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LEAN PRODUCTION, MARKET SHARE AND VALUE CREATION IN THE AGRICULTURAL MACHINERY SECTOR IN BRAZIL

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ABSTRACT

By adopting Lean Manufacturing firms wants to see the value created in its results at the bottom line. The agricultural machinery and implements sector in Brazil had experienced in Lean and saw its results affected by the program. Using an established analytical model, the paper tests three hypotheses: H1: firms with a high degree of management commitment to the program simultaneously support this commitment with investments in support of the plant infrastructure and problem-solving groups; H2: firms that adopt lean principles have made changes in the direction of these principles; H3: firms that made continuous investments in plant infrastructure in to support lean principles have better performances. All hypotheses H1, H2 and H3 were fully accepted and corroborated.

Key words: Lean manufacturing, Value Creation, Agricultural machinery sector.

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Introduction

The resource-based view (RBV) has gained prominence in the strategy literature by emphasizing the firm's internal resources as the main determinants for improved performance. Despite its global appeal and attractiveness of this view, studies to prove its worth empirically are still in short supply in Brazil. On the other hand, the economic success attained by companies engaged in lean production programs has boosted interest in the understanding and adoption of "lean" by Brazilian companies.

This article tests the relationship between the adoption of lean production programs and the market share and value creation of companies from the agricultural machinery and implements manufacturing sector in Brazil that have fully or partially adopted the lean production philosophy. The sector was chosen for its growing strategic importance in the country, as Brazil is now fast becoming a major world grain and animal products provider, which has attracted multinational companies in the sector interested in obtaining or increasing their market share and profitability.

The paper makes use of academic literature, which argues that the capacity to perform lean production is the key resource for the creation of a competitive advantage. The constructs relating to the degree of leanness were replicated from a study by Soriano-Meier and Forrester (2002). For value creation measures of profitability (value creation rates) and measures of sum (sundry accounting measurements for profit) were used. In addition the article also features a theoretical benchmark based on RBV emphasizing the attributes that a resource needs to have to create a sustainable competitive advantage, the theoretical grounds to consider the degree of leanness a resource that fulfills the requirements of RBV, the hypotheses and results of the tests.

Three hypotheses are proposed:

H1: firms with a high degree of management commitment (Com) to the program (measured by

Com-to-JIT and Com-to-TQM) simultaneously back up this commitment with investments in support of the plant infrastructure, measured by quality leadership (QLEAD), problem-solving groups (GROUP), training (TRAIN) and empowerment (WEMP).

H2: firms that adopt lean principles (measured by degree of adoption DOA) have made changes in the direction of these principles (measured by elimination of waste 'EW', continuous improvement 'CI', zero defect 'ZD', JIT deliveries 'JIT', pulling of materials 'PULL', multifunctional teams 'MFT', decentralization 'DEC', integration of functions 'IF' and vertical information system 'VIS').

H3: firms that made continuous investments in plant infrastructure (SMI) in the direction of lean principles (measured by degree of Leanness 'DOL' and degree of adoption 'DOC') have better performances (measured by PERF).

Correlation and multiple regression analyses were carried out to test H1. Using these statistical analyses, it was verified that there is support to accept H1. For H2 it was verified that the relationship of degree of adoption of the model (measured by DOA) proved significant when compared with the variables: elimination of waste 'EW', continuous improvement 'CI', zero defect 'ZD', pulling of materials 'PULL', multifunctional teams 'MFT', decentralization 'DEC', integration of functions 'IF' and vertical information system 'VIS'. The relationship with the variable JIT deliveries 'JIT', did not prove statistically significant, but we can consider that for the agricultural machinery sector in Brazil this hypothesis is true. Correlation, multiple regression, Cluster and one-way ANOVA analyses followed by a Turkey HSD test were applied to test H3. With a basis on the data and the analyses proposed, it was verified that the data corroborates the validation of H3.

Theoretical benchmark: RBV and the degree of leanness.

Barney (1991) identifies that resources are sources of sustainable competitive advantage if they are:

Valuable: valuable meaning the resource that enables the company to maintain or implement a strategy that increases its effectiveness or efficiency.

Scant or rare: it is intuitive that if a company possesses a resource that is absolutely rare or scanty among its competitors, this resource will generate at least one competitive advantage in relation to its rivals, and will also have the possibility of becoming a sustainable competitive advantage, as only the company that holds the resource (on the short term at least) can accrue profits thereupon.

Imperfectly imitable: meaning the capacity of the resource to allow the company to implement strategies that other competitors cannot come up with or even implement due to a lack of relevant and key resources that comprise the strategy. Resources are imperfectly imitable when: a) the company's ability to obtain the resource depends solely on historic conditions, b) the connection between the ownership of the resource and the sustainable competitive advantage is ambiguous as far as the cause of the advantage is concerned, i.e., casual ambiguity exists when the connection between the resources controlled by the company and the competitive advantage is not understood. The means of arriving at the result are not known, c) the resource that generates sustainable competitive advantage is socially complex, and depends on the relationship between people and processes. For example: interpersonal relationships between and among managers, the company culture and reputation among suppliers and customers.

Imperfectly substitutable: another characteristic of a resource that provides the company with a competitive advantage is that there is no equivalent resource that enables the rival to implement a similar strategy.

According to Grant (1991), the RBV performs a critique of the focus targeted at external factors. He observes that the internal resources and capabilities of the organization represent a more stable and secure basis for the formulation of competitive strategies. Hence the resources and the organizational capabilities should be the bases for the definition of competitive strategies sustainable over the long term, as they are more efficient than strategies sustained by external factors. Therefore, companies should be well coordinated internally and aware that the level of resources (physical, financial and technological media and the reputation of the company) and the organizational climate (organizational skills) will define the company's capacity to adapt to changes in the standard of competition (GRANT, 1991).

The same author emphasizes that the assumption of RBV is that companies differ as each one has a set of tangible and intangible assets and an organizational capacity that we call resources. As resources cannot be accumulated instantaneously, the strategic choice is sketched out by its stock of resources and its speed in acquiring or accumulating new resources. Without asymmetries or restrictions on the rates of change, any organization could follow any strategy it wanted to, and, as a result, winning strategies could be easily imitated and profits would tend to be non-existent. Accordingly, resources are of essential importance for the formation of the strategy that is the essence of sustainable competitive advantage. The company resources include all the assets, capabilities, **organizational processes**, attributes, information, knowledge and other properties of the company that enable it to design and implement strategies that improve efficiency and effectiveness (DAFT, 1983).

In the language of traditional strategic analysis, company resources are forces that can be used to design and implement strategies (LEARNED; CHRISTERSEN; ANDREWS and GUTH, 1969 *cited in* BARNEY 2002; PORTER, 1981). According to Collis and Montgomery (1997), resources can come in various shapes, ranging from the most common, widely available and easily purchasable factor to the most differentiated resource such as brand, which should be developed for many years and is very hard to imitate. The same authors propose the classification of resources in three categories: tangible assets, intangible assets and organizational capabilities.

Tangible assets are the easiest to value, as they are those that appear in the balance sheets. These include buildings, land, plants, materials, and many others. Even though tangible assets are resources essential to the company strategy, due to their nature, they are rarely a source of competitive advantage. There are exceptions; the communication infrastructure (telephone wires and cables), a high-speed connection for the exchange of information and properties located close to tourist spots are also resources that bear uncommon profits.

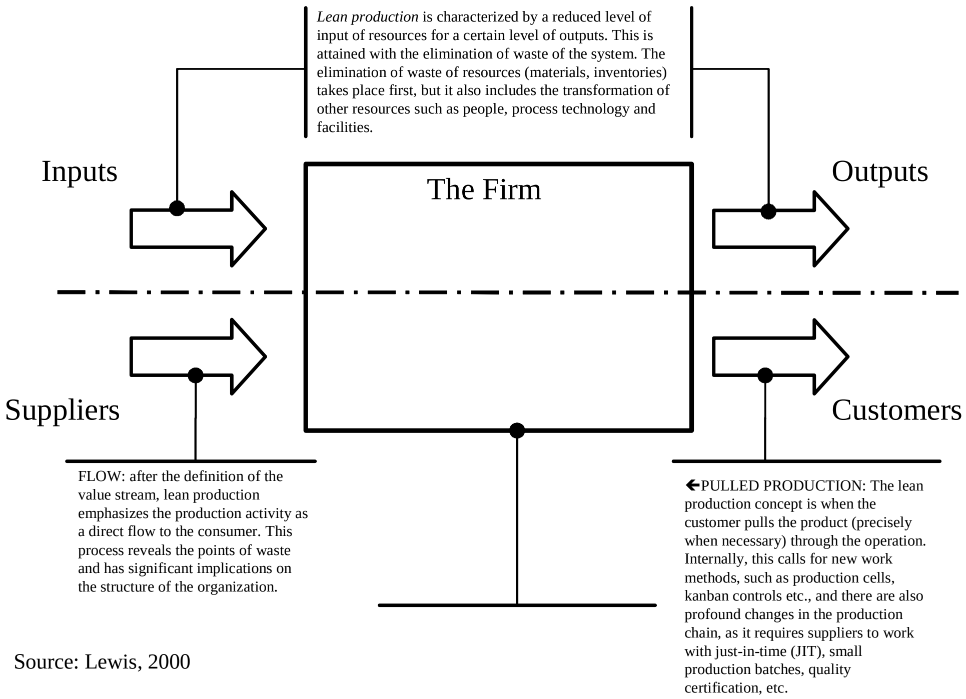
Intangible assets include resources such as company reputation, brands, cultures, technological knowledge, patents, accumulated knowledge and experience. These assets play an important role in the firm's competitive advantage. They also have an important quality of not being consumed through use; to the contrary, intangible assets can increase through use instead of diminishing. For this reason, they can be a valuable basis for diversified expansion.

Organizational capability is not an isolated factor like tangible and intangible assets, but a complex combination of assets, people and processes that the organization uses to transform inputs into outputs (raw material into finished product, for example). Applied to production, this organizational capability is what governs the efficiency of the company's activities. If well developed, the organizational capabilities can be sources of competitive advantage, as they enable the organization to convert inputs (whether services or products that result in greater efficiency or quality), into outputs, such as Lean Manufacturing, more efficiently than its rivals.

The use of the resources and capabilities of the firm as the foundation for a long-term strategy is based on two assumptions: Firstly, internal resources and capabilities provide the basic direction for the firm's strategy. Secondly, resources and capabilities are the primary origin of profit for the firm (GRANT, 1991).

Based on Lewis (2000), figure 1 illustrates how the dynamics of sustainable competitive advantage works. For example, some resources can be strategic if inimitable by rivals. Firms do not need to own strategic resources; they can belong to their suppliers, and likewise all the value creation processes go beyond the borders of the firm, involving current and potential customers. Significant results are attained when they make the firm better and/or different.

Figure 1 – The internal dynamics of sustainable competitive advantage



Source: Lewis, 2000

In his survey, Lewis (2000) attempts to verify whether a company has increased its internal effectiveness by converting inputs into outputs (measured in relation to criteria such as: inventories of work in process, inventories of finished products, delivery and quality performance, headcount, production space etc.). This relatively reduces the costs, which could result in an improvement of the performance of the business as a whole (measured by profitability or market share etc.).

The Lean Manufacturing model associates advantage in productive performance with adherence to three key principles:

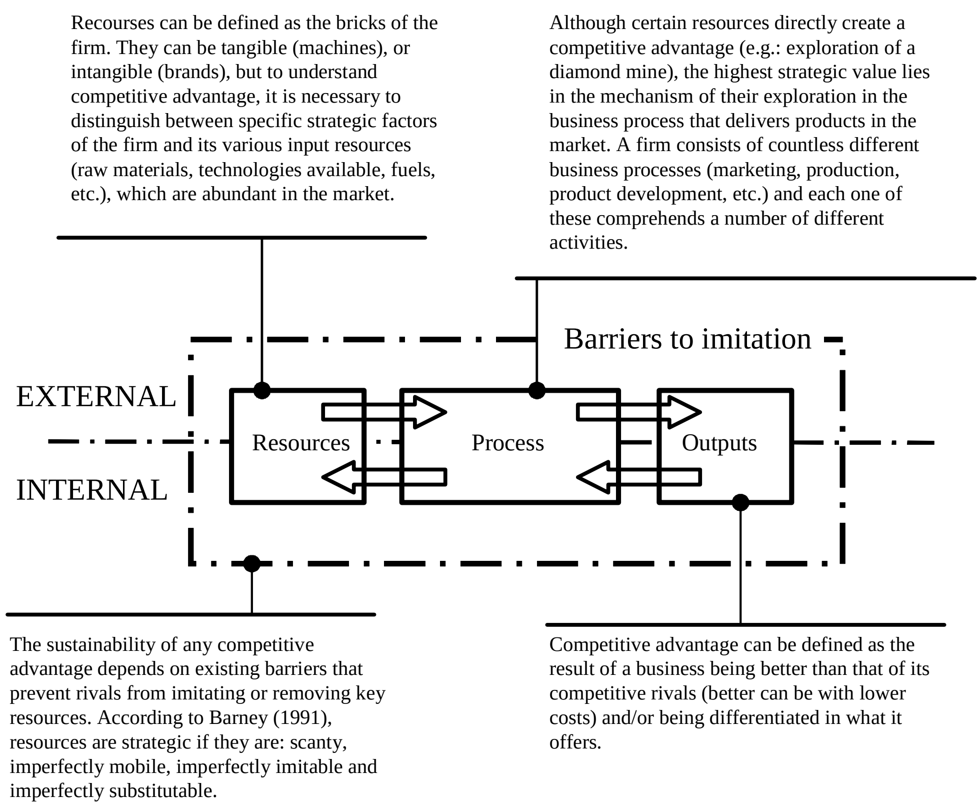
1) Improvement in the flow of materials and information through the business functions.
2) The emphasis on letting the consumer pull products through purchases, instead of pushing the organization through the production of inventories (this system triggers plant floor production by *kanban*).
3) The commitment to continuous improvement that is facilitated by people development.

All these grounds indicate that Lean Manufacturing is included in the category of a production process that cannot be easily imitated. Interestingly, the original study of IMVP was largely influenced by Toyota and the work of Taichi Ohno in particular, who ten years after his retirement wrote a book (OHNO, 1988) in which he was capable of describing the productive process of Toyota as a coherent process. This was a great incentive for many social scientists, engineers and consultants to seek the systematic explanation of the success of Toyota (WOMACK *et al*, 1990; MONDEN, 1983; GODDARD, 1986; HARRISON, 1992; CHENG and PODOLSKY, 1996). This served to encourage the “deconstruction” of the system, i.e., the tools used by Toyota, which supposedly guaranteed the superior results, were identified, and attention was deviated from the 30 years of rights and wrongs in which Toyota learned with the use of these tools (LEWIS, 2000). The entire systems analysis should take into account the history and the context in which it was designed. And it is now widely accepted that Lean Manufacturing was born in Japan, fathered by Taiichi Ohno, but this formation influence is not divulged much. As an example, innovations in operations acclaimed as the work of Toyota (OHNO, 1988) were already being used by Ford in 1920 (WILLIAMS *et al*, 1994).

Lewis (2000) places importance not only on the relationship between results and tools/techniques that apparently derive from the result, but also considers where the firm began (its history) and the implementation of specific strategies that it adopted along the route. Each company will take its own and unique path to implement Lean Manufacturing. This can be defined as initial conditions to which all firms are subject, and the specific implementation through which they passed (which techniques were applied in which orders etc.) to attain the result of Lean Manufacturing. Lewis (2000) understands that it is hard to define Lean Manufacturing. Although the three firms studied appear similar, at first they showed themselves to be different when studied in more depth. This demonstrated the importance of the initial conditions, which lead to a unique course followed by each company in the implementation of lean manufacturing.

Lewis (2000) proposes that the success of Lean Manufacturing in affording sustainable competitive advantage is contingent to the external context of the firm, as shown in Figure 2. Contextual factors can include: type of market (competition activity, profile of different demands); dominant technology in the sector; productive chain structure etc.

Figure 2 – Elements of sustainable competitive advantage.



Source: Lewis, 2000

Evidence already exists that suggests the need for more extensive contingency-related studies about the Lean Manufacturing model. Some surveys (KATAYAMA and BENNETT, 1996) have claimed that Lean Manufacturing is incapable of responding to major oscillations of added demands of volume, arguing that, at the time of the IMVP study, the Japanese economy exhibited highly specific characteristics that created conditions for a high and stable domestic demand.

The sustainable competitive advantage model argues that resources (prepared staff, market information, technological data etc.) create value when they act in processes. Sometimes these processes allow the company to learn and thus to create new resources. Learning at organizations can occur in a countless number of ways (HUBER, 1991), but it is useful to distinguish between:

the development of progressive efficiency and reliable routines vs. progressive excelling when facing new situations (SITKIN, 1991). The first (progressive efficiency and reliable routine) is the soul of the Lean Manufacturing model, with its emphasis on perfection through continuous improvement. When allied with the concepts of value stream and pull production, Lean Manufacturing suggests a model of information and flow of material that is highly organized.

If the environment of the firm is stable and changes slowly over time, then the competitive advantage could become sustainable by means of this adaptation (LEWIS, 2000). Another finding presented by Lewis (2000) is that the greater the success of the firm in the principles of Lean Manufacturing, the lower the degree of engagement for innovative or transforming activities, as the emphasis of the programme is on continuous improvement (*kaizen*), which is understood to be incremental and not revolutionary or transforming.

A great deal of attention has been paid to the results that lean manufacturing can offer to companies (SORIANO-MEIER and FORRESTER, 2002; LEWIS, 2000; KARLSSON and AHLSTRON, 1996) and how to measure them. According to the model proposed by Karlsson and Ahlstron (1996), to be able to determine whether a firm is lean, in transition or still works according to traditional models, it is necessary to measure the progress made in relation to an earlier period. It is important to distinguish between the determinants and performance of Lean Manufacturing. The objective of lean manufacturing when implemented is to obtain an improvement in productivity, attain an adequate level of quality, reduce production times, cut costs and others. The determinants of Lean Manufacturing are the actions taken, the principles implemented and the changes made in the organization to attain the desired performance (KARLSSON and AHLSTRON, 1996). According to the same authors, when Lean Manufacturing is studied as the determinant of performance, it is necessary to carry it into effect in detail in order to analyze the change process appropriately. The idea of progress is important in the concept, as according to Soriano-Meier and Forrester (2002), lean manufacturing is not a short-term tool, but rather a long-term strategic tool. This model can be used as a tool to keep track of progress in the direction of Lean Manufacturing. It can provide answers to the most frequent questions: are the actions we take leading us in the direction of Lean Manufacturing? What progress are we making in the different variables? (KARLSSON and AHLSTRON, 1996).

Creating and Measuring Value

Value creation is one of the contentious topics in economic theory, as there is no consensus among the various economic theories. To Marxists the creation of value is the product of labor, while to neoclassicists it is the product of utility. RBV focuses on resources (with the properties mentioned by Barney) as value creators. Our concern here will be with the measuring of value creation. Young and O’Byrne (2003) divide the measures into five categories: measures of residual profit, measures of the components of residual profit, market-based measures, cash flow measures and traditional profit measures. They argue that residual profit measures take into consideration the cost of own and of third party capital, unlike the market-based measures where the advantage lies in the incorporation of the market expectation, yet they are restricted to listed companies. However, residual profit ratios, such as EVA, are not limited to generally accepted accounting principles, making them ratios that generate numbers with appropriate economic significance. On the other hand, they require complex adjustments, making them limited in calculation.

Measures based on components of residual profit, although more direct in their calculations, can only be calculated at the level of sector, division or business unit. Below these levels, apportionments and allocations are necessary, which is why their results are not precise. Cash flow measures stand out on account of the ease in their calculation, and offer the advantage of associating performance with the business’s capacity to generate cash flow. Yet in an analysis carried out by the authors Young and O’Byrne (2003), it was verified that the calculation for these ratios requires accounting adjustments, which makes it complex and hard work. Traditional measures of profit have the advantage of already being available in the required financial reports, and in spite of their weak points, are accompanied by the market and are well known and widely used, as is the case of earnings per share. One of the main negative aspects is that they do not consider the costs of own capital.

Two economic-financial ratios were used in the Soriano-Meier and Forrester study (2002): sales by employee and the asset-turnover ratio. These ratios were used in a replica of the study for Brazil (Shimizu, Basso and Nakamura, 2006) but are limited as concerns the measuring of value creation. The first ratio is a market share ratio and market share does not necessarily lead to greater profitability. For example, a company can be increasing its market share by acquiring similar companies with old plants. Old plants imply a slump in productivity and an increase of costs, which can reduce the profitability. On the other hand, it is possible that greater market share is being obtained via competition over prices, which implies a profitability downslide. To surmount these limitations we opted to work with measures of value creation rates (profitability/growth concepts, expressed in the division of a flow by total asset) and of sums (expressed in value streams), which measure value creation.

The measures are included in the category of traditional measures (accounting) of profit and profitability. These measures were:

Table 1: Measures of Flow

MEASURES OF FLOW

Description	Variable
Growth of turnover between 2000 e 2003	ratioturnov
Growth of total assets between 2000 e 2003	rationetass
Growth of sales between 2000 e 2003	ratiovendas
Growth of operating revenues between 2000 e 2003	ratiorecoper
Growth of operating result between 2000 e 2003	ratioresultoper
Growth of result before Income Tax between 2000 e 2003	ratioresultair
Growth of result for the year between 2000 e 2003	ratioresultexerc
Growth of asset turnover between 2000 e 2003	ratioasstur

Source: compiled by the author

Table 2: Measures of Value:

MEASURES OF VALUE

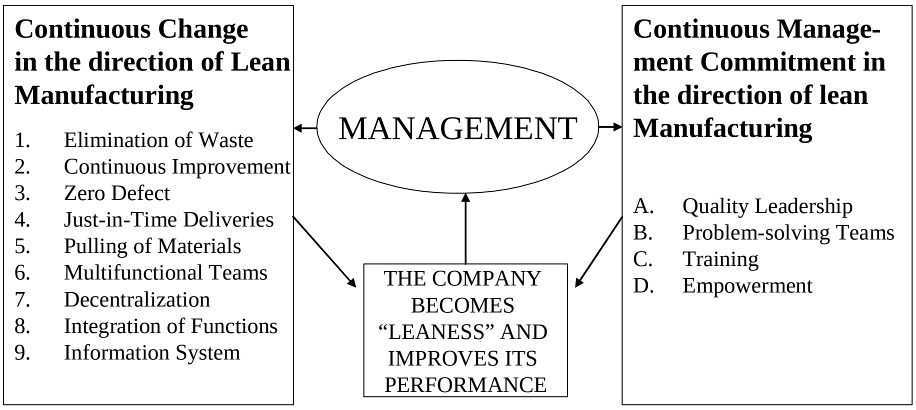
Description	Variable
Growth of turnover value (turnover2003/total asset2003)-(turnover 2000/total asset 2000)/(turnover2003/total asset2003)	turnover
Growth of sales value (sales2003/total asset2003)-(sales2000/total asset 2000)/(sales2003/total asset2003)	vendas
Growth of operating revenue value (recoper2003/total asset2003)-(recoper 2000/total asset 2000)/(recoper2003/total asset2003)	recoper
Growth of operating result value (resultoper2003/total asse2003)-(resultoper 2000/total asset 2000)/(resultoper2003/total asset2003)	resultoper
Growth of value of result before Income Tax (resultair2003/total asset2003)-(resltair 2000/total asset 2000)/(resultair2003/total asset2003)	resultair
Growth of value of result for the year (resultexerc2003/total asset2003)-(resultexerc 2000/total asset2000)/(resultexerc2003/total asset2003)	resultexerc
Growth of value of operating result (resultoper2003/sales2003)-(resultoper2000/sales2000)/(resultoper2003/sales2003)	resultopervendas
Growth of value of result before income Tax (resultair2003/sales2003)-(resultair2000/sales2000)/(resultair2003/sales2003)	resultairvendas
Growth of value of result for the year (resultexerc2003/sales2003)-(resultexerc 2000/sales2000)/(resultexerc2003/sales2003)	resultexercvendas

Source: compiled by the author

Model and Hypotheses

The Soriano-Meier and Forrester (2002) model, shown in figure 7, tests a set of hypotheses with respect to lean production, The model refers to the performance of senior management in the transformation of the firm through the adoption of Lean Manufacturing. On one side there is the commitment of senior management to investing in manufacturing infrastructure through quality leadership, the formation of problem-solving teams, training and empowerment, which means to say release of decision-making power to levels below. On the other side there is continuous change through the implementation of Lean Manufacturing concepts, which are: elimination of waste, continuous improvement, Just-in-Time deliveries, pulling of materials, multifunctional teams, decentralization of responsibilities, integration of functions and vertical information system. With the implementation of these two lines, the company becomes leaner and improves its performance.

Figure 3 – Model 4-C



Source: Soriano-Meier and Forrester (2002).

The study aimed to corroborate three hypotheses:

H1: companies that say they have a high management degree of commitment to Lean Manufacturing (measured by commitment to JIT and TQM program), simultaneously demonstrate this commitment to investments in manufacturing infrastructure (SMI – human infrastructure that provides support to manufacturing), measured by quality leadership (QLEAD); problem-solving groups (GROUP); training (TRAIN) and worker empowerment (WEMP).

H2: companies that allegedly adopt Lean Manufacturing principles (measured by degree of adoption DOA) have made changes in the direction of these principles (measured by elimination of waste, continuous improvement, zero defect, JIT deliveries, pulling of material, multifunctional teams, decentralization, integration of functions and vertical information system).

H3: companies that continuously made investments in the plant infrastructure (SMI) and changes in the direction of Lean Manufacturing principles are lean companies, and therefore have better performances than those in transition and those still working in the traditional model.

The three hypotheses are needed to examine the conceptual structure developed in this study. H1 evaluates the first component of the 4-C model, the degree of management commitment to Lean Manufacturing. H2 analyses the degree of changes made in the direction of Lean Manufacturing. H3 associates the first two components, commitment to lean manufacturing and changes in the direction of lean manufacturing, with performance.

Dependent variables

The dependent variables tested in the model are: Commitment to Just in Time, Commitment to Total Quality Management, Degree of adoption of the principles of Lean Manufacturing and Performance (this variable covers both the variables of market share (Shimizu, Basso and Nakamura, 2006), and the variables of value creation.

Independent variables

The independent variables tested in the model are: Quality leadership, Problem-solving group, Training, Empowerment, Elimination of waste, Continuous improvement, Zero Defects, Just in Time, Pulled instead of pushed, Multifunctional teams, Decentralization of responsibilities, Integrated functions and Vertical Information System.

ANALYSES AND RESULTS

Testing the Hypotheses

Management commitment and investment in manufacturing infrastructure

Correlation and multiple regression were applied to test the H1 hypothesis. The hypothesis verifies the relationship between the level of management commitment to the Lean Manufacturing program (measured by commitment to JIT 'Com-to-JIT' and commitment to the TQM program 'Com-to-TQM'), and the level of investments made in the manufacturing infrastructure (measured by quality leadership 'QLEAD', problem-solving group 'GROUP', training 'TRAIN' and empowerment 'WEMP').

The CEOs confirmed that 65% (24 out of 37) of the firms have an average or low level of commitment to the JIT program. Of these 24, 10 (27%) informed an average level of commitment. One of the possible causes for this low commitment is that the sector is still in the initial stage of implementation of the Lean Manufacturing program, since as verified during the fact finding, many of the companies that started the journey in the direction of Lean Manufacturing began in around the year 2000, when strong incentive was provided by the sectorial chamber of agricultural machinery and implements of ABIMAQ for companies from the sector to hear about the program. This characteristic could be distorting the vision of the CEO when it is asked whether there is a commitment to Just-in-Time.

As was the case of the commitment to JIT, the commitment to TQM is not high, as 62% (23 out of 37) declared that the degree of commitment is low, and of these 23, 7 (19%) attribute an average level of commitment in relation to TQM. Among senior managers, there is an understanding that the program is still taking its first steps, and that there is a lot of space yet to be covered for companies to reach a threshold where there is a commitment to Just-in-Time and to TQM.

Correlation analysis:

Correlation among variables is a ratio that ranges from -1 to +1, indicating the power of association among them. When positive, between 0 and +1, it indicates that when a variable increases, the other accompanies the increase in the proportion calculated. If the correlation is negative, between -1 and 0, this indicates that when a variable increases, the order decreases in the proportion indicated by the value calculated. Therefore, values close to -1 and +1, indicate that there is a strong relation among the variables analyzed, while values close to 0 show a lesser degree of correlation.

Table 3 – correlation between and among Com-to-JIT, Com-to-TQM, QLEAD, GROUP, TRAIN and WEMP.

Variable	1	2	3	4	5	6
	bjit	btqm	xqlead	xgroup	xtrain	xwemp
1 - Commitment to JIT (Com-to-JIT)	1	0.411**	0.307*	0.447**	0.381**	0.319*
2 - Commitment to TQM (Com-to-TQM)		1	0.538**	0.351*	0.296*	0.368*
3 - Quality Leadership (QLEAD)			1	0.443**	0.548**	0.597**
4 - Problem-solving Group (GROUP)				1	0.471**	0.33*
5 - Training (TRAIN)					1	0.728**
6 - Empowerment (WEMP)						1

**Correlation is significant at the 0.01 level (1-tailed).
*Correlation is significant at the 0.05 level (1-tailed).

Source: compiled by the author

As emphasized by Soriano-Meier and Forrester (2002), lean manufacturing can only be obtained with time, and is not a tool for short-term problem solving, instead, it is a strategic tool in markets of growing competitiveness. According to Liker (2004), knowledge about Lean Manufacturing at Toyota was gradually accumulated in daily activities by the workers and managers through the constant learning of new methods and variations of methods consolidated on the plant floor, without a documentation of this theory. The tacit knowledge acquired was then passed on to the other production units of Toyota, and subsequently also to suppliers.

Sirkin (1999 *cited in* Soriano-Meier & Forrester, 2002) perceives that correlations in social surveys found above 0.70 are rare, and many tend to be in the interval between 0.0 and 0.50. As we can see, according to this statement, the coefficients found for both the dependent variables, commitment to JIT (measured by Com-to-JIT) and commitment to TQM (measured by Com-to-TQM) are located in this interval from 0.20 to 0.50. (although some are in the confidence interval of 5% and other coefficients in the interval of 1%). A possible explanation for the low correlation among the variables analyzed, in relation to commitment to TQM, unlike what happened in the survey by Soriano-Meier & Forrester (2002) where the correlations were above 0.5, is the recent history of implementation in the sector of agricultural machinery and implements in Brazil, which according to reports from some interviewees commenced in the year 2000.

Analyzing the data for this study (Table 3), there is a strong correlation between empowerment and the training given to employees (0.728), which is significant at 1%, which indicates that the sector seeks to release decision-making power to employees as they are trained in the tasks they perform.

The multiple regression analysis was performed with the following purposes:

1) to verify the degree of relationship between the two dependent variables and the four independent variables, considered one by one;
2) to determine the relative importance of each independent variable in the forecast of the dependent variable; and finally
3) to determine the existence of colinearity effects.

Table 4 – Analysis of multiple regression H1.

Model1 (dependent va Com-to-TQM)	F	p	R^2 Adjusted	β	t	p
Commitment to TQM (Com-to-TQM)	193,92	0,000	0,843			
Quality Leadership (QLEAD)				0,697	13,93	0,000
Model2 (dependent va Com-to-JIT)						
Commitment to JIT (Com-to_JIT)	97,489	0,000	0,843			
Problem-Solving Group (GROUP)				0,562	4,294	0,000
Commitment to TQM (Com-to-TQM)				0,342	2,149	0,039

Source: compiled by the author

The results show to what extent the dependent variable is explained by each one of the independent variables. The standardized regression coefficient or the beta coefficient (β) is used to determine the relative importance of each independent variable in the dependent variable. It explains the individual contribution that each type of investment in plant infrastructure makes in the commitment to JIT and commitment to TQM.

As a conclusion, there is support to accept the H1 hypothesis with a basis on the previous analyses, where it was verified that all 15 variables proved significant at statistically acceptable levels, and also, taking into consideration the initial stage of the Lean Manufacturing programme in the sector of agricultural machinery and implements in Brazil.

Correlation and multiple regression analyses were conducted to test the H2 hypothesis. This hypothesis seeks to verify whether the companies that allegedly adopt the Lean Manufacturing principles (measured by degree of adoption DOA) have made changes in the direction of these principles (measured by elimination of waste 'EW', continuous improvement 'CI', zero defect 'ZD', JIT deliveries 'JIT', pulling of material 'PULL', multifunctional teams 'MFT', decentralization 'DEC', integration of functions 'CI' and vertical information system 'VIS'). Paradoxically to the variables of commitment to JIT and commitment to TQM, where there is a low degree of commitment, we verified that for the degree of adoption, 73% of the firms (27 out of 37) have a mean value of four or higher, which indicates a high degree of emphasis on the adoption of the Lean Manufacturing program.

This perception of degree of adoption of the Lean Manufacturing program is provided by the COO, and we can now verify congruence in the perception among the CEO's and COO's as to the stage of implementation of the program at the companies.

a) Correlation analysis

Table 5 – correlation between and among DOA, EW, CI, ZD, JIT, PULL, MTF, DEC, IF and VIS.

Variable	1	2	3	4	5	6	7	8	9	10
1 - Degree of Adoption (DOA)	1	0.831**	0.849**	0.762**	0,026	0.745**	0.803**	0.756**	0.686**	0.735**
2 - Elimination of Waste (EW)		1	0.832**	0.640**	0,019	0.535**	0.582**	0.503**	0.514**	0.608**
3 - Continuous Improvement (CI)			1	0.643**	0,062	0.527**	0.635**	0.505**	0.513**	0.677**
4 - Zero Defect (ZD)				1	0,087	0.476**	0.537**	0.439**	0.422**	0.504**
5 - Just-in-Time Deliveries (JIT)					1	-0,076	-0,115	-0,118	0,124	-0,056
6 - Pulling of Materials (PULL)						1	0.751**	0.590**	0.401**	0.352**
7 - Multifunctional Teams (MTF)							1	0.562**	0.517**	0.501**
8 - Decentralization (DEC)								1	0.538**	0.671**
9 - Integration of Functions (IF)									1	0.390**
10 - Vertical Information System (VIS)										1

**Correlation is significant at the 0.01 level (1-tailed).
*Correlation is significant at the 0.05 level (1-tailed).

Source: compiled by the author

Table 5 presents the analysis of correlation between the degree of adoption (measured by DOA) and the changes in direction of these principles (measured by elimination of waste 'EW', continuous improvement 'CI', zero defect 'ZD', JIT deliveries 'JIT', pulling of material 'PULL', multifunctional teams 'MFT', decentralization 'DEC', integration of functions 'IF' and vertical information system 'VIS').

In the Soriano-Meier and Forrester study (2002), the variables pulling of material (PULL) and integration of function (IF), did not appear to be prove statistically significant; likewise in this study we also verified the same behavior in relation to the variable Just-in-Time deliveries.

Even with the broad scope of the program, which contemplates all the areas of the manufacturing process, we can verify that there are significant correlations of the degree of adoption of the programme with practically all the variables analyzed in this hypothesis, with the exception of Just-in-Time (JIT) deliveries. The statistical analyses performed corroborates the acceptance of the H2 hypothesis.

Degree of leanness, degree of commitment and the relation with performance.

Using the same techniques adopted for other hypotheses, correlation analyses, analysis of multiple regression, Cluster analysis and one-way ANOVA were performed, followed by a Tukey HSD test. This hypothesis verifies the relationship between the degree of leanness (measured by DOL), the degree of commitment to the Lean Manufacturing program (measured by DOC) and the performance (measured by PERF).

The variable degree of leanness (measured by DOL) was obtained through the mean of the variables that measure the degree of adoption of the Lean Manufacturing program, which are: elimination of waste (EW), continuous improvement (CI), zero defect (ZD), JIT deliveries (JIT), pulling of material (PULL), multifunctional teams (MFT), decentralization (DEC), integration of functions (IF) and vertical information system (VIS). The variable degree of commitment (measured by DOC) is the mean of the variables: quality leadership (QLEAD), problem-solving group (GROUP), training (TRAIN) and empowerment (WEMP). Variable performance (measured by PERF) was measured by a proportion between billing by employee and turnover of assets, in comparison to the years 2000 and 2003.

a) Correlation analysis

Table 6 – Correlation between and among dol, doc and perf.

	dol	doc	perf
Degree of "Leaness" (dol)	1	0.294*	0.625**
Degree of Commitment (doc)		1	0.599**
Performance (perf)			1

***Correlation is significant at the 0.05 level (1-tailed).**
****Correlation is significant at the 0.01 level (1-tailed).**

Source: compiled by the author

As we can see, Table 6 shows that all three variables have high levels of correlation, and in accordance with the parameters to avoid colinearity do not exceed 0.80. The results of this correlation analysis can be considered acceptable and we will develop the regression analysis below in order to identify the nature of this relationship.

b) Regression Analysis

Table 7 – Analysis of regression between PERF and DOL.

Variable	**F**	**P**	**R^2 Adjusted**	**β**	**t**	**p**
3 - Performance (PERF)	657,39	0,000	0,954			
1 - Degree of Leaness (DOL)				0,977	0,000	25,640

Source: compiled by the author

Table 7 shows the result of the regression analysis conducted for the coefficients of DOL and DOC. We verified that only the variable DOL explains the variable PERF at 95% and with high significance ($p<0.01$).

c) Cluster Analysis

The cluster analysis was performed in order to group individuals or objects in Clusters, hence individuals in the same Cluster are more alike than individuals in the other Cluster. The objective is to maximize the homogeneity of individuals inside the Cluster, while there is also a maximization of heterogeneity between and among the Clusters (HAIR et al., 1998 *cited in* SORIANO-MEIER and FORRESTER, 2002).

Table 8 – Firm classification criterion

1- Lean Firms	For DOL > 4.57 and DOC > 4.70
2- Firms in Transition	For DOL ? 4.57 and DOC ? 4.70 or For DOL ? 4.57 and DOC ? 4.70
3- Traditional Firms	For DOL < 4.57 and DOC < 4.70

Source: compiled by the author

With a basis on this criterion, Table 8 shows the classification of firms as either lean firms, firms in transition or traditional firms. The classification reveals that 27% (10 out of 37) of the firms studied are classified as Lean firms, 46% (17 out of 37) of these are classified as firms in transition and 27% (10 out of 37) are traditional according to the criterion adopted.

d) One-way ANOVA test

After the classification of the firms in these criteria, the one-way ANOVA test was conducted in order to verify how these differ in terms of the variables that we are analyzing for the H3 hypothesis: degree of Leanness (measured by DOL), degree of commitment (measured by DOC) and performance (measured by PERF).

Table 9 – One-way ANOVA test

Variable	df	F	p
dol	2	19,009	0,000
doc	2	10,224	0,000
perf	2	128,655	0,000

Source: compiled by the author

Table 9 shows the main results for each type of firm, with statistical significance. In essence, the one-way ANOVA test examines the total difference in the mean, and can only indicate that the mean values of the groups are not equal and therefore reject the null hypothesis that the mean values of the groups are equal. Hence the Tukey HSD test is necessary.

e) Tukey HSD test

The one-way ANOVA test helps us to conclude that there are differences among the groups, but is unable to indicate where they are. Carrying out a procedure similar to that of the survey by Soriano-Meier and Forrester (2002), the Tukey HSD test was applied to the variables degree of leanness (measured by DOL), degree of commitment (measured by DOC) and performance (measured by PERF).

Table 10 presents the comparison of the Tukey HSD test for the three variables: degree of leanness (measured by DOC), degree of commitment (measured by DOC) and performance (measured by PERF).

Table 10 – Tukey HSD test

Tukey HSD				
Variable	**(I) type**	**(J) type**	**Difference of Mean Values (I-J)**	**P**
Degreee of *Leaness* (DOL)	1	2	0,651	0,000
		3	0,927	0,000
	2	1	-0,651	0,000
		3	0,276	**0,130**
	3	1	-0,927	0,000
		2	-0,276	**0,130**
Degree of Commitment (DOC)	1	2	1,095	0,003
		3	1,510	0,000
	2	1	-1,095	0,003
		3	0,415	**0,387**
	3	1	-1,510	0,000
		2	-0,415	**0,387**
Performance (PERF)	1	2	2,212	0,000
		3	4,700	0,000
	2	1	-2,212	0,000
		3	2,488	0,000
	3	1	-4,700	0,000
		2	-2,488	0,000

Source: compiled by the author

The test was aimed to verify whether Lean firms have higher significant mean values than traditional firms, in the three variables studied in the model, and as we can verify in Table 10, this is confirmed. Another important analysis was to verify whether Lean firms also have higher mean values than firms in transition, which was confirmed in the table, as Lean firms have higher statistically significant mean values than firms in transition for the three variables studied. It was concluded that, with a basis on the tests carried out and on the results of the correlations, multiple regression analysis, cluster analysis and one-way ANOVA test followed by the Tukey HSD test, the results corroborate H3.

CONCLUSION

The objective of this paper was to study the performance of manufacturing companies from the agricultural machinery sector in Brazil, which strategically opted for the implementation of Lean Manufacturing.. The variables defined and studied in this paper were based on the survey by Soriano-Meier and Forrester (2002), where nine independent variables were defined to measure the degree of adoption of the program, which was summarized in a dependent variable designated degree of Leanness. Another metric was also developed to identify the degree of commitment to the program. Once these two variables were obtained, the authors verified their relationship with performance, which was measured through the ratios of billing by employee and turnover of assets, calculated using secondary data. A group of 37 firms from the sector of agricultural machinery and implements took part in the survey. Two questionnaires per firm were applied, the first for the CEO and the second for the COO.

The study proposed three hypotheses:

H1: firms with a high degree of management commitment to the program (measured by Com-to-JIT and Com-to-TQM) simultaneously support this commitment to investments in support of the plant infrastructure, measured by quality leadership (QLEAD), problem-solving groups (GROUP), training (TRAIN) and empowerment (WEMP).

H2: firms that adopted the lean principles (measured by degree of adoption DOA) have made changes in the direction of these principles (measured by elimination of waste ‘EW’, continuous improvement ‘CI’, zero defects ’ZD’, JIT deliveries ‘JIT’, pulling of materials ‘PULL’, multifunctional teams ‘MFT’, decentralization ‘DEC’, integration of functions ‘IF’ and vertical information system ‘VIS’).

H3: firms that made continuous investments in plant infrastructure (SMI) in the direction of the lean principles (measured by degree of Leanness ‘DOL’ and degree of adoption ‘DOC’) have better performances (measured by PERF).

Correlation and multiple regression analyses were conducted in order to test H1. On the basis of the statistical analyses performed, it was verified that there is sufficient support to accept H1. For H2, it was verified that the relationship of degree of adoption of the model (measured by DOA) proved significant when compared with the variables: measured by elimination of waste ‘EW’, continuous improvement ‘CI’, zero defect ’ZD’, pulling of materials ‘PULL’, multifunctional teams ‘MFT’, decentralization ‘DEC’, integration of functions ‘IF’ and vertical information system ‘VIS’. The relationship with the variable JIT deliveries ‘JIT’, did not prove statistically significant. Although this single variable did not prove statistically significant, we can accept that for the sector of agricultural machinery and implements in Brazil, this hypothesis is true. Correlation, multiple regression, Cluster and one-way ANOVA analyses followed by a Tukey HSD test were applied to test H3. On the basis of the data and the analyses proposed, it was verified that the data corroborates the validation of H3. The next step is to test the model in other sectors of the Brazilian economy.

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