Lean versus agile production

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Lean versus Agile Production: Flexibility Trade-offs within the Automotive Supply Chain

Abstract

Given the recent dynamics of the automotive industry in the UK, the ability for a firm to be flexible has often taken priority over other performance indicators. Using the notion of distinct business models and trade-offs as our theoretical lens, the purpose of this study was to: (1) Distinguish lean and agile firms based upon production methods; and (2) Compare lean and agile levels of external flexibility (EF) and supply chain flexibility (SCF). Data was obtained from 140 automotive firms in the Midlands (UK) via a survey which was sent by emails. Findings supported the theoretical notion of trade-offs, as firms implementing agile production methods were found to be more flexible in comparison with firms implementing lean production methods. More importantly, the agile firms that possessed high EF levels and SCF levels were predominantly positioned at the lower end of the automotive supply chain, whereas the lean firms were largely found to be operating at the top of the supply chain. First, we provide an innovative way in which lean and agile firms can be conceptualised. Second, as flexibility levels were assessed on actual numerical values, as opposed to using opinion based Likert Scale questions, a methodological contribution is made. Third, as flexibility is in its infancy stage of theoretical development we make an empirical contribution by developing a taxonomy that distinguishes each production concept. Finally, given the supply chain position to where lean and agile firms were found, we invoked a power perspective better understand this phenomenon.

***Key Words*:** Flexibility; Lean; Agile; Automotive; Trade-offs; Business Models; Power.

1.0 Introduction

The majority of studies which have investigated lean and agile production have explored each of these production concepts in silos, which is a growing trend in the recent literature (Johansson & Osterman, 2017; Pinho & Mendes, 2017; Tarafdar & Qrunfleh, 2017; Tortorella & Fettermann, 2017; Knol *et al*., 2018). Given that a number of studies assert that flexibility is an essential factor for differentiating lean and agile production (Naylor *et al*., 1999; Narasimhan *et al*., 2006; Gunasekaran *et al*., 2008), there is an important need to explore both of these production concepts simultaneously, as opposed to in silos. Furthermore, there is limited research on flexibility, especially Supply Chain Flexibility (SCF), which is as a gap identified in the literature (Pujawan, 2004; Sanchez & Perez, 2005; Purvis *et al*., 2014). Few studies have addressed the trade-offs in flexibility between lean and agile production simultaneously and the studies which have looked into this further (Naylor *et al.*, 1999; Narasimhan *et al.*, 2006; Hallgren & Olhager, 2009; Purvis *et al*., 2014) have: (1) only explored limited dimensions of flexibility; and (2) assessed flexibility through the use of case studies or opinion-based, Likert Scale-type questions. The reliability and validity of using the latter is a widespread concern within the field of performance and Operations Management (OM) (Vachon & Klassen, 2008), highlighting the need for future studies, as well as this investigation, to include more objective performance data.

This paper examines the automotive manufacturing industry within the Midlands of the UK. Although lean originated from the automotive industry, Doran (2004) and Boonsthonsatit & Jungthawan (2015) have previously asserted that the Automotive Supply Chain (ASC) also requires high levels of flexibility, thus, broadening our attention to agile production. Costs are not as important as they were in the past as one in six firms decided to bring manufacturing back to the UK between 2011 and 2014 (Tovey, 2014), with flexibility being a key driving force (Qamar, 2016). More generally, the global automotive industry has been facing six challenges: (1) A general shortage of qualified engineers/operators; (2) Extreme fluctuations in terms of product mix and production volume etc.; (3) Safety precautions; (4) Energy efficient production techniques; (5) Reduction of production costs; and (6) The availability of products in time (Elmoselhy, 2013). This study is partly motivated by a need to better-understand how firms and supply networks cope with issues (2) and (6). There is also a deficiency in studies that seek to determine where flexibility levels are positioned within the Automotive Supply Chain (ASC), highlighting the need for greater development. Therefore, the propositions for this paper were to: (1) explore the critical differences between levels of flexibility which are derived from lean and agile production methods; and (2) investigate where lean, agile and high levels of flexibility are located within the ASC.

Several contributions are made. First, an innovative contribution is made as we conceptualise and highlight how lean and agile firms can be distinguished based upon a set of production methods. Second, we make an original methodological contribution to the field by empirically operationalising flexibility in terms of range and mobility, followed by evaluating the trade-offs between, and within, EF and SCF with regards to lean and agile systems. We do so without using Likert Scale-type questions, minimising validity and reliability concerns (Vachon & Klassen, 2008). Third, our findings theoretically support the notion of trade-offs and Skinner's (1969) assertion that manufacturing strategies compete on different performance objectives. This is framed by an approach taken from the strategy literature on business models and dynamic capabilities, which links the positioning of supply firms within the ASC to specific tools, practices, routines and concepts they have evolved to underpin different kinds of competitive advantage. Fourth, we identify the flexibility variables which demonstrated the largest differences between each of the production concepts in order to develop a lean, agile and flexibility taxonomy. Finally, and perhaps most importantly, we build on Qamar & Hall's (2018) Lean Agile Automotive Supply Chain (LAASC) Model, by illustrating where flexibility levels are located within ASCs. Flexibility findings in conjunction with the LAASC model refutes extant SC literature as ASCs were not identified as solely being lean, as both lean and agile firms were found to be operating in the ASC. More specifically, high levels of flexibility (agile) and low levels of flexibility (lean) were found upstream and downstream of the ASC respectively. As this finding directly contests Mason-Jones *et al*.'s (2000) '*received wisdom'* regarding where lean and organisations are located within a 'leagile' supply chain (SC), we provide insights from the business models, dynamic capabilities and power literatures to explain our findings.

2.0 Theoretical Foundation

Addressing the theoretical framing on which an empirical investigation is grounded is important, especially considering Chicksand *et al*. (2012) and Walker *et al*. (2015) found that only one third of studies within the realms of Supply Chain Management (SCM) and OM have applied theoretical traditions to ground their research. We conceptualize lean and agile as types of firms with distinctive business models (BM), each identifiable by a particular shared set of characteristics. These characteristics underpin both their differentiation relative to other firms and their value proposition in the market. According to Foss & Saebi (2017), the growing literature on BM and business model innovation (BMI) has reached a consensus around the accepted definition of a BM as the "design or architecture of the value creation, delivery, and capture mechanisms" of a firm (Teece, 2010: 172). This has been extended to include "the firm's value proposition and market segments, the structure of the value chain required for realizing the value proposition, the mechanisms of value capture that the firm deploys, and how these elements are linked together in an architecture" (Saebi *et al*., 2016).

The literature on BM and BMI has evolved alongside the complementary concept of dynamic capabilities. This widespread approach focuses attention on the internal practices, mechanisms, capabilities and behaviours that enable firms to "(1) to sense and shape opportunities and threats, (2) to seize opportunities, and (3) to maintain competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the business enterprise's intangible and tangible assets" (Teece, 2007: 1348).

Studies that combine these conceptual frameworks argue that different kinds of dynamic capability are necessary for firms to maintain different BMs. Moreover, a common differentiation is between the kinds of dynamic capabilities which give rise to strengths in exploration (R&D, creativity, radical innovation), in contrast to those which underpin BMs that focus on exploitation (incremental innovation, efficiency in leveraging existing assets and capabilities). This distinction follows the landmark studies of James March (March, 1991). Zott & Amit (2007) for example examined novelty- and efficiency-centred BM designs and found a positive relationship between novelty-centred BMs and firm performance in entrepreneurial firms. After adopting the same differentiation of novelty- and efficiency-centred BM designs, Wei *et al*. (2014) adopted the same approach to examine how exploitative and exploratory innovation fit with different BM designs to promote growth in Chinese firms.

These theoretical approaches have been used to better-understand firms' positioning in supply chains, but not extensively. Closer to our study, Blome *et al*. (2013), for example used a dynamic capabilities approach to understand both the antecedents and the performance effects of agility. Their central question was the degree to which dynamic capability positively influenced the operational performance of the firm, defined as a firm's 'competitive position in terms of supply chain cost, customer service, service level performance and supply chain flexibility.' We build on Blome *et al*. (2013) and suggest that both lean and agile supply firm types can evolve different and distinctive competitive advantages, allowing them to occupy different and distinctive niche positions in the same supply chain.

Finally, the process by which firms evolve a specific set of distinctive dynamic capabilities and a specific BM involves 'trade-offs' made by decision-makers at all levels. Also referred to as the law of 'trade-offs' (Schmenner & Swink, 1998) the notion of trade-offs can be traced back to Skinner's (1969) assertion that firms compete on varying performance aspects other than just costs. As firms cannot compete on all levels of performance there are strategic choices which lead to different forms of specialisation (structural, assets, knowledge, capabilities etc.). Consequently, lean and agile production were conceptualised with the assumption that each strategy would inevitably lead to different performance strengths and that trade-offs will be present (Da Silveira & Slack, 2001). The resource-based view (RBV) proposes that if a firm is to reach a position of sustainable competitive advantage it must acquire and control valuable, rare, inimitable, and non-substitutable (VRIN) resources and capabilities (Barney, 2002). Our approach is to examine lean and agile firms as having evolved business models and dynamic capabilities that conform to the VRIN archetype as they underpin sustained competitive advantage (otherwise such firms would not survive and co-exist in the same ASC markets).

3.0 Literature Review

3.1 Lean and Agile Production Methods

Since the birth of agile production (Institute, 1991) there has been an intense academic debate surrounding the definition of this concept (Gunasekaran, 1999) and ways in which we can distinguish it from lean production (Shah & Ward, 2003). Lean definitions (Shah & Ward, 2003; Hopp & Spearman, 2004; Narasimhan *et al*., 2006; Hallgren & Olhager, 2009; Taj & Morosan, 2011; Alves *et al*., 2012; Pakdil & Leonard, 2014; Godino Filo *et al*., 2016) and agile definitions (Christopher, 2000; Calvo *et al*., 2008; Gunasekaran *et al*., 2008; Jain *et al*., 2008) each emphasise a different set of performance priorities and related processes and capabilities which characterise them as different business models. Porter (1996) suggested that strategy is executed via a unique set of processes or activities. With this in mind, we suggest that lean and agile strategies can be identified and therefore distinguished via a particular set of practices. More recently, this approach of distinguishing strategies based upon a set of practices was also used by Tarafdar & Qrunfleh (2017), who investigated practices associated with agile supply chain strategies. Table 1 highlights a range of production methods and practices ascribed with lean, agile and 'hybrid' production methods within the literature. Importantly, Table 1 does not to list all production methods associated with each production strategy, but focusses on identifying production methods that have repeatedly been associated with lean and agile production in prior research. In total, we found twenty-two items related to lean, agile and hybrid production methods (see Table 1). We define these as the tools, practices, routines and concepts (TPRCs), which are the identifiable components of dynamic capabilities in the firm. Table 1 signifies that lean production places a large emphasis on resources that eliminate waste and capabilities affiliated with high levels of efficiency (Shah & Ward, 2003; Vinodh & Joy, 2011; Pakdil & Leonard, 2014). Whereas agile production focuses on adaptability, where as much waste possible is eliminated, but ultimately geared towards high flexibility capabilities (Naylor *et al*., 1999; Rao, 2006). The hybrid strategy encompasses elements from both lean and agile production methods, which may explain why there has been confusion between lean and agile production methods (Narasimhan *et al*., 2006).

Table 1: Distinguishing Lean and Agile TPRCs

Concept	TPRCs	Source
Lean	• Elimination of waste • Continuous improvements • Zero defects • Production smoothing • Line balancing • Value Stream mapping • Total productive maintenance • 5s	White et al. (1999); Sanchez & Perez (2001); Soriano-Meier & Forrester (2002); Hopp & Spearman (2004); Abdulmalek & Rajgopal (2007); Shah & Ward (2007); Sezen et al. (2012); Amin & Karim (2013); Belekoukias et al. (2014); Sundar et al. (2014); Godino Filo et al. (2016)
Hybrid	• Just-in-time • Kanban • Multi-functional machines • Multi-functional teams • Total quality management • Employee empowerment • Single minute exchange dies	Gunasekaran (1999); Sanchez & Perez (2001); Sharifi & Zhang (2001); Soriano-Meier & Forrester (2002); Vazquez-Bustelo & Avella (2006); Abdulmalek & Rajgopal (2007); Shah & Ward (2007); Erande & Verma (2008); Inman *et al.* (2011); Taj & Morosan (2011); Abraham *et al*. (2012); Bhasin (2012); Belekoukias et al. (2014); Sundar *et al*. (2014); Godino Filo et al., (2016); Yin et al. (2017)
Agile	• Virtual enterprise • Concurrent engineering • IT driven enterprise • Rapid prototyping • Reconfiguration • Core competence management • Knowledge driven enterprise	Gunasekaran (1999); Sharp et al. (1999); Yusuf et al. (1999); Dowlatshahi & Cao (2006); Vazquez-Bustelo & Avella (2006); Erande & Verma (2008); Tseng & Lin (2011); Vinodh & Kuttalingam (2011); Kang et al. (2014); Yin et al. (2017)

3.2 Lean and Agile Flexibility Levels

Within the lean and agile debate, flexibility has consistently been identified as the most significant performance measure that could be used to distinguish each of the BMs (Narasimhan *et al*., 2006; Gunasekaran *et al.*, 2008), where speed and responsiveness are fundamental (Reichhart & Holweg, 2007). Lean production is a process which removes all non-value adding activities, which in turn produces an efficient operation that is as flexible as required. Flexibility is not a prerequisite in order to become lean, although the elimination of waste is a prerequisite when becoming agile (Naylor *et al.*, 1999). High flexibility creates large internal and external variances in terms of volume, variety, delivery and supplier capabilities. Agile production systems can manage such variances and derive advantages from their flexibility, whereas lean archetypes gain competitive advantage via efficiency, which in turn, reduces the internal and external variances of the same factors (Hofer *et al*., 2012). However, Naylor *et al.* (1999) suggested that lean production can also result in high levels of mix flexibility, hence capability to produce a large range of products, but cannot cope with large volume fluctuations. Agile systems can cope with both high levels of mix flexibility and high levels of volume flexibility.

Recent discussion surrounding flexibility and lean and agile production has been more focussed on suppliers and the supply chain context, beyond the characteristics of the individual firm (Pujawan, 2004; Sanchez & Perez; 2005; Stevenson & Spring, 2007) and further research is called for in this area (Bernardes & Hanna, 2009; Malhotra & Mackelprang, 2012). Most studies associate lean production with close long-term relationships between buyers and suppliers (Lamming, 1993; Handfield & Bechtel, 2002; Abdollahi *et al.*, 2015), therefore, it would be expected that there are low levels of supply chain flexibility. By contrast, agile firms form a temporary network of suppliers which are needed when producing goods of short life-cycles (Narasimhan, 2006), which would lead one to believe these firms possess high levels of supply chain flexibility. Taking this into account the following hypothesis was conceptualised:

***H_a*: Firms implementing agile production methods acquire higher levels of flexibility when compared with firms implementing lean production methods.**

3.3 Supply Chain Positional Tier

'leagile' SCs are a combination of both lean and agile concepts encompassing a total SC strategy that involves a decoupling point (Mason-Jones *et al*., 2000). The decoupling point is a point in a SC where order-driven and forecast-driven orders meet (Hoekstra & Romme, 1992; Vinodh & Aravindraj, 2013). The 'leagile' approach is often necessary, as there are decoupling points within particular SCs that require a lean approach at one point and an agile approach at another. Amongst 'leagile' SCs, lean firms operate upstream the SC, enabling a level schedule in output (Naylor *et al*., 1999; Mason-Jones *et al*., 2000). Whereas agile firms operate downstream from the decoupling point, ensuring there is an agile response capable of delivering to unpredictable market demand. With regards to the automotive industry, firms that operate downstream the ASC generally produce more added-value products and tend to be more specialised, in comparison to firms operating upstream the ASC. The latter have to devise a manufacturing strategy that emphasises speed, flexibility and a broader range of products (Doran, 2004; Boonsthonsatit & Jungthawan, 2015). Given this we conceptualise that firms implementing agile practices are more likely to be found upstream the ASC and firms implementing lean practices are more likely to be found downstream the ASC. Importantly, this contends the existing 'leagile' literature. Agile production relative to SC positional tier has not been fully researched and the findings from studies of the SC positioning of lean production are mixed (Sezen *et al*., 2012; Reves *et al*., 2015; Marodin *et al*., 2016), signalling the need for clarification in this area. With this in mind, we hypothesise as follows:

H_b: Firms implementing lean production methods are more likely to be found downstream the automotive supply chain when compared with firms implementing agile production methods.

In summary, our approach uses the notion of trade-offs within a theoretical framework that focuses our attention on dynamic capabilities associated with distinctive BMs within ASCs. This leads us to expect lean and agile firms to acquire or develop dynamic capabilities which allow for high levels of efficiency and adaptability respectively (Calvo *et al*., 2008; Pakdil & Leonard, 2014). We anticipate that firms implementing agile production methods will have greater flexibility compared to firms implementing lean production. The motivation for this study was not only to examine if this observation is supported by more rigorous empirical data than we find in previous studies, but also to assess how much more flexible agile firms are in comparison with lean firms.

4.0 Methodology

In total, 1710 manufacturing firms were identified as the population who were operating within the UK Midlands ASC. We randomly contacted approximately a quarter (450 Managing Directors) of the original population as the sample population via the use of emails and LinkedIn, asking for their participation in completing a survey questionnaire for this study. A total of 140 surveys were completed, revealing a response rate of 31%.

4.1 Distinguishing Lean & Agile Firms

In order to distinguish lean, agile and 'hybrid' firms, through the use of the constructed survey we asked participants to state which production concept (lean, agile, hybrid) was being implemented within their organisation. Initially, 77, 63 and 0 firms asserted that they were implementing a lean, agile and hybrid production strategy respectively. However, to refine the rigour when distinguishing between each of the production concepts, a scorecard was developed where respondents were then asked to state the extent to which each of the twenty-two TPRCs in Table 1 were being implemented on a Likert-Scale ranging from 1 (no levels) to 5 (high levels). The mean values were calculated between each of these three bundled groups (lean, agile, hybrid) and depending on which group scored the highest, firms were distinguished as being lean, agile and 'hybrid'. The rationale for this is simple, firms that more strongly implement lean or agile set of bundled TPRCs (resources) will exhibit capability strengths associated with that production strategy respectively. In total, 74 and 66 firms were identified as pursuing lean and agile production respectively, which was 97% consistent with the original responses. Importantly, no firm scored the highest within the 'hybrid' group.

Cronbach’s alpha was used when testing the internal consistency and reliability amongst the bundled TPRCs. Generally, values above 0.70 have been acknowledged to suggest that the sub-items are measuring the same construct (Vogt, 1999). Results are presented in Table 2. Lean and agile bundled TPRCs acquired a Cronbach's alpha score of 0.72 and 0.70 respectively. Excluding the TPRCs affiliated with both i.e the leagile ones the Cronbach's alpha for lean and agile production increased to 0.82 and 0.92 respectively. Although the Cronbach's alpha score for the hybrid strategy was also above the threshold criteria, as no firms were implementing hybrid strategy, this was disregarded. In summary, as both lean and agile production TPRCs were above the 0.70 thresholds, both were deemed as being internally consistent and reliable.

Table 2: Reliability of TPRCs Associated with Lean and Agile production

Manufacturing Strategy	Number of Items	Cronbach’s Alpha
Lean	15	0.72
Lean excluding hybrid TPRCs	8	0.82
Hybrid	7	0.73
Agile	13	0.70
Agile excluding hybrid TPRCs	7	0.92

When testing the validity of using two factors (lean and agile), as opposed to three factors (lean, agile, leagile), we conducted a confirmatory factor analysis (CFA). Kaiser (1960) asserted that the number of factors should rely on the number of factors which have eigenvalues greater than the value of 1. Although, results from the CFA did reveal three factors (lean, agile and hybrid) as the third factor’s (hybrid) eigenvalue was only marginally over the value of 1, and considering that the two-factor solution accounted for 69% of the variance, as opposed to 75% with the three factor solution, we excluded the examination of a third factor.

4.2 Non-Respondent Bias

Surveys were returned over a six-month period within the 2014 annual year, thus, eliminating any influence of seasonal economic trends. In total 42, 64 and 34 surveys were returned within months 0-2, 2-4 and 4-6 respectively. The latter groups may have been non-respondents if we did not follow-up with reminder emails. Therefore, in order to test for non-respondent bias, using Armstrong & Overton’s (1997) technique, late respondents were considered as a surrogate for non-respondents and the first 30 received surveys were compared relative with the last 30 received surveys. T-tests were conducted using firm size, sales and each of the flexibility measures. As no significant differences were found between both groups, the participating firms were deemed as representative of the Midlands’s automotive industry with no significant non-respondent bias.

4.3 Operationalisation of Flexibility

Oke (2005) suggested that flexibility can be operationalised into two groups: Internal Flexibility (IF); External Flexibility (EF). More recently, the literature (Stevenson & Spring, 2007; Purvis *et al.*, 2014) has also emphasised the importance of a third dimension of flexibility, Supply Chain Flexibility (SCF). IF refers to flexibility that can occur within systems, EF refers to flexibility that can be observed by external customers and SCF refers to the ability to reconfigure the SC. We consider these to be specific types of dynamic capability that underpin particular kinds of competitive advantage. We exclude the examination of IF, as each of the production concepts were distinguished based upon the collection of bundled TPRCs, which in turn can be argued to be a method of evaluating IF. Rather, we were particularly interested in the trade-offs of these bundled set of TPRCs (internal processes) on EF and SCF levels. Importantly, lean and agile literature has rarely operationalised flexibility constructs (Gerwin, 1993), as each dimension of flexibility compromises of range and mobility. With this in mind, our intention was not to present an exhaustive list of flexibility measures, but rather to investigate key flexibility measures which have been repeatedly been ascribed within lean and agile production. Building on Gerwin's (1993) seven dimensions of flexibility, namely; volume flexibility; materials flexibility; mix flexibility; modification flexibility; changeover flexibility; rerouting flexibility; flexibility responsiveness, D'Souza and Williams (2000) narrowed these down into four groups: (1) volume flexibility; (2) variety flexibility; (3) process flexibility; (4) materials handling flexibility, where (1) and (2) belong within EF and (3) and (4) are part of IF. As delivery flexibility can also be used to differentiate lean and agile production (Hallgren & Olhager, 2009), we compiled three groupings (volume, variety, delivery) within EF, where the range and mobility concerning delivery flexibility are captured within SCF and EF respectively. Literature surrounding SCF has been heavily focussed on supplier flexibility (Purvis *et al.,* 2014), with some advocating logistic flexibility, which can be argued as the range in which to measure delivery flexibility. In terms of supplier flexibility, we classified supplier base flexibility as the range for this measure and both sourcing flexibility and supplier offering flexibility as the mobility of supplier flexibility. Table 3 provides a summary concerning the range and mobility regarding each of the four flexibility groupings (volume, variety, delivery, supplier).

Table 3: Range & Mobility of EF & SCF

EF/SCF	Flexibility	Range	Mobility	Description	Source
EF	Volume	F_v	-	Range in volumes in which firm can be profitable.	Sethi and Sethi (1990)
		-	F_{vc}	Cost of doubling the output of the system	Carter (1986)
	Variety	F_m	-	Number of unique products.	Gerwin (1987)
		-	F_n	Time required to introduce new products	Sethi & Sethi (1990)
	Delivery	See F_l	-	-	-
			F_d	Time in which delivery can be reduced.	Gosling *et al.* (2010)
SCF	Supplier	F_{sbf}	-	Number of alternative suppliers that are readily available.	Gosain *et al.* (2004)
		-	F_s	Time required when sourcing alternative suppliers.	Sánchez & Pérez (2005)
		-	F_o	Change in output suppliers are able to accommodate.	Gosain *et al.* (2004); Stevenson & Spring (2007)
	Delivery	F_l		Number of logistic organisations readily available when delivering products.	Gosling *et al.*, 2010
		-	See F_d	-	-

4.4 Flexibility Measurement Instruments

All flexibility levels were captured via the use of the constructed survey.

4.4.1 Volume Flexibility Demand (F_v)

Volume flexibility demand is associated with the range of volumes in which a firm is profitable over a given time period (Sethi & Sethi, 1990). Data were collected which measured the highest (D_{max}) and lowest (D_{min}) volume of goods ordered (demanded) in each respective month over a 12-month period. Next, the total volume of goods produced (D_T) in the 12-month period was subsequently divided by 12, which represents the average volume of goods demanded (D_A) each month (1). The standard deviation was then calculated which illustrated the volatility of orders each month from the mean. However, as standard deviations varied quite sharply between each firm, the coefficient of variance (CV) was used when making comparisons (2).

(1) $D_T / 12 = D_A$

(2) $CV = SD / D_A$

(3) $F_v = CV (t)$

The CV generally ranges from 0 to 1 and measures the uniformity of the data. The greater the uniformity of the data, the closer the CV will be to the value of 0. In contrast, the closer CV is to 1 or greater than 1, the greater the flexibility (dispersion) of demand.

4.4.2 Volume Flexibility Cost (F_{vc})

Carter (1986) suggested that in order to measure the mobility of volume flexibility one must observe the total costs required when doubling the output volume. Therefore, we asked respondents to state the average percentage of total costs saved when doubling the volume of goods produced within the respective year.

(4) $F_{vc} = \Delta\%$ cost savings when doubling volume output.

4.4.3 Product Mix Flexibility (F_m)

The variety flexibility range can be measured by the product mix flexibility, which represents the range of individual product types that can be manufactured over a certain period of time (Slack, 1991).

(5) $F_m = N (t)$

Product mix flexibility was measured as the range of different products produced over a given time period, where N (t) represents the total number of different types of products that can be manufactured within the time period t (12 months). Therefore, mix flexibility represents the total number of different (unique) products produced over 12 months.

4.4.4 New Product Flexibility (F_n)

The mobility of variety flexibility can be measured by new product flexibility, which is defined as the 'ease with which a firm can introduce new products within its organisation' (Beamon, 1999). New product flexibility can either be assessed by the time required to produce a new product or the excess cost required when setting up a new product (Sethi & Sethi, 1990). As speed and responsiveness have repeatedly been identified as key to some forms of differentiation and competitive advantage, speed was used as the unit of measurement. This is shown in equation (6), where F_n (new product flexibility) is simply equal to the time (T_n) required for the development of the new product.

(6) $F_n = T_n$ (t)

As we have observed flexibility over an annual period, organisations were asked the average time spent (days) when introducing new products over a 12-month period.

4.4.5 Delivery Speed Flexibility (F_{ds})

The range in which delivery flexibility was measured was based upon the ability to change delivery dates (Gosling *et al.*, 2010). Delivery plays an important role within a firm's flexibility. For instance, if a customer places an urgent order, regardless of how flexible an individual manufacturing system is, they will judge the performance of the relevant supplier in terms of their ability to respond flexibly and deliver to the new deadline. With this mind, we measured delivery flexibility as the total delivery time that can be reduced when an order is processed as urgent.

(7) $F_d = T_d$ (t)

Therefore, delivery flexibility (F_d) was measured by asking organisations to state the total average delivery time (days) that was reduced when orders were processed as urgent within the respective annual year.

4.4.6 Supplier Base Flexibility (F_{sb})

Arguably flexible sourcing will inevitably result in a firm acquiring a large supply base when re-structuring the SC, therefore, in order to measure the range of supplier flexibility we asked respondents to state the average number of alternative suppliers readily available.

(8) $F_{sb} = N_s$ (t)

In essence, supplier base flexibility can be empirically captured by observing the total number of suppliers that are readily available to the respective firm. Therefore, N_s represents the total average number of different suppliers that were readily available in the SC in the annual time period (t).

4.4.7 Sourcing Flexibility (F_s)

The mobility of supplier flexibility was measured using sourcing flexibility, which refers to the ease with which an organisation may change SC partners when accommodating changes within the business environment (Gosain *et al.,* 2004; Sánchez & Pérez, 2005). The sourcing of suppliers is a dynamic capability giving rise to a particular competitive advantage because it directly affects flexibility and speed (Abdollahi *et al*., 2015). With this in mind, sourcing flexibility can be measured by either recording the costs associated with switching suppliers or the time required when sourcing different suppliers. As time has previously been used as unit of analysis, time was also used when measuring new product flexibility, which is represented in equation (9).

(9) $F_s = T_s\ (t)$

Once again, as this study involved collecting information over an annual period, respondents were asked to state the average time (days) spent when sourcing new suppliers.

4.4.8 Supplier Offering Flexibility (F_o)

In order to measure the mobility of supplier flexibility, we looked to measure the flexibility of the supplier's offer, also known as 'offering flexibility' (Gosain *et al.*, 2004). This represents the capability of an SC linkage to support changes in product in conjunction with current partners. However, as this study seeks to examine the degree to which suppliers can flexibly change their offer to accommodate the firm in question, this study labels this flexibility measure as 'supplier offering flexibility'.

(10) $F_o = \Delta\%\ \text{output}\ (t)$

An organisation's own flexibility may inevitably be restricted based upon its suppliers, therefore, in an attempt to capture supplier offering flexibility, this study asked respondents to state the total average percentage change in output (Δ%) suppliers were able to accommodate within the 2014 annual year (t).

4.4.9 Logistic Flexibility (F_l)

Finally, in order to investigate the range of delivery flexibility, the ability to change delivery dates, this study incorporated the use of measuring logistic flexibility. Logistic flexibility refers to the number of logistic organisations readily available when delivering products.

(11) $F_l = N_l\ (t)$

Logistic flexibility is captured in equation (11), where N_l represented the total average number of different suppliers readily available within the annual time period (t).

5.0 Analysis

Initially, firms were distinguished by size based on the same parameters used within Bhasin's (2012) study (see Table 4). As the Midlands is largely populated by SMEs, it is no surprise that the majority of organisations were SMEs.

Table 4: Distinguishing Lean and Agile Firms by Size

Size		Lean		Agile		Total	
	Number of employees	n	% of firms	n	% of firms	n	% of firms
Small	0-50	27	37%	22	33%	49	35%
Medium	51-250	32	43%	34	52%	66	47%
Large	250+	15	20%	10	15%	25	18%
Total		74	100%	66	100%	140	100%

Next, the dataset was screened to ensure that there were no drastic outliers or errors present and independent T-tests were performed to examine if firm size or firm age were factors impacting flexibility levels. Firms were distinguished as small, medium or large (see Table 4) and three independent T-tests (small and medium, small and large, medium and large) were conducted. Using Shah & Ward's (2003) parameters, firms were also categorised into two groups (old & new), firms which had started operating within the last 20 years were classified as 'new' and firms which had been operating for greater than 20 years were classified as 'old'. All T-tests indicated that firm size and firm age demonstrated no significant difference with regards to flexibility.

Next, T-tests were conducted in order to determine if there was a significant difference between each of the flexibility measures in association with lean and agile production firms. With the exception of logistic flexibility, which had a p value of 0.06, the p value for the remaining independent T-tests were less than 0.05, which supports the assertion (Naylor *et al*., 1999; Narasimhan *et al*., 2006; Gunasekaran *et al*., 2008) that flexibility can distinguish lean and agile production systems. Although the T-test for logistic flexibility had a p value of 0.06, this was only slightly above the significance criteria, therefore a large difference may still be observed.

5.1 Inter-Flexibility Correlations

Next, we conducted a Pearson correlation in SPSS in order to determine if all nine flexibility measures were significantly correlated with one another and the results are reported in Table 5 (please refer to footnote[1]). Logistic flexibility and supplier base flexibility (.117), and supplier offering flexibility and logistic flexibility (.165) did not show to be correlated as they were the only combinations which did not acquire levels of significance. In addition, logistic flexibility illustrated levels of 0.05 significance with volume flexibility demand (.191*), product mix flexibility (.207*) and sourcing flexibility (-.187*). The remaining possible flexibility combinations demonstrated correlations which were of significance at the 0.01 level.

Table 5: Inter-Flexibility Pearson Correlation Coefficients

	F_v	F_{vc}	F_m	F_n	F_d	F_s	F_{sb}	F_l	F_o
F_v	1								
F_{vc}	-.452**	1							
F_m	.697**	-.518**	1						
F_n	-.678**	.525**	-.731**	1					
F_d	.597**	-.382**	.554**	-.666**	1				
F_s	-.668**	583**	-.730**	.831**	-.670**	1			
F_{sb}	.310**	-.282**	.375**	-.375**	.304**	-.341**	1		
F_l	.191*	-.243**	.207*	-.235**	.321**	-.187*	.117	1	
F_o	.396*	-.518**	.511**	-.443**	.359**	-.452**	.286**	.165	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The range and mobility concerning volume, variety, delivery and supplier flexibility are shaded in Table 5. The range and mobility concerning variety flexibility illustrated the highest level of correlation (-.731**) among the four paired combinations. However, the actual strongest correlation (.831**) between any two combinations was between sourcing flexibility and new product flexibility. According to the literature, the ease which an organisation can change SC partners is directly linked with supplier base (Gosain *et al*., 2004; Sánchez & Pérez, 2005), and the ability to change delivery dates is strongly linked with firms involving the use of multiple logistic organisations (Gosling *et al.*, 2010). Although the range and mobility concerning both supplier flexibility combinations (-.341**, -.452**) and delivery flexibility (.321**) portrayed significant levels of correlation, the strength of these two correlations was not as high as expected or other flexibility correlations. Furthermore, the range and mobility concerning volume, delivery and supplier flexibility did not reveal such large correlations as to other paired combinations, therefore,

[1] Please note that new product flexibility and sourcing flexibility were measured with time (days) being the unit of measurement, which do not imply negative association, but connotes a negative association with the unit of measurement in mind. In essence, a negative correlation corresponding to these two flexibility measures refers to a positive correlation with other flexibility levels.

we did not use them further when seeking to distinguish lean and agile firms. Individual flexibility correlations were also conducted within lean and agile systems separately. Due to the limited responses within each paradigm, the majority of flexibility correlations among lean and agile systems alone did not portray the same levels of significance as results in Table 5.

5.2 Ratio Analysis

A ratio analysis was conducted which captured the proportional difference in mean flexibility levels between lean and agile systems. Taking lean manufacturing systems as the base (1), the flexibility ratios are illustrated within Table 6 (please refer to footnote 1). Sourcing flexibility illustrated the greatest difference in flexibility levels between lean and agile firms (1: 0.21), suggesting that the average lean firm may require over four times the duration when sourcing new suppliers. Tachizawa & Thomsen (2007) asserted that, as a mode of measuring SCF, sourcing flexibility can evaluate a firm's ability to redesign its current SC in order to meet the market demand. The remaining SCF measures captured in this study did not illustrate differences between each of the production concepts to the same extent as sourcing flexibility. New product flexibility and product mix flexibility were proportionally calculated as the second (1: 0.29) and a third (1: 2.84) largest difference, as the average agile firm was approximately three times more flexible in comparison with the average lean firm across these two dimensions. Furthermore, the average agile firm was recorded as being just over twice as flexible in terms of volume flexibility (1: 2.22) and just under twice as flexible in terms of delivery flexibility (1: 1.91) and volume cost flexibility (1: 1.76). Additionally, the average agile firm had just under 50% more suppliers' available to choose from. Lean and agile illustrated relatively even levels of logistic flexibility and supplier capacity flexibility.

These results support existing theory as agile firms are shown to have higher flexibility levels (Naylor *et al*., 1999; Narasimhan *et al*., 2006; Gunasekaran *et al.*, 2008; Hallgren & Olhager, 2009; Purvis *et al.,* 2014), especially volume demand flexibility, volume cost flexibility, product mix flexibility, new product flexibility, delivery flexibility and sourcing flexibility. However, the results do not support the argument that lean production can also lead to high levels of product mix flexibility (Naylor *et al.*, 1999). Table 6 not only reports on the mean flexibility levels between lean and agile firms, but also examines flexibility levels at different levels of the SC, which reveals that no matter whether lean or agile, flexibility levels increase lower down the SC. However, this may be explained by an inverse relationship between where lean and agile firms are positioned within the ASC. For instance, lean and agile firms are relatively more likely to be positioned at the top and lower tiers of the ASC respectively. Taking these findings into account it was deemed appropriate to accept $\mathbf{H_a}$ and $\mathbf{H_b}$.

Table 6: Mean Flexibility Levels between Lean and Agile Systems within the ASC

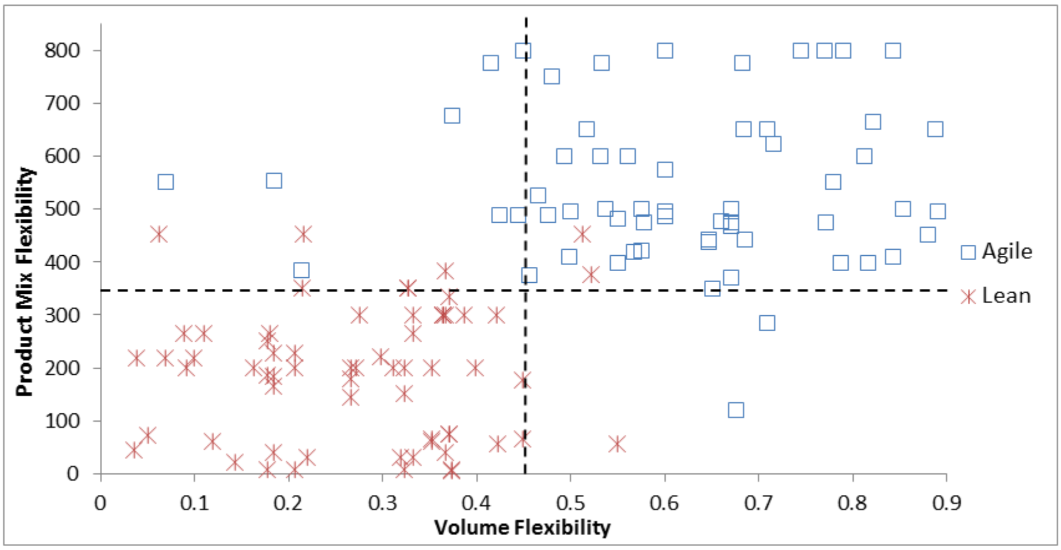
	ASC Position	F_v cv	F_{vc} %	F_m number	F_n days	F_d days	F_s days	F_{sb} number	F_l days	F_o %
Lean										
N = 12	OEM	.223	4.7	69	45	2.5	24.8	19.6	2.6	8.9
N = 26	1^{ST}	.276	5.1	177	50	3.5	24.4	16.6	2.6	14.3
N = 17	2^{ND}	.265	6.1	226	45	3.2	23.2	18.6	2.7	22.6
N = 13	3^{RD}	.286	7.8	226	41	3.6	21.6	23.0	2.9	27.0
N = 6	4^{TH} & 5^{th}	.317	7.2	295	39	4.2	20.0	26.2	3.0	29.8
N = 74	Mean	0.270	6.3	199	44	3.5	23.1	19.0	2.69	23.2
Agile										
N = 4	OEM	.572	7.0	470	15	5.9	5.3	25.5	2.8	11.3
N = 10	1^{st}	.570	10.6	530	15	6.5	5.3	25.2	2.8	22.2
N = 15	2^{nd}	.579	10.8	534	12	6.4	4.6	26.2	3.0	26.7
N = 19	3^{rd}	.617	11.9	540	12	6.8	4.9	28.0	3.4	31.2
N= 18	4^{th} & 5^{th}	.670	12.6	571	10	7.2	3.5	32.1	3.8	34.3
N = 66	Mean	0.612	11.1	537	13	6.72	4.71	27.5	3.3	28.48
Mean Ratio	L: A	1 : 2.22	1 : 1.76	1: 2.84	1 : 0.29	1 : 1.91	1 : 0.21	1 : 1.45	1 : 1.22	1 : 1.22
Total										
N = 16	OEM	.367	6.1	169	37	4.4	19.9	21.2	2.6	9.5
N = 36	1^{st}	.373	7.9	295	33	4.6	17.4	21.6	2.6	16.6
N = 32	2^{nd}	.440	9.0	399	33	4.7	13.4	21.8	2.8	24.5
N = 33	3^{rd}	.438	10.8	403	25	5.7	13.4	24.7	3.2	29.8
N= 23	4^{th} & 5^{th}	.542	11.1	472	18	5.7	9.0	26.2	3.6	33.2
N=140	Mean	.431	9.6	359	29	5.0	14.4	23.0	3.0	23.4

Next, in order to develop a similar taxonomy to the one in which Naylor *et al*. (1999) distinguished lean and agile production, we analyse the four flexibility variables which illustrated both the largest ratio differences between lean and agile production, as well as the strongest correlations amongst each other.

5.3 Volume Flexibility Demand & Product Mix Flexibility

Figure 1 illustrates volume demand flexibility on the y-axis and mix flexibility on the x-axis. Most lean firms acquired a volume flexibility (CV) value less than 0.45 and the mean CV was calculated as 0.270. In contrast, the mean volume flexibility (CV) for agile firms was 0.612. Therefore, over the 12-month time period, the uniformity of demanded orders within agile firms varied to a greater extent in comparison with lean firms. In terms of product mix flexibility, lean organisations generally produced a lower quantity of unique products when compared with agile organisations. A cut-off point, which distinguishes lean and agile production concepts most effectively, suggests that lean firms generally produce no more than 350 unique products, whereas agile firms can produce up to a total of 800 different products. The mean number of different types of products produced was 199 and 539 for lean and agile firms respectively. In conclusion, these results support Naylor *et al.'s* (1999) observation that agile firms have high volume and mix flexibility levels. However, our findings contradict the assumption that lean manufacturing systems can actually attain high levels of mix flexibility.

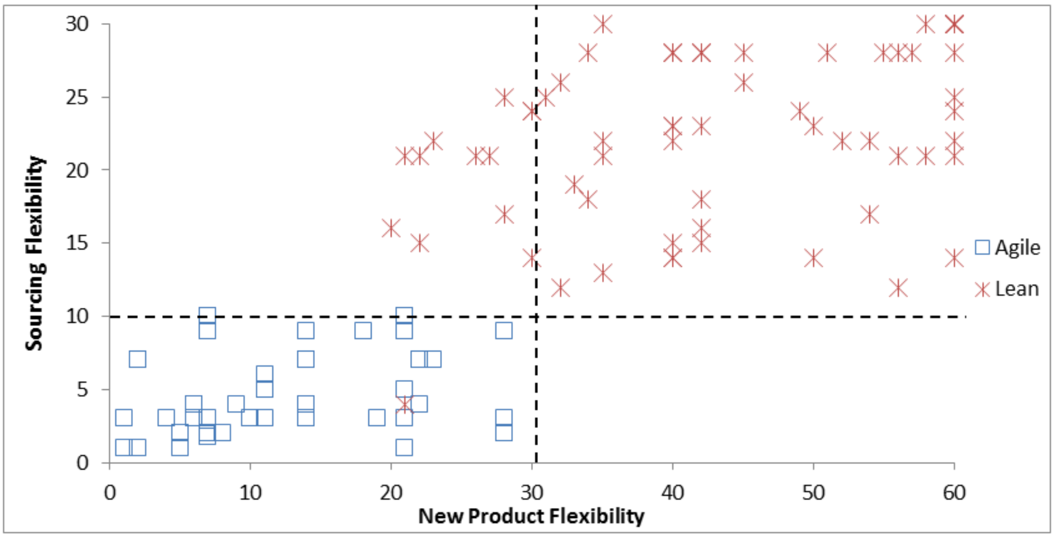
Figure 1: Volume Flexibility Demand vs Product Mix Flexibility



5.4 New Product Flexibility & Sourcing Flexibility

Figure 2 illustrates new product flexibility on the x-axis and sourcing flexibility on the y-axis. As flexibility is measured where response (Reichhart & Holweg, 2007) time is the unit measurement, it would be expected that time has an inverse relationship with flexibility. Agile firms generally required between 1-30 days when introducing new products into their system, which is far less than the duration required for lean firms (30-60 days). Agile firms require 1-10 days when sourcing different suppliers, whereas lean firms generally required a range between 10-30 days. The mean new product flexibility times within lean and agile systems were calculated as 44 days and 13 days respectively. Furthermore, the mean times required when sourcing new suppliers within lean and agile systems were calculated as 23 days and 5 days respectively. These findings support the assertion that response times can distinguish both concepts (Reichart & Holweg's, 2007). In summary, a firm's ability to redesign its current SC in order to meet the market demand (Tachizawa & Thomsen, 2007) was found to be directly linked with the speed at which a firm can introduce new products within its organisation (Beamon, 1999).

Figure 2: New Product Flexibility vs Sourcing Flexibility



6.0 Discussion

Figures 1 and 2 above depict very clear and novel findings from our ASC study. Two distinctive BMs, one lean and one agile are identified from a robust analysis of the TPRCs listed in Table 1. Combinations of TPRCs underpin dynamic capabilities which characterise each BM and give rise to sustained competitive advantages, explaining how they can co-exist in the same market. We focus on certain forms of flexibility as particularly important dynamic capabilities in the context of the ASC studied. A major debate concerns whether or not capabilities lead to trade-offs or whether capabilities are cumulatively gained, also known as the 'Sand Cone Model' which has given rise to the notion of world-class manufacturing (Brown *et al.*, 2007), World-class manufacturing and the 'law of cumulative capabilities' revolves around the belief that manufacturing organisations are able to compete on all measures of performance via the implementation of 'best-practices'. However in this study, as will be discussed, flexibility trade-offs were apparent, thus the main theoretical contribution of this study was the empirical validation of Skinner's (1969) assertion that production strategies compete on unique BMs. Therefore, this study sides with the notion of the 'trade-off law' as opposed to the 'law of cumulative capabilities' (Schmenner & Swink, 1998). Flexibility findings were consistent with our scorecard developed from Table 1, as no firm was identified as implementing a 'hybird' production strategy. This may explain why lean and agile flexibility levels in Figures 1 and 2 were so different. If our scorecard identified firms implementing a 'hybrid' strategy, we suspect that these firms would possess flexibility levels within the relatively empty quadrants in Figures 1 and 2. Therefore, as no firm was found to be most strongly implementing a 'hybrid' production strategy this may explain why our flexibility findings acquired limited outliers within Figures 1 and 2.

6.1 Developing a Flexibility Model to Distinguish Lean & Agile Firms

Figure 1 shows that lean firms generally do *not* develop low levels of volume flexibility and high levels of product mix flexibility simultaneously, as both volume flexibility *and* product mix flexibility were deemed to be low, in contrast to Naylor *et al.*'s (1999) assertion. Also, volume demand flexibility, product mix flexibility, new product flexibility and sourcing flexibility show the largest differences in comparison with the other flexibility levels when distinguishing lean and agile. As these four flexibility levels also show the strongest correlations amongst each of the flexibility combinations, we set out to develop a more refined framework (Figure 3) following Naylor *et al.*'s (1999) attempt to distinguish lean and agile systems. Firms located in quadrant 1, within Figure 3, attain low flexibility levels in each of the four dimensions. In contrast, firms located in quadrant 4 possess high flexibility levels in all four dimensions of flexibility. The set of parameters which are used when identifying and separating low (lean) and high (agile) flexible firms are consistent with Figures 1 and 2.

Figure 3: Flexibility Taxonomy Distinguishing Lean & Agile Production

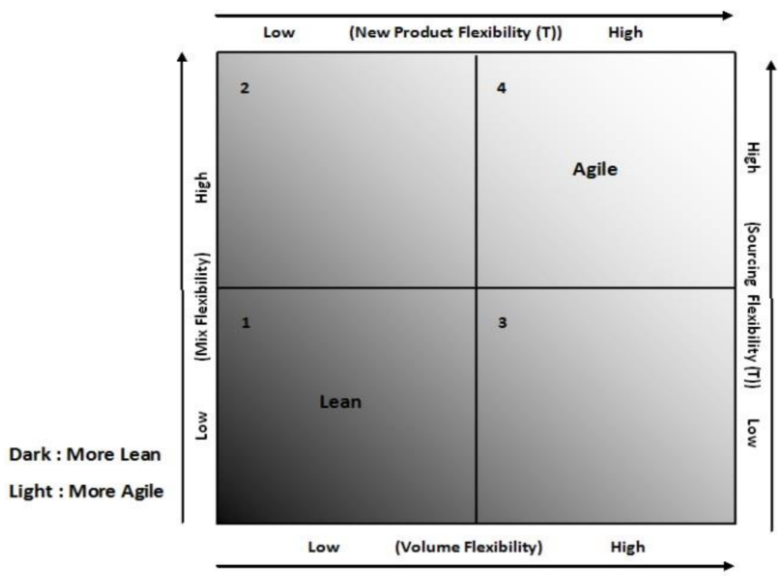


Table 7 highlights the reliability of using Figure 3 when distinguishing each manufacturing concept. Previously, using our scorecard, we found 66 firms as being agile and 74 firms as being lean. With regards to the parameters highlighted above, we observe that 66 out of the possible 74 lean firms can be placed in quadrant 1 and 56 out of the possible 66 agile firms can be placed in quadrant 4. As these were 89% and 88% consistent with the original scorecard, we propose that Figure 3 is a viable tool for distinguishing lean and agile BMs. But despite the consistent findings presented in Figure 3, it only accounts for four possible combinations out of the possible sixteen that can be made between each of the four flexibility measures. Lean firms that were not positioned in quadrant 1 attained a minimum of one high level of flexibility, and similarly agile firms that were not positioned in quadrant 4 attained a minimum of one low level of flexibility. However, as the majority of firms can be placed into these four combinations we suggest that the range and ability to accommodate change in production output (Gosling *et al.*, 2010), the time required between product mix changes (Beamon, 1999), the ease at which an organisation may change SC partners (Gosain *et al*., 2004; Sánchez & Pérez, 2005) and the ability to accommodate the production of new products (Gosling *et al.*, 2010) can be used to distinguish the majority of lean and agile firms. These are highlighted as critical dynamic capabilities in the context of this ASC.

Table 7: Reliability of Figure 3 when Distinguishing Lean and Agile Firms

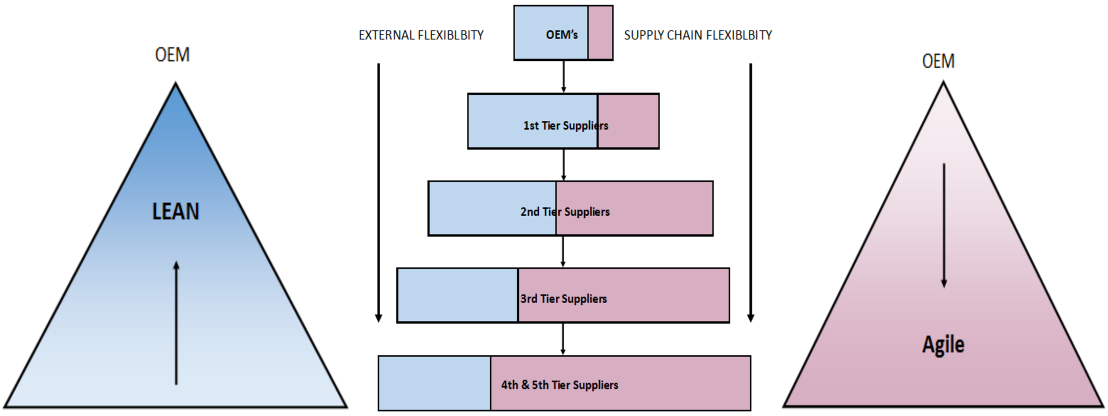
Production Concept	N	Using Figure 3 to Distinguish Lean & Agile	Reliability of Figure 3
Lean	74	66 (Low (LLLL))	89%
Agile	66	56 (High (HHHH))	88%

6.2 A New Way of Theoretical Thinking: The LAASC Model

Our next contribution focuses on extending the discussion (Reves *et al*., 2015; Sezen *et al.*, 2012) regarding the positional tier to which lean and agile firms belong within the ASC (Figure 4). Our findings clearly show that the ASC is not predominantly lean, but in fact 'leagile'. Figure 4 presents these findings graphically, showing that lean and agile firms are located at the top tiers and lower tiers of the ASC respectively. In essence, there is an inverse relationship between each of the triangles. This strongly suggests that firms either evolve the necessary dynamic capabilities to be efficient (lean) to be positioned in the top tiers of the ASC, or those that facilitate flexibility (agility) to be positioned in the lower tiers. Assuming that the manufactures positioned upstream in the ASC are more likely to smaller in comparison with firms operating downstream in the ASC, arguably our findings complement the notion that manufacturing SMEs find it difficult to implement lean practices (Shah & Ward 2003; McGovern *et al*., 2017; Knol *et al*., 2018), as firms upstream in the ASC were found to be implementing practices associated with agile production. However, results contend Knol *et al*. (2018) who indicated high-variety/low volume manufacturers were more easily reaching the full potential of implementing lean practices, compared to low-variety/high volume manufacturers and jobbers, as findings from this study suggested high variety manufacturers were in fact implementing agile production. Although not the focal point to this discussion, findings concerning low volatility and high volatility in flexibility levels located downstream and upstream ASCs, side with Dolgui, *et al*.'s (2017) assertions concerning the 'Ripple Effect'. Dolgui *et al.* (2017) outlined that SC disruption risks can be affiliated with high levels of production efficiency, limited sourcing and limited safety stocks. Now considering that findings presented from this study illustrated that most of the firms operating downstream in the

ASC possessed low flexibility levels (sourcing flexibility, supplier base flexibility) and implemented lean practices, we expect to see propagated flexibility levels upstream ASCs. Thus, our findings also align with traditional thinking within SCM, namely the 'Bullwhip Effect'. As the findings from this study highlight a clear increase in flexibility levels upstream in the ASC, in line with Li *et al*.'s (2017) debate of 'Bullwhip Effects' and 'Anti-Bullwhip Effects' our results imply that 'Bullwhip Effects' are present within ASCs in the UK.

Figure 4 – LAASC (Lean Agile Automotive Supply Chain) Model

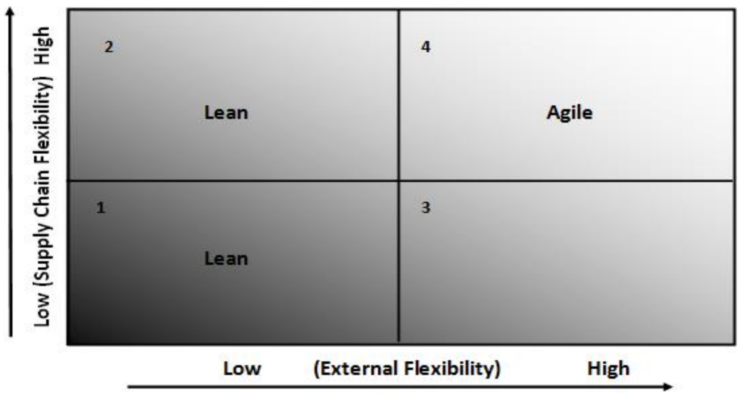


Source: Adapted from Qamar & Hall (2018)

Extending the discussion surrounding EF and SCF (Bernardes & Hanna, 2009; Malhotra & Mackelprang, 2012) we also find that different types of flexibility are more important than others to sustain one or other of these BMs. In terms of EF, agile systems were found to be up to three-times more flexible compared with lean systems. With the exception of sourcing flexibility, SCF levels failed to illustrate differences to the same extent as EF levels. For instance, supplier base flexibility, logistic flexibility and supplier offering flexibility did not portray such large differences between lean and agile systems in comparison with volume flexibility, new product flexibility, product mix flexibility and delivery flexibility. As research into SCF is in its infancy (Bernardes & Hanna, 2009; Purvis *et al.,* 2014), this study proposes Figure 5 as a starting point when identifying lean and agile differences within both SCF and EF. The rectangular shape in Figure 5 is to emphasise that there are large differences between lean and agile EF levels, but 'smaller' differences concerning SCF levels.

These large EF differences can partly be explained by variations in product portfolios. For instance, lean firms that are generally positioned at the top of the ASC have evolved dynamic capabilities that exploit economies of scale and incremental efficiency gains by specialising in the production of a narrow set of products, thus providing an explanation why Naylor *et al*.'s (1999) assertions were refuted. Contrasting this, agile firms positioned at the lower levels of the ASC displayed a wider portfolio of products as they compete on the capacity to quickly adapt to changes in demand, passed down from firms positioned at the higher levels of the ASC. Related to this, agile firms have a wider supplier base to facilitate responsiveness when demand specifications change. But Figure 5 keeps open the option for lean systems to also maintain relatively high levels of SCF.

Figure 5: EF and SCF within Lean & Agile Systems



More recently, Yin *et al*. (2018) outlined the evolution of the production industry from 2.0 to 4.0. Coined in 2011, Industry 4.0 has been defined as "an industry whose main characteristics comprehend connected machines, smart products and systems, and inter-related solutions. Such aspects are put together towards the establishment of intelligent production units based on integrated computer and/or digital components that monitor and control the physical devices" Tortorella & Fetterman, 2017: 2). Although findings from this study found that firms operating upstream in the ASC were prioritising practices and capabilities (Virtual Enterprise, IT Driven Enterprise etc.) affiliated with Industry 4.0, it seems as though the state of the automotive industry in the UK has not quite reached Industry 4.0., as the firms operating downstream ASCs were found to be largely prioritising efficiency practices. Industry 4.0 may be more suited to products with relatively short life cycles, for instance, electronic products typically have a life-cycle of six months, whereas the life-cycle for automobiles is around six years (Yin *et al.*, 2018). However, as lean production is primarily driven to achieve efficiency via the elimination of waste, lean firms cannot achieve responsiveness levels to the extent of Industry 4.0. However, as the average automobile consists of approximately 40,000 components, some of the life-cycles for these components may be shorter than others. Therefore, in conjunction with the volatile market of Industry 3.0, automotive OEMSs and first tier suppliers seem to be recognising the need to be flexible, but do not necessarily possess the relvant capabilities to achieve high levels of flexibility. Instead, these capabilities are passed on to firms operating upstream within ASCs. Therefore, the dynamic capabilities approach can be used to explain which TPRCs lead to EF differences and partly why lean and agile firms were found to be operating at different levels of the ASC. But to explain why lean firms tend to cluster at the top of the ASC and agile firms at the bottom and to understand why lean firms portrayed more similar levels of SCF when compared to EF, we turn to literature concerning Resource-Dependence-Theory (RDT) and more specifically the nature of power relations within ASC's.

RDT has become one of the most useful theoretical stances within organizational theory and strategic management (Hillman *et al*., 2009). Within RDT, the corporation is viewed as an open system which is reliant on multiple contingencies within the external environment (Pfeffer & Salancik, 1978). In order to understand the behaviour within an organisation, it is necessary to understand the context of that behaviour. Literature surrounding RDT has power at its heart (Touboulic *et al*., 2014; Wang *et al*., 2015) in that maximising various kinds of power in competitive market structures (intra-firm and inter-firm) contributes to survival or success (Ulrich & Barney, 1984). Moreover, one organization's ability to exercise power over another will play a part in its success, where levels of dependency are crucial. Cox *et al*., (2001) asserted that there are four general buyer and supplier positions concerning power, namely: buyer dominance; interdependence; independence and supplier dominance. Although Wang *et al*. (2015) asserted that the relationship between power and opportunism is inconsistent in the literature, lean firms were found to acquire low levels of sourcing flexibility and supplier base flexibility. Therefore, we can say that lean firms were found to have developed long term relationships with suppliers, suggesting power levels of interdependence, our study reveals lean BMs tend to be located at the top of the ASC. An important characteristic of ASC pyramids is that there are few buyers at the top and many potential suppliers at the lower end. Therefore, lean firms (buyers) are actually in a position of buyer dominance in the face of change and when they are required to make adjustments due in changes in demand they are able to fulfil these conditions opportunistically by passing flexibility constraints to their suppliers (Cox & Chicksand, 2005). Their BM positioning towards the top of the ASC allows them to limit the vulnerabilities that stem from being specialised and inflexible, allowing them to focus on efficiency. This observation aligns with the findings of Crute *et al.* (2003), who assert that firms will find it extremely difficult to implement lean within their organisation when in a position of low negation power.

7.0 Conclusion

Flexibility has been asserted to be an important performance measure with which to distinguish lean and agile production (Purvis et al., 2014) However, there is a deficiency in studies investigating flexibility amongst the lean- agile debate, as authors have tended to focus on each production concept in silos, which is evident amongst recent literature (Belekoukias *et al*., 2014; Reves *et al*., 2015; Godinho Filho *et al*., 2016; Johansson & Osterman, 2017; Pinho & Mendes, 2017; Tarafdar & Qrunfleh, 2017; Tortorella & Fettermann, 2017; Knol *et al*., 2018). With this in mind, this study explored the relationship between flexibility and lean and agile firms, using the automotive industry in the Midlands of the UK as our sample. We find that two distinctive BMs have evolved in the same ASC, identified by particular dynamic capabilities which give rise to particular kinds of competitive advantage. These firms co-exist in different, but complementary positions in the ASC, with lean firms clustering at the top and agile firms towards the bottom.

Our research focussed on the contention in the literature, that agile outperforms lean production in terms of EF and SCF, but lean production methods can also lead to high product mix flexibility. Although results from this study support the former contention, our study refutes the claim that lean manufacturing systems attain high levels of mix flexibility. Furthermore, we refute extant SC literature as ASCs were not identified as solely being lean, as both lean and agile firms were found to be operating in the ASC. As this final finding directly contrasts Mason-Jones *et al*.'s (2000) 'received wisdom' regarding where lean and agile organisations are located within a 'leagile' SC, we invoked a power perspective, to shed some light and better understand why this may be occurring. We assert that automotive OEMs and first tier suppliers do require high levels of flexibility, but do not have to possess flexibility capabilities, as these flexibility constraints can be passed down operationally at the expense of their suppliers upstream in the ASC.

8.0 Managerial Implications

This paper not only outlines the relevant dynamic capabilities as combinations of TPRCs that can enable firms to achieve high flexibility levels, but adds to the understanding concerning where flexibility levels are required within an ASC. The LAASC model proposed in this research suggests that when operating within a complex SC, firms positioned at the higher levels may not need to achieve high levels of flexibility. Partly because of their relative power over large numbers of suppliers in the lower levels of the SC pyramid, they can instead focus on dynamic capabilities which give rise to economies of scale and efficiency and result in lower costs, reliability and related competitive advantages. On the other hand, firms positioned at the lower end of complex SCs have less power and are more likely to require dynamic capabilities that underpin flexibility and responsiveness to remain competitive. There are trade-offs and uncertainties in both BM positions, but our study provides insights for managers to proactively decide on which strategic position might serve a firm best and which dynamic capabilities or bundles of TPRCs are needed to achieve this positioning.

9.0 Limitations

First, although a range of TPRCs were used to distinguish lean, agile and hybrid firms, this list may have been the reason why no hybrid firms were identified. Future studies can build on our TPRCs (postponement, integration of functions etc.) which were not included in this study. Second, involving the use of flexibility alone when distinguishing lean and agile firms may be argued to be limited as each manufacturing concept highlights different strengths. For instance, future studies must include additional performance measures, such as costs, dependability, quality and speed when differentiating lean and agile systems. Although this study incorporated the use of both EF and SCF, it would be beneficial to incorporate additional flexibility measures; however, future studies may use this study as a starting point when examining multiple dimensions of flexibility. Finally, although 140 firms were investigated in this study, only 74 and 66 firms were lean and agile in nature, it is vital for future studies to replicate a similar approach to this study with a greater number of firms.

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