobalInsight, 2009).

Whatever measure is used the reality is that China will be a pre-eminent player in global manufacturing at least for the first half of the twenty-first century, and likely well beyond. The importance of understanding the local contingencies affecting improved quality management in China is therefore high. In order to achieve this in this study the Chinese plants are treated as a separate group for the purposes of comparison with plants in other emerging and industrialized economies. The premise is that China, being an emerging economy, will be subject to the same hypothesized relationships as those in other emerging economies. The Chinese plants can therefore be compared with both those in industrialized economies, as well as those in other emerging economies, in order to ascertain characteristic differences and commonalities.

Hypothesis development

The theory of performance frontiers indicates that there are natural limits to investment returns available over time to manufacturers seeking to extend their tangible and intangible asset base (Schmenner and Swink, 1998). Such natural limits can be expected to also place constraints on the extent of investment in management systems and methods (Vastag, 2000; Rosenzweig and Roth, 2004). In economies where there has been extensive investment over time in quality management systems there is empirical evidence that plants will, on average, be approaching those natural limits (Power *et al.*, 2010; Schoenerr *et al.*, 2009). The opposite should be the case for plants in emerging economies where it is expected that the scope for investment is yet to reach these natural limits. On this basis it is hypothesized that:

H1. Investment in quality management systems and methods over the measured time span will be higher in the Chinese and emerging economy plants than in those in the industrialized economies.

The concept of competence in the operations management literature is one that has been subject to debate for the past 20 + years (Safizadeh *et al.*, 2000; Swink and Hegarty, 1998; Vickery *et al.*, 1993, 1994; Cleveland *et al.*, 1989). The exact definition of what competence is in operations is still open to discussion, the major advance in the debate being that there is evidence suggesting that competence and performance are

related (Cleveland *et al.*, 1989; Schmenner and Vastag, 2006). Using definitions that have been used in cognate management disciplines of HRM and strategic management, competence can be simply defined as "what we can do" that is consistent and repeatable (Lado and Wilson, 1994; Zhang *et al.*, 2003). Given that the operations management literature has established a link between competence and plant outcomes, a base level of performance at a point in time provides a good surrogate measure of competence. In the area of quality management a straight forward measure of plant performance is to assess reject rates at multiple levels of the value chain.

Manufacturing plants in the industrialized economies have been investing in quality management programs extensively since the 1950s. Expressed in terms of the theory of performance frontiers it would be expected that the performance frontier (or boundary) for these plants would be extended further on average (Vastag, 2000; Schmenner and Swink, 1998) than for plants in emerging economies. As a result they can be expected to have, on average, been able to develop a base level of competence in quality management (as measured by reject rates at multiple points in the value chain) that will be higher (i.e. lower reject rates) than for plants in emerging economies. This then leads to the hypothesis that:

H2. Competence in quality management will be significantly greater in plants in the industrialized economies than in China and the emerging economies.

Capability, and in particular how it differs from competence, has also been a concept in operations management subject to some debate and discussion (Swink and Hegarty, 1998). Building on the proposed definition of capability given by Swink and Hegarty, and using concepts borrowed from HRM and the strategic management literature (Lado and Wilson, 1994; Teece and Pisano, 1994; Teece *et al.*, 1997), it is proposed that the ability to learn, improve or change over time provides a simple definition of capability in operations. Similar to the link proposed between competence and plant outcomes (Schmenner and Vastag, 2006; Cleveland *et al.*, 1989), representing capability in terms of performance also has some support from Swink and Hegarty when they propose that capability "improvement" is best expressed as:

> […] the ability to steadily increase the efficiency and productivity of existing manufacturing resources over time (Swink and Hegarty, 1998).

In terms of the theory of performance frontiers, as economies become industrialized, while the performance frontier (and therefore competence) extends due to further asset investment over time, the physical limits of technology also come into play. When technologies (methods, systems, physical assets, etc.) mature, operations and asset frontiers will tend to converge reducing the opportunities for creating improvement over time (capability) in performance (Vastag, 2000; Schmenner and Swink, 1998). Innovation then becomes the primary potential source of differentiation between plants in industrialized economies (Rosenzweig and Roth, 2004).

In the emerging economies, on the other hand, investment is at a lower level of maturity and scope for improvement over time (capability) is not necessarily subject to these limits as the gap between the operations and asset frontiers can be expected to be significant with each new investment cycle (Vastag, 2000). These plants should have greater potential for improvement and building capability. Greater scope for improvement is associated with pursuit of a "learning curve" (Wright, 1936).

It is therefore proposed that there will be a differential on average between the capability (ability to learn, improve or change over time) of plants in emerging and industrialized economies. As such, unless a plant manager in an industrialized economy is able to create extra leverage through innovation (i.e. create an innovation cycle) (Rosenzweig and Roth, 2004), it is expected that capability (scope for improvement in operations performance over time) in a plant in an emerging economy will, on average, be greater than in an industrialized one. It is therefore hypothesized that:

H3. Capability for improvement over time in quality management will be lower in the industrialized economies than in China and the emerging economies.

Following on from the arguments offered above regarding the relative positions of operating and asset frontiers in industrialized and emerging economies it is expected that the ability to leverage investments in quality management methods will be greater in China and the emerging economy plants. In plants in the industrialized economies investment in quality management methods will be at a higher level of maturity on average, and the performance frontiers will likely also be reaching their technological limits. At the same time the theory of performance frontiers tells us that both the operations and asset frontiers will likely be converging making it more difficult for plant managers to improve performance on multiple competitive dimensions (Vastag, 2000). As such there may be the need to accept trade-offs between these dimensions. At this stage the only real option open to a plant manager is to pursue innovation (Rosenzweig and Roth, 2004) to reset the natural limits of technology and thus the absolute (determining competence) and/or relative (determining capability) positions of asset and performance frontiers. Capability in the area of innovation is a rare and valuable commodity, often being firm and/or plant specific as noted by Teece below:

> The competitive advantage of firms is seen as resting on distinctive processes (ways of coordinating and combining), shaped by the firm's (specific) asset positions (such as the firm's portfolio of difficult-to-trade knowledge assets and complementary assets), and the evolution path(s) it has adopted or inherited (Teece *et al.*, 1997).

In plants in the emerging economies this would not be expected to be the case as the absolute (determining competence) and/or relative (determining capability) positions of asset and performance frontiers would not be expected to be subject to these constraints. Under these circumstances for every unit invested, on average, in quality improvement programs, the return would be expected to be greater in the plants in emerging economies than in the industrialized ones. In the emerging economies it would be expected that there would be more scope for both extending the absolute and relative positions of performance frontiers. As such it is hypothesized that:

H4. Variance explained in competence as a result of investment in quality management will be significantly greater in China and the emerging economies than in the plants in industrialized economies.

H5. Variance explained in capability as a result of investment in quality management will be significantly greater in China and the emerging economies than in the plants in industrialized economies.

Method

Research database and sample

The data used to test the hypotheses came from the Global Manufacturing Research Group (GMRG). The GMRG is an international group of researchers focussing on the study of manufacturing practices globally (Wacker and Sheu, 2006). The group uses a validated survey instrument that is administered to manufacturing plant managers in multiple countries. The questionnaire is translated into the native language of respective countries from the English original, with the aim of ensuring equivalency of meaning, validity and reliability of the survey. The questionnaire is also revised periodically, in order to update the content of questions in line with developing issues of interest to the operations management research community. After administration of the survey in the various countries the data are pooled, validated and re-distributed to the participating members of the group. This study uses data collected in the fourth round of the survey between 2006 and 2008. The fourth version of the questionnaire was the outcome of a rigorous process of assessment and revision based on previous versions (Whybark *et al.*, 2009). This global database is therefore designed for the comparison of operations management practices and performance across multiple countries and economic regions (Whybark, 1997).

A total of 1,293 usable responses were gathered in this round from 23 countries. Out of this data set there were 343 plants identified as being from the two industry categories (US-SIC/ISIC) of interest to this study: first, industrial and commercial machinery and computer equipment; second, electronic and other electrical equipment and components (except computer equipment). These sectors collectively capture manufacturers engaged in making high-tech products. These two groupings were chosen as they represent an industry category that has experienced significant growth over the past 30 years, has been subject to significant investment in quality management programs internationally (e.g. Six Sigma was a quality improvement methodology developed by Motorola operating in this sector). All the data collected from the Chinese plants (all located in and around the Shanghai region) in this round of the GMRG survey were from this sector.

This group of 343 plants were then separated into two groups (industrialized and emerging economies) based on the extent of industrialization of the economy of the country of location. The Chinese plants were then separated from the rest of the emerging economy sub-sample to provide a specific comparison for this group. This left three groupings: industrialized economy plants $n = 195$; emerging economy plants $n = 91$; Chinese plants $n = 57$. Table I contains the breakdown by of plants in these categories by country and economic region.

Measures

In order to test the hypotheses a number of different survey items were used. For *H1* (*H1*: investment in quality management systems and methods over the measured time span will be higher in the Chinese and emerging economy plants than in those in the industrialized economies) five items relating to the extent of investment in quality improvement programs were used as detailed: in the last two years, to what extent has the plant invested resources (money, time and/or people) in programs in the following areas? Total quality management; ISO 9000 Certification; Supplier Certification; Statistical Process Control; Six Sigma. Each of these was measured on a seven-point Likert scale anchored from "Not at All" to "To a Great Extent." The test used in this case was ANOVA for comparison of mean scores between the three groups.

Industrialized economy plants		Emerging economy plants		Chinese plants	
Countries	No. of respondents	Countries	No. of respondents	Country	No. of respondents
Australia	3	Hungary	19	China	57
Austria	3	Korea	5		
Finland	37	Mexico	4		
Germany	21	Taiwan	50		
Italy	16	Poland	12		
Sweden	11	Croatia	1		
USA	33				
Canada	43				
Ireland	10				
Switzerland	18				
Total	195	Total	91	Total	57

Notes: Breakdown of plants (US-SIC/ISIC categories: industrial and commercial machinery and computer equipment, electronic and other electrical equipment and components, except computer equipment) by country and extent of industrialization (six countries from the original GMRG data set had no respondents from these two sectors and are therefore excluded from the analysis)

Table I.
Breakdown of respondents by extent of economic development and country

For *H2* (*H2*: competence in quality management will be significantly greater in plants in the industrialized economies than in China and the emerging economies), the objective was to capture the performance of the plant in the area of quality at the time of the survey being administered (i.e. assess the quality competence of the plant) and compare this between the three groups. For this purpose four items assessing the percent of rejects at different points in the value chain were used as detailed: current percent of rejects of incoming material; current percent of rejects during processing; current percent of rejects at final inspection; current percent of rejects from the customer.

For *H3* (*H3*: capability for improvement over time in quality management will be lower in the industrialized economies than in China and the emerging economies) the purpose was to be able to assess the ability of a plant to improve performance in quality management over time (i.e. assess the quality capability of the plant) and compare this between the three groups. For this purpose the difference was calculated in the percentages reported for the following four pairs of variables assessing the percent of rejects at different points in the value chain as detailed: difference between percent of rejects of incoming material currently and percent of rejects of incoming material two years ago; difference between percent of rejects during processing currently and percent of rejects during processing two years ago; difference between percent of rejects at final inspection currently and percent of rejects at final inspection two years ago; difference between percent of rejects from the customer currently and percent of rejects from the customer two years ago. The test used for comparison between the three groups for both of these hypotheses was ANOVA for comparison of mean scores.

For *H4* (*H4*: variance explained in competence as a result of investment in quality management will be significantly greater in China and the emerging economies than in the plants in industrialized economies) the purpose was to assess the variance in quality performance explained by investment in quality management programs at the time of the survey being administered (i.e. assess the affect of investment in quality management programs on quality competence of the plant) and compare this between the three groups. For this purpose a hierarchical regression model was developed. Three independent variables were used in the model, two being control variables

and the third being a summated scale developed from the five variables relating to the extent of investment in quality improvement programs (as also used to test *H1*). These five variables were subjected to factor analysis and combined to form a single variable by averaging the mean scores for each to create a single summated scale. The validity of this scale was established by the factor loadings (the items were not forced into a single factor but based on an eigenvalue >1), and the face validity of the items. The reliability of the scale was established through a Cronbach's α test with the result being 0.758. Table II illustrates these results.

The two control variables used were Plant Size (approximately how many total employees work for the plant?) measured as a number, and foreign ownership (what percent of the plant ownership is international?) measured as a percentage. Plant Size was used in order to control for the benefits larger plants with more financial resources may be able to extract from such investments, and foreign ownership was used to extract variance explained by plants in one economic region that may be governed and controlled from another economic region (a condition common in emerging economies, and in China in particular). A recent study has indicated in fact that in China foreign ownership and joint ventures are particularly important in determining take up of quality management methods in SME's (Lee, 2004). The dependent variables in the model were the same four items assessing the current percent of rejects at different points in the value chain used to test *H2* and detailed above.

For *H5* (*H5*: variance explained in capability as a result of investment in quality management will be significantly greater in China and the emerging economies than in the plants in industrialized economies) the objective was to assess the variance in quality performance over time explained by investment in quality management programs (i.e. assess the affect of investment in quality management programs on quality "capability" of the plant) and compare this between the three groups. A hierarchical regression model was also used incorporating the same independent variables as those for *H4* outlined above. The dependent variables in this case were the same four items assessing the change in percent of rejects at different points in the value chain used to test *H3* and detailed above.

Results

H1. Investment in quality management systems and methods over the measured time span will be higher in the Chinese and emerging economy plants than in those in the industrialized economies.

In the last two years, to what extent has the plant invested resources (money, time and/or people) in programs in the following areas?	Factor Investment: quality management
Total quality management	0.815
Supplier Certification	0.886
Statistical Process Control	0.790
ISO 9000	0.777
Six Sigma	0.676

Notes: Kaiser-Meyer-Olkin measure of sampling adequacy: 0.787; Bartlett's test of sphericity: sig. = 0.000; Cronbach's $\alpha = 0.758$

Table II.
Factor analysis: investment in quality management

In testing *H1* the results indicated statistically significant differences between the emerging economy plants and those in the industrialized economies on all four investment criteria except for TQM. The results for the Chinese plants showed that there were significant differences in investment compared to the industrialized plants for all criteria except Six Sigma. In all cases investment levels reported were higher for both the Chinese and emerging economy plants. Investment in TQM was also significantly greater in the Chinese plants than those in the other emerging economies, and less (though not statistically significant) for Six Sigma. Significant differences in investment levels were therefore noted between the Chinese and emerging economy plants and those in the industrialized economies leading to the conclusion that *H1* can be accepted. The results are shown in Figure 1 and Table III:

H2. Competence in quality management will be significantly greater in plants in the industrialized economies than in China and the emerging economies.

Reject rates at all four points in the value chain were substantially lower for the plants in the industrialized economies than for those in the emerging economies. In the case of final inspection and customer returns these differences were recorded to be statistically significant, and marginally so for work in process rejects ($p = 0.059$). In the Chinese plants percentages for work in process and final inspection rejects were higher than those recorded for the other emerging economy plants, and statistically significant in difference when compared with industrialized economy plants for both. For customer returns the difference was significant at $p < 0.1$ ($p = 0.059$).

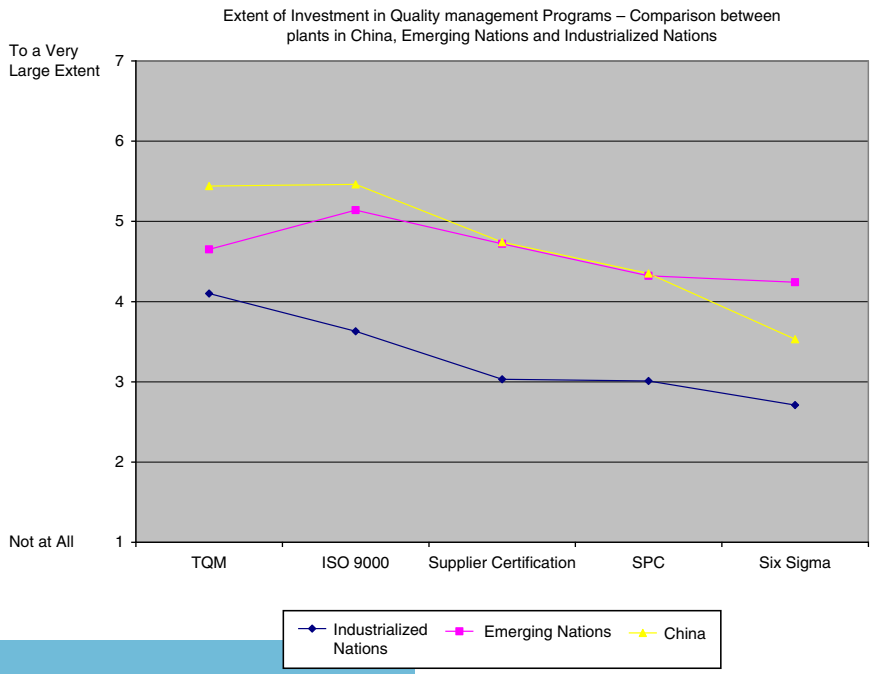

Figure 1.
Investment in quality management programs

Extent of resources invested	Economic group (1)	Economic group (2)	Mean difference (1-2)	Significance
Total quality management	Industrialized	Emerging	−0.556*	0.039
		China	−1.343*	0.000
	Emerging	China	−0.787*	0.024
ISO 9000	Industrialized	Emerging	−1.517*	0.000
		China	−1.828*	0.000
	Emerging	China	−0.312	0.651
Supplier Certification	Industrialized	Emerging	−1.695*	0.000
		China	−1.710*	0.000
	Emerging	China	−0.015	0.999
Statistical Process Control	Industrialized	Emerging	−1.317*	0.000
		China	−1.346*	0.000
	Emerging	China	−0.029	0.996
Six Sigma	Industrialized	Emerging	−1.529*	0.000
		China	−0.819	0.192
	Emerging	China	0.710	0.372

Note: *Significant at $p < 0.05$ or greater

Table III.
Investment in quality management programs – ANOVA results

One possible interpretation of these results is that the higher reject rates within the plant (emerging economy plants and China) are also indicative of quality control being exercised through inspection rather than having been institutionalized through mature systems and processes. There is also evidence of more stability and consistency in the results from the plants in industrialized economies supportive of there being a higher level of base competence in this group. By way of contrast, the results from the Chinese plants exhibit some degree of inconsistency, there being a relatively higher proportion of rejects being identified within the plant in comparison to those from the other emerging economies. The results indicate support for the hypothesis, and also show that the point of difference in reject rates is not attributable to problems with incoming goods, but more with internal processes and systems. The results are shown in Figure 2 and Table IV:

H3. Capability for improvement over time in quality management will be lower in the industrialized economies than in China and the emerging economies.

There is only limited support for *H3* evident in the results. Although there are differences recorded in the mean values for improvement in reject rates between the emerging and industrialized groups none are statistically significant. Both groups indicate that they are recording improved reject rates over the two-year period. Having said this there are substantial (if not statistically significant) differences recorded between the Chinese plants and the other two groups for work in process and final inspection in particular. In both cases the Chinese plants record negative rates of improvement (i.e. higher reject rates over the two-year period) with a 3-4 percent differential compared to the plants in emerging and industrialized economies. Where the Chinese plants do report improvement is in incoming goods and customer returns – a result not inconsistent with the observation from *H2* that there is evidence of inspection led quality control in the Chinese plants. In other words, higher internal reject rates (as a result of more rigorous inspection), is a plausible scenario to account

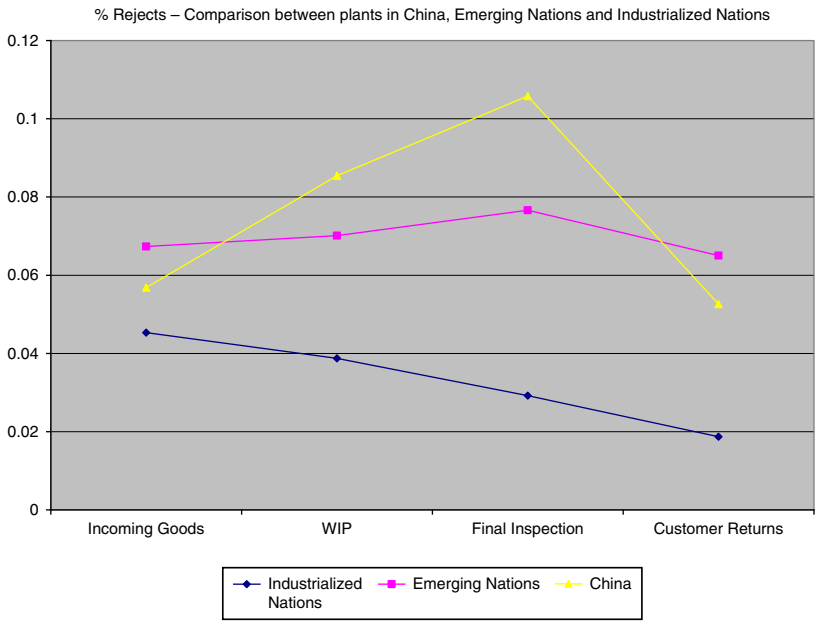

Figure 2.
Comparison of reject percentages

% rejects currently	Economic group (1)	Economic group (2)	Mean difference (1-2)	Significance
Incoming goods	Industrialized	Emerging	−0.021	0.360
		China	−0.011	0.837
	Emerging	China	0.010	0.885
Work in process	Industrialized	Emerging	−0.031	0.059
		China	−0.046*	0.018
	Emerging	China	−0.015	0.698
Final inspection	Industrialized	Emerging	−0.047*	0.016
		China	−0.076*	0.001
	Emerging	China	−0.029	0.418
Customer returns	Industrialized	Emerging	−0.046*	0.001
		China	−0.033	0.059
	Emerging	China	−0.123	0.739

Note: *Significant at $p < 0.05$ or greater

Table IV.
Comparison of reject percentages – ANOVA results

for improvement in, for example, customer returns. The results are shown in Figure 3 and Table V:

H4. Variance explained in competence as a result of investment in quality management will be greater in China and the emerging economies than in the plants in industrialized economies.

The results for *H4* indicate that plants in the emerging economy group are deriving greater benefit (in terms of quality competence) from investing in quality management programs than are the plants in the industrialized economies. Significant variance in

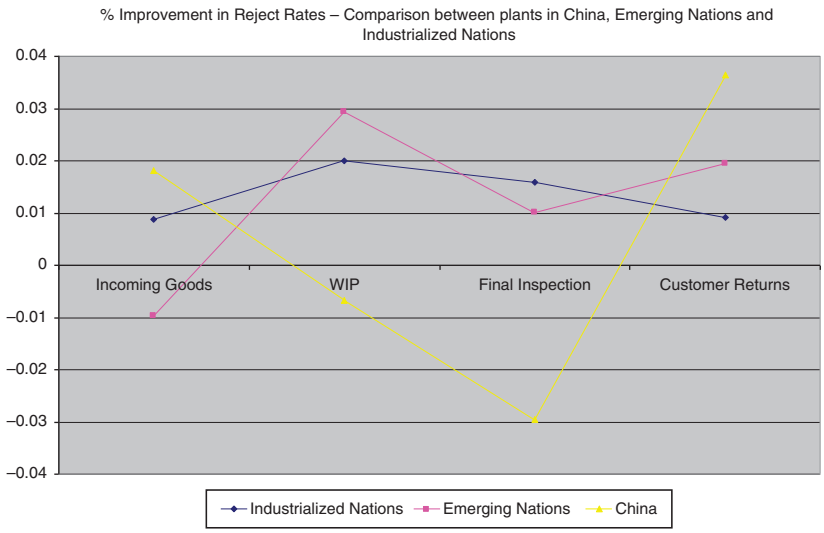

Figure 3.
Percentage improvement in reject rates

Improvement in % rejects over two years	Economic group (1)	Economic group (2)	Mean difference (1-2)	Significance
Incoming goods	Industrialized	Emerging	0.018	0.251
		China	−0.009	0.804
	Emerging	China	−0.027	0.204
Work in process	Industrialized	Emerging	−0.009	0.746
		China	0.026	0.227
	Emerging	China	0.036	0.108
Final inspection	Industrialized	Emerging	0.005	0.935
		China	0.045	0.068
	Emerging	China	0.039	0.182
Customer returns	Industrialized	Emerging	−0.010	0.670
		China	−0.027	0.142
	Emerging	China	−0.016	0.545

Note: Significant at $p < 0.05$ or greater

Table V.
Percentage improvement in reject rates – ANOVA results

reject rates for incoming goods (13 percent), final inspection (8 percent) and customer returns (8 percent) were recorded as a result of this investment in the emerging economy plants. By way of contrast no significant variance in the four dependant variables was recorded in the industrialized sector. The only variable influencing reject rates in this group was Plant Size (approximately 3 percent) in the work in process category. An interpretation of this finding is that the industrialized plants record no effect because they are at a level of competence in quality currently (on average) such that reject rates are stable and not likely to be readily impacted by further investment in quality management. This would also be consistent with the findings from *H2*.

The emerging plants, on the other hand, are recording a significant effect as a result of investment, at least in part due to being at a lower level of competence overall. As such, further support is provided for *H2*, as well for this hypothesis in that the

emerging plants are deriving benefit from investment aimed at extending their base level of competence. The results for China, rather than aligning with those for the other emerging economy plants, are similar to those from the plants in the industrialized economies in that they also report no significant effect. One interpretation is that these plants in this particular industrial sector have developed their competence to a point where it is on a par with those in the industrialized economies, and as a result there is no effect being recorded. However, the results for *H2* would indicate that this is not the case. In fact, the Chinese plants report significantly higher reject rates within the plant (work in process, final inspection) than those in the industrialized economies.

The only variable impacting on reject rates in the Chinese plants is Plant Size, explaining 21 percent of variance in incoming goods reject rates and 10 percent for work in process. As such, the plants in China have this factor in common with the industrialized plants, but not the same level of competence. At the same time there is not the evidence that they are extending their competence as a result of investment in quality management programs. Interestingly the results for *H1* indicate that they are investing in quality management extensively – at least to a similar extent to the plants in the other emerging economies – and in the case of TQM significantly more. There was no effect recorded in any group attributable to foreign ownership. The results provide partial support for *H4* in that the hypothesis is valid for the emerging economy plants but not for those in China. They are presented in Table VI:

H5. Variance explained in capability as a result of investment in quality management will be greater in China and the emerging economies than in the plants in industrialized economies.

As with the results reported for *H4* above the emerging economy plants were the only group where significant variance in capability for quality improvement was attributable to investment in quality management programs. In this case the variance explained over a two-year period was for changes in reject rates for incoming material (3 percent) and final inspection (5 percent). No similar effect was recorded for either the industrialized group or the Chinese plants. Plant Size did, however, again explained 35 percent of the variance in reject rate change for incoming material in the Chinese plants, and approximately 3 percent for work in process in the industrialized group. The results again provide partial support for *H5* in that the emerging economy plants do show evidence of a relationship (albeit weak) between investment in quality management programs and change in reject rates at a number of points in the value chain. The weak nature of the relationships may also be attributable to the time frame for change (two years) in the independent variable. The industrialized plants show no such relationship.

However, as with *H4*, despite being an emerging economy the Chinese plants do not appear to be experiencing any measurable outcomes (in terms of reject rate variance) from this investment. At the same time, mirroring the results for *H4*, there is evidence that Plant Size is again a more important determinant of capability in this area for these plants. As stated above, in the context of the evidence for high levels of investment in quality management in the Chinese plants (at least the equal of those in the other emerging economies), this is not a trivial observation and the possible reasons are canvassed in the discussion of the findings. There was no effect recorded in any group for foreign ownership. As with *H4*, the results provide only partial support for *H5* in that

Table VI.
Regression models – quality competence effect on performance

	Chinese plants		Emerging economy plants		Industrialized economy plants	
	Adj. R^2	R^2 change	Adj. R^2	R^2 change	Adj. R^2	R^2 change
Quality competence: dependent variable – percent of rejects – incoming material						
Plant size	0.214	*0.241***	0.002	0.016	−0.006	0.000
Foreign ownership	0.269	0.079	−0.007	0.006	−0.011	0.001
Investment: quality management	0.243	0.002	0.135	*0.150***	−0.014	0.003
Quality competence: dependent variable – percent of rejects – work in process						
Plant size	0.103	*0.135**	−0.005	0.010	0.026	*0.032**
Foreign ownership	0.099	0.028	0.007	0.026	0.024	0.003
Investment: quality management	0.110	0.042	−0.008	0.000	0.022	0.003
Quality competence: dependent variable – percent of rejects – final inspection						
Plant size	−0.019	0.015	−0.007	0.007	−0.005	0.001
Foreign ownership	−0.051	0.004	0.005	0.026	−0.011	0.000
Investment: quality management	−0.089	0.001	0.081	*0.087**	−0.009	0.008
Quality competence: dependent variable – percent of rejects – customer returns						
Plant size	−0.033	0.001	0.001	0.015	−0.004	0.002
Foreign ownership	−0.066	0.002	0.015	0.028	−0.009	0.001
Investment: quality management	−0.076	0.026	0.088	*0.084**	−0.002	0.012

Notes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

the hypothesis is valid for the emerging economy plants (noting that the recorded effect is weak) but not for those in China. The results are presented in Table VII.

Discussion

Four of the hypotheses are supported in terms of the proposed relationships between the emerging and industrialized economy plants. The emerging economy plants record investing significantly more resources in quality management programs than the plants in the industrialized economies. This is consistent with the predicted outcome using the theory of performance frontiers (Vastag, 2000; Schmenner and Swink, 1998). The evidence suggests that investment in quality improvement is constrained in the industrialized economy plants by the technological limits of assets (Rosenzweig and Roth, 2004), and it is a plausible scenario that this is due to the maturity of quality systems. There is also evidence to indicate that the industrialized plants have a higher degree of competence in quality. Consistent with the establishment of a link having been established between competence and performance in operations (Schmenner and Vastag, 2006), these plants can therefore be expected, on average, to be more consistent and reliable in this area. The two groups do, however, converge in capability for quality improvement over time, a result not as hypothesized. This is perhaps consistent with the constraints on improvement inherent in a learning environment (emerging economy group) (Wright, 1936) outweighing the relative levels of maturity of systems and the natural limits of performance frontiers hypothesized for the industrialized group (Vastag, 2000).

The evidence also shows that the emerging economy group are able to leverage investment in quality management programs to both promote greater competence in quality management, and to build capability for further improvement over time. This opportunity does not appear to be as readily available to the plants in the industrialized economies, at least as measured by reject rates. This result is also consistent with the hypothesized nature and relative positions of performance frontiers in both groups, and of (in the case of the industrialized plants) the relevance of the concept of an "innovation cycle" (Rosenzweig and Roth, 2004) for promoting competitive advantage in operations.

The results for the Chinese plants, apart from those for *H1*, are not entirely consistent with those for other emerging economy plants, and to a degree perplexing as a result. The evidence that investment in quality management programs in China is on a par with that in the other emerging economy plants is strong. In fact, in the area of TQM extent of investment was found to be significantly greater. Competence levels, however, in the Chinese plants (particularly where measured by reject rates within the plant) are significantly lower than in the industrialized plants, and there is also evidence that they are lower than in the plants in emerging economies. It may be that these results are related to those for *H1* in that the investment in quality management is being driven by a need to correct this. It may also be that recording higher reject rates is a symptom of increased inspection-related activity within the plant.

There is some indication in the results that reject rates from customers are lower and that this may also be attributable to the activity being expended in this regard. This scenario is further supported by the finding for *H3* that the Chinese plants recorded rising reject rates (comparison of two points in time over a two-year period) for work in process and at final inspection when both the emerging and industrialized economy plants were recording an average improvement over the same time period at all points in the value chain. Rising reject rates indicate lower levels of capability and

Table VII. Regression models – quality capability effect on performance

	Chinese plants		Emerging economy plants		Industrialized economy plants	
	Adj. R^2	R^2 change	Adj. R^2	R^2 change	Adj. R^2	R^2 change
Quality capability: dependent variable – change in percent of rejects (two years) – incoming material						
Plant size	0.356	*0.381***	–0.011	0.004	–0.005	0.001
Foreign ownership	0.329	0.000	–0.023	0.003	0.001	0.012
Investment: quality management	0.350	0.044	0.034	*0.069**	0.013	0.018
Quality capability: dependent variable – change in percent of rejects (two years) – work in process						
Plant size	–0.027	0.011	–0.015	0.000	0.025	*0.031**
Foreign ownership	–0.066	0.002	–0.029	0.001	0.031	0.012
Investment: quality management	–0.111	0.000	–0.015	0.028	0.028	0.002
Quality capability: dependent variable – change in percent of rejects (two years) – final inspection						
Plant size	–0.024	0.010	–0.013	0.002	–0.006	0.000
Foreign ownership	–0.053	0.007	–0.024	0.004	–0.012	0.000
Investment: quality management	–0.090	0.002	0.056	*0.091**	–0.018	0.000
Quality capability: dependent variable – change in percent of rejects (two years) – customer returns						
Plant size	–0.016	0.016	–0.009	0.005	–0.006	0.000
Foreign ownership	–0.036	0.014	–0.016	0.008	–0.012	0.000
Investment: quality management	0.001	0.066	–0.014	0.016	–0.015	0.003

Notes: *$p<0.05$; **$p<0.01$; ***$p<0.001$

are also consistent with increased levels of inspection and surveillance within the plant. That competence and capability in quality management is apparently lower in the Chinese plants despite similar investment levels is not inconsistent with findings from other studies where moderating factors noted have included: the critical role played by "[…] cultural dynamics and organizational complexities in Chinese enterprises" (Pun, 2001); while the principles and strategic foci of TQM are understood and acknowledged, in practice many Chinese enterprises still focus on inspection while claiming to be TQM plants (Lau *et al.*, 2004); the importance of environmental uncertainty in determining the attitude to quality (particularly relevant in a dynamic sector such as computing and electronics) (Zhao *et al.*, 2004); and the reluctance to take an holistic view of quality as evidenced by the slow take up of accounting methods assessing cost of quality factors (Lin and Johnson, 2004). Another factor that cannot be ignored here is the dramatic rate of growth in China over the past ten years (annualized gross output growth rate of 25-30 percent in this sector between 1997 and 2007 (Zhang and Zhang, 2009), and the stress this surely places on manufacturing systems and processes.

The findings for *H4* and *H5* also indicate that the plants in China are not experiencing the same results as other emerging economy plants as a result of investing in quality management programs. Being an emerging economy, plants in China should be able to leverage investment in quality as predicted by the theory of performance frontiers. The evidence suggests, however, that this is not the case, and in this context it is also worth noting that a substantial plant size effect was recorded in the Chinese plants, while there was no effect recorded for foreign ownership. The finding regarding foreign ownership contrasts with that of an earlier study wherein this factor was found to be of critical importance, at least in the SME sector (Lee, 2004). The proportion of variance explained in both competence (21 percent) and capability (35 percent) by plant size was recorded in both cases at the incoming material point in the value chain. In essence this suggests that larger plants are using their scale to influence the competence and capability of trading partners (suppliers). At the same time, the application of resources within the plant is having no discernible effect on internal competence and capability (as measured by internal reject rates). The full explanation of this phenomenon is not able to be articulated in this study, but it provides some further evidence of a quality culture in these plants consistent with valuing inspection more so than continuous improvement.

The net result is that the relationships hypothesized and predicted for competence and capability levels, extent of investment in quality management methods, and the ability to leverage those investments, appear to hold more for the emerging economy plants than for the plants in China. The consistency of the results for the emerging and industrialized economy plants, and the recognition that China is still an emerging economy, would indicate that the difference is more likely due to a local contingency (or combination of contingencies) specific to those plants in that country. The theory of performance frontiers appears to be able to explain the relationships recorded for emerging and industrialized groups in general, but not for plants in China in this industry specifically. The conclusion that can be drawn (and opportunity for future research implied) is that implementing quality management practices in China in this industry is perhaps more problematic due to local contingencies than in other parts of the world. There are also implications for the generalization of theory as a result, and for the practical application of quality management methods in this region.

Implications for theory

There are a number of implications for theory resulting from this study. First, the differentiation between and measuring manufacturing competence based on current performance (in this study reject rates at four different points in the value chain), and capability based on improvement in performance outcomes over time (in this study changes in reject rates over a two year period at four different points in the value chain) has been proposed and tested. The debate in the operations management literature over the past 20 years around what constitutes competence, capability and related concepts such as competitive priorities has been considerable (Safizadeh *et al.*, 2000; Swink and Hegarty, 1998; Vickery *et al.*, 1993, 1994; Schmenner and Vastag, 2006; Cleveland *et al.*, 1989). In this study definitions of competence and capability from other management disciplines have been used to clarify and simplify these concepts. Competence has been distilled into "what we can do now," and capability into "performance improvement over time." The testing of the hypotheses using these two measures provides evidence supporting the conceptual and predictive validity of this method. As such, this study contributes to the debate clarifying the difference between competence and capability, and importantly establishes why this difference is an important point of definition in operations. The relevance and practicality of using theory developed and tested in other management and cognate disciplines is also highlighted.

Second, the study increases our understanding of the workings of the theory of performance frontiers by explaining different levels of competence and capability in manufacturing plants based on the extent of economic development of the country in which they are located. Importantly, using this theory to predict relative levels of competence and capability has not been tested empirically in the operations management literature previously. The finding that plants in industrialized economies can be expected (on average) to be more competent (better in terms of "what we can do now") in the management of quality than those in emerging economies is not entirely unexpected. However, that capability (or performance improvement over time) in quality management in the emerging economy plants (excluding those in China) is shown to be on a par with those in the developed economies – at least in terms of management of quality within the plant – is perhaps attributable to learning effects acting as a constraint on progress over time rather than an enabler. It could be argued that this is particularly so in the domain of quality management where while investment is mature in the industrialized economies, the temporal and learning issues associated with developing a culture of quality could slow down capability development in emerging economy plants.

However, the supporting proposition that there would be a greater opportunity for plant managers in emerging economy plants to leverage investment due to the relative positions of operating and asset frontiers (Vastag, 2000; Schmenner and Swink, 1998) has been empirically verified (Rosenzweig and Roth, 2004; Power *et al.*, 2010; Schoenerr *et al.*, 2009; Zhang and Zhang, 2009). It could be inferred from these results that plants in emerging economies have greater potential for building capability (ability to change outcomes over time).

Third, the plants in this study from China, despite being from an emerging economy, exhibit characteristics inconsistent with both the other emerging economy plants, and in many cases with those predicted for them by the theory of performance frontiers. The fact that they report substantial investment in quality management methods, and still exhibit lower levels of both competence and capability than other

emerging economy plants is significant. At the same time there is evidence that, unlike their counterparts, they are also slower to develop competence and build capability in quality management as a result of this investment. As such the Chinese plants are apparently subject to particular characteristics or combinations of contingencies such that the predictions of the theory of performance frontiers that hold for other plants in emerging economies, do not necessarily appear to hold for them. The importance of understanding the local context when testing theory in operations management is therefore further highlighted.

Implications for practice

Investment in quality management methods may not always result in discernible variance in quality indicators. In this study this has been shown to be the case in plants in the industrialized world, highlighting the importance of developing a requisite proficiency in innovation. For the plants in an emerging economy significant changes in performance can be realized, but should not be expected. In fact the evidence suggests that factors such as the apparent gap between an operations and asset frontier may at the same time offer opportunity and some risk. If the gap is to be bridged, investment in quality management must lead to changes in both culture and practice, neither of which have been shown to be easily achieved. For the plants in China the lack of positive variance in either competence or capability attributable to investment in quality management programs presents a dilemma. On the one hand, if quality competence is low it would not be recommended to abandon such programs. On the other, continued investment in programs not yielding discernible outcomes becomes more difficult to justify over time. The solution may lie in focussing on how and where these resources are being invested, and how quality management is actually valued within a firm and/or plant. Much of the research in this area highlights the importance of "commitment" in changing the quality culture of an organization. Perhaps these results further serve to highlight the salience of this concept in this context.

Limitations and opportunities for further research

Although this study draws on a reasonably large data set (343 plants from 17 countries) it is recognized that access to further longitudinal data would be of particular value. It is also noted that in segmenting the data into three groups based on the extent of economic development the statistical power of the regression models within each group has been reduced. As such some of the findings may be subject to Type 11 error. Further studies in this area are encouraged based on larger (and preferably longitudinal) data sets within each of the countries of interest. We also recognize that the sample from China is drawn from a single city (Shanghai) and therefore further studies may be needed drawing responses from a wider range of economic zones within this country.

A number of opportunities for further research are evident from this research. The evidence supporting the conceptual validity of the theory of performance frontiers is further extended in this study. At the same time, however, the role of contingencies in making such a theory contextually relevant has also been highlighted. Further research along these lines could assess the moderating role of factors such as industry sector, capital intensity, product and or service characteristics, and national cultural characteristics. Further, a particularly useful contribution would be to design a study such that these conceptual frontiers could be empirically observed and measured.

The concepts of competence, capability and competitive priorities also need to be further examined and tested. In particular, some work has already been done specifically identifying types of capabilities (see Swink and Hegarty, 1998 for a good example) – but there has been little empirical testing of these. Validating sets of capabilities in a global survey of manufacturing firms would be a particularly valuable line of future enquiry.

Further study of the particular characteristics relevant to manufacturing in China is also required. Given the rate at which China is assuming the role of being the "factory of the world," understanding the complexities of an emerging giant with a semi-planned economy is critical to understanding the nature of operations management in such a context moving forward. Of particular interest would be examining the role of joint ventures and other collaborative governance mechanisms, national cultural norms and their influence on operations, and the rate of growth and access to resources. In Japan, for example, resources were always in shortage creating the need to be innovative in the development of manufacturing systems and processes capable of reducing waste and maximizing quality. Given this is not the case in China it is uncertain that there will there be the same imperative.

Conclusion

This study has developed a method for differentiating and empirically measuring quality competence and capability using data from a global manufacturing plant level study. It has been shown that the theory of performance frontiers can be used to explain differences in levels of investment in quality management, as well as competence and capability, in plants across regions with varying levels of economic development. In doing so, it has been shown that this theory is a useful predictor of competence and capability in this context. Further, it is shown that China provides an example of a special case in that it does not display the same characteristics as other emerging economy plants. In particular, the evidence that the plants in China in this study do not possess similar levels of quality competence and capability, and struggle to make investment in quality management alter outcomes, is of importance. As China takes over more global manufacturing, the ability to develop systems and processes able to deliver reliable and high-quality products will become a competitive imperative of great interest to all stakeholders.

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