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Does CMMI Implementation affect the Performance of the Firm? An Evaluation from a Dynamic Capabilities Approach

Eduardo Ajenjo[a1], Natalia Martín-Cruz[a2], Cristina Ruiz-Martin[a3] and Adolfo López-Paredes[a4]

Grupo INSISOC. Escuela de Ingenierías Industriales.
Universidad de Valladolid, Pº. del Cauce 59, 47011-Valladolid, Spain

[a1] *eduardo.ajenjo@gmail.com,* [a2] *ambiela@eco.uva.es,* [a3] *cruiz@eii.uva.es,* [a4] *aparedes@eii.uva.es*

Abstract: In this paper, we study the impact of the Capability Maturity Model Integration (CMMI) on firm performance both during and after its implementation. The literature pointed out that CMMI is theoretically related to the generation of dynamic capabilities. To give an empirical view of these theories, we built a database of economic and financial data from Spanish firms involved in programming, consultancy or another computer-related sector. This data allowed us to study the relationship between the use of CMMI and the firm economic and financial performance in an empirical way. The main finding of the analysis is a negative relationship between the use of CMMI and profitability in the firms during the analyzed period and sector.

Key words: Dynamic Capabilities, CMMI, Firm Performance.

1. Introduction

In the last decades, several maturity models have been developed with the focus on improving different tasks in organizations such as the processes, the project management or the knowledge management. One of these models is the Capability Maturity Model Integration (CMMI). CMMI is a set of good practices developed by the Software Engineering Institute. It is focused on improving the company processes with special application in the software industry. This maturity model has been theoretically related to the development of several capabilities in the organizations that helps in their performance (Lee & Wu, 2007).

Our goal is to test whether there is or not an empirical relation between the implementation of maturity models and the performance of the organizations. To achieve our goal, we performed an empirical analysis based on Spanish firms involved in programming, consultancy or another computer-related sector to test two hypotheses.

We will examine if the performance of a firm is likely to increase after the process of CMMI implementation and if it is likely to decline during the process of CMMI implementation

In the following sections, we discuss the results we obtained. In section 2, we present the background and our research hypothesis. In section 3, we explain the methodology we have followed to drive our analysis. In section 4, we describe the results of our study. Finally, in section 5 we discuss our results, we present the main conclusions and future lines of this research.

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2. Background and Hypothesis

Nowadays, more and more organizations adopt maturity models, such as CMMI or other Project Management Maturity Models (PMMM), to improve their performance.

Despite CMMI has been criticized for the lack of developed procedures (Reifer, 2000; Sun & Liu, 2010) or for the difficulty in finding the areas where the improvement efforts have to be focused (Huang & Han, 2006), it is a good tool to improve schedule, costs and even the return of investment in the organizations (Gibson, Goldenson, & Kost, 2006; Goldenson & Gibson, 2003).

Other maturity models, such as PMMM are also related to a better organizational performance (de Oliveira Moraes & Barbin Laurindo, 2013; Nenni, Arnone, Boccardelli, & Napolitano, 2014), although they have been criticized for being irrelevant and for the need for greater flexibility and adaptability to the organization (Mullaly, 2014).

Young *et al.* (2014) state that higher levels of maturity will help to increase the organization performance. However, other authors conclude that a higher level of maturity does not necessarily imply greater success; each organization needs to find its appropriate level (Albrecht & Spang, 2014; de Oliveira Moraes & Barbin Laurindo, 2013).

Staples and Niazi (2008) affirm that the most common reasons to adopt capability maturity models are to improve quality and project performance, and to enhance process management. Lee and Wu (2007) study CMMI as a source of strategic capabilities, which are related to the developing of dynamic capabilities.

The dynamic capability approach (Teece, Pisano, & Shuen, 1997) tries to explain the internal processes that a firm uses to be competitive. Dynamic capabilities are best practices and organizational processes that allow creating competitive advantages (Eisenhardt and Martin, 2000). Organizations need them for long-term enterprise success (Augier & Teece, 2009; Wu, He, & Duan, 2013), but they also require a good strategy and own VRIN resources (Valuable, Rare, In-imitable and Non-substitutable resources) (Teece, 2014). Furthermore, dynamic capabilities affect positively to organizational (Chien & Tsai, 2012; Tseng & Lee, 2014) and innovation performance (Zheng, Zhang, & Du, 2011).

Dynamic capabilities can be viewed as the result of Knowledge Management activities (Nielsen, Paarup, & Paarup, 2006; Zheng *et al.,* 2011). Tseng and Lee (2014) give evidence to support that development of Knowledge Management promotes the growth of dynamic capabilities. Besides, Knowledge Management and CMMI can be used together, allowing the organization to be more efficient (Dayan & Evans, 2006).

Despite the lack of consensus on the terminology used in knowledge management area (Klimko, 2001), several authors state the possibility of implementing knowledge management maturity models to enable the organization to pursue a path of improvement in this field (Kuriakose & Raj, 2010).

Several scholars have found a positive correlation between better knowledge management and financial performance of the firm (Andreeva & Kianto, 2012; Tanriverdi, 2005; Zack, McKeen, & Singh, 2009), innovation capacity (Darroch, 2005) and organizational performance (Kruger & Johnson, 2011; Tseng & Lee, 2014).

Based on previous literature, we present the first hypothesis:

H1. The performance of a firm is likely to increase after the process of CMMI implementation.

The implementation of CMMI requires a deep organizational change, for which is need to invest several resources and time. These kinds of changes can mean financial losses at least in the short term (Mellert, Scherbaum, Oliveira, & Wilke, 2015) caused by different reasons such as the resistance to change or a bad planning (Kotter, 2007).

Several scholars have pointed the lack of standardized procedures or a clear structure to implement CMMI as some of the main disadvantages of this model (Niazi, Wilson, & Zowghi, 2005; Reifer, 2000), which could hinder achieving the desired results.

In a practical way, Shih *et al.,* 2013 study the implementation of CMMI in an organization, noting that in a first step this change has negative effects on the firm performance.

Based on previous literature, we present the second hypothesis:

H2. The performance of a firm is likely to decline during the process of CMMI implementation.

3. Methods

To study whether the implementation of CMMI creates or not a competitive advantage that is reflected in the economic or financial performance of the firm, we carried a statistical analysis to compare the results of different firms which have or do not have CMMI implemented.

For our analysis, we have chosen Spanish firms in the Information and Technology (IT) sector. This election is based on the fact that despite CMMI is now used in almost every sector, it was initially developed for IT companies. The firm's economic and financial data were obtained from the database "Amadeus". We selected the Spanish firms belonging to the NACE code 62 (Statistical classification of economic activities in the European Community). All these firms belong to the IT sector. We obtained 2130 firms.

We refined this search because, although Amadeus usually contains data of the main economic and financial indicators for the last 10 years, it had incomplete data for some firms. We selected a period of time that gives us a balance between the length of the time interval to study and the number of firms we are able to analyze. We selected the period 2008-2013 for the following reasons:

- It is long enough (6 years) to see a tendency
- It belongs to the same economic cycle: the economic crisis
- The number of firms in this period is quite large: 899 firms, giving us 5394 observations. If we extend the period one year more, the number of firms will drop to 779.

We have selected the following financial and economic indicators for our analysis as they are non-dimensional and they are not prejudiced by the size of the firm: Return on Equity (ROE), Return on Assets (ROA) and Return on Capital (ROC).

The data regarding CMMI implementation was acquired analyzing the results of the CMMI appraisal published on the CMMI website (https://sas.cmmiinstitute.com/pars/pars.aspx). Despite this is the official site for CMMI, it has a drawback for getting the data: it only shows the firms with an active CMMI certification. It means, that we cannot get when the organization first got the certification or if a firm has abandoned it. To deal with this issue, we also looked at Javier Garzas' blog (http://www.javiergarzas.com/2011/12/empresas-espanolas-evaluadas-con-cmmi.html). In this blog, we checked which companies had the certification in 2011. The Caelum consulting website showed which firms had the certification upon February 2007. As these last two sources of information were not the official ones, we validated the information directly with the firms. We contacted them either by phone or email. We found 40 firms that have or have had a CMMI certification during the time period 2008-2013. The annual distribution is shown in Table 1. We can easily see that some firms may have abandoned the certification, and others have got it.

Table 1. CMMI annual distribution for Spanish firms in the IT sector (NACE code 62).

Year	2008	2009	2010	2011	2012	2013
# of firms with CMMI certification	17	23	26	31	36	38

4. Results

We have first performed a descriptive analysis of the data used in this study for a better understanding of the influence of CMMI on the firm performance. We cannot forget that the period under study (2008-2013) belongs to the economic crisis. The initial number of observations was 5394. However, we see that during the analysis this number has decreased due to the closure of some firms.

4.1. Descriptive Analysis of the Data

We analyze the number of employees in the firms, foundation year, sales revenue, ROA, ROC and ROE to understand the evolution during the studied time period.

4.1.1. Number of employees in the firm

In Table 2, we depict the evolution of the number of employees of the firms during the time period. We compare firms with and without CMMI. We can see that the number of employees globally increased despite the economic crisis. Conversely,

the number of employees within the firms which implement CMMI decreases over this time period. One explanation may be that the firms are more efficient and they need fewer employees. However, a better one may be that at the beginning only big corporations implemented CMMI, but over time more and more medium and small firms adopt this maturity model.

4.1.2. Foundation year

Analysing the firms' foundation year, we found that most firms were founded in the 90s. We need to take into account that there are much older firms (founded in the 30s) and much younger firms (founded after 2000). Firms with CMMI implemented are on average a bit older (1993) than firms without CMMI (1997).

4.1.3. Sales Revenue

Analysing the sales revenue we observe a great variability. There are firms without incomes (probably representing closed companies) and companies such as "Indra Sistemas" with almost 3.000 million €.

Distinguishing firms with and without CMMI, we found that on average, firms with CMMI implemented have a greater average (151.70 million €) than the ones without CMMI (8.97 million €).

4.1.4. ROA

Analysing the evolution of the ROA, we find a decreasing tendency during the studied period. We found that the ROA was higher in the firms with CMMI during 2008 and 2011. It was the opposite during 2009, 2010, 2012 and 2013.

For a clear analysis, we discard the 50 more extreme observations, which is less than 1% of our data (see Table 3 for the trend). We observed the same tendency and we reached the same conclusion when we analysis firm with CMMI and without it separately.

Table 3. Evolution of the ROA annual mean without the 50 more extreme observations.

Year	2008	2009	2010	2011	2012	2013
ROA. All firms	9.01	5.93	6.16	5.10	5.17	4.33
ROA. Firms with CMMI	9.05	5.39	6.07	6.25	4.17	1.07
ROA. Firms without CMMI	9.00	5.95	6.17	5.06	5.21	4.48

4.1.5. ROC

Analysing the evolution of the ROc, we find a decreasing tendency during the studied period. We found that the ROC was higher in the firms with CMMI during 2008 and 2010. It was the opposite during 2009, 2011, 2012 and 2013.

For a clear analysis, we discard the 50 more extreme observations, which is less than 1% of our data (see Table 4 for the trend). We observed the same tendency and we reached the same conclusion when we analysis firm with CMMI and without it separately. However, when we discard the extreme observations we find that the distance between the firms with and without CMMI is smaller.

Table 4. Evolution of ROC annual mean without the 50 more extreme observations.

Year	2008	2009	2010	2011	2012	2013
ROC. All firms	22.47	14.99	15.87	13.35	12.74	10.93
ROC. Firms with CMMI	26.81	12.62	17.19	10.76	9.41	1.83
ROC. Firms without CMMI	22.37	15.06	15.83	13.45	12.9	11.39

4.1.6. ROE

Analysing the evolution of the ROE, we find a decreasing tendency during the studied period. We found that the ROE was higher in the firms with CMMI only during 2008. For a clear analysis, we discard the 50 more extreme observations, which is less than 1% of our data (see Table 5 for the trend).

Table 2. Evolution of the number of employees. The data represent the annual mean of employees.

Year	2008	2009	2010	2011	2012	2013
# of employees. All firms	121.88	120.02	124.84	134.13	143.00	145.13
# of employees. Firms with CMMI	2706.80	2058.10	2047.20	1911.40	1838.10	1767.80
# of employees. Firms without CMMI	68.08	66.57	67.76	72.62	71.60	72.71

We observed the same tendency and we reached the same conclusion when we analysis firm with CMMI and without it separately.

Table 5. Evolution of ROE annual mean without the 50 more extreme observations.

Year	2008	2009	2010	2011	2012	2013
ROE. All firms	26.55	15.45	16.11	13.91	11.62	9.42
ROE. Firms with CMMI	28.17	14.97	16.04	8.24	9.27	-11.08
ROE. Firms without CMMI	26.52	15.47	16.11	14.11	11.72	10.37

4.2. Panel Analysis

After describing our sample, we focus on the influence of CMMI on the firm performance. For this purpose, we do a regression analysis during the period of the panel data. The dependent variables are ROA, ROC, ROE and their interannual differences (Dif ROA, Dif ROC, Dif ROE).

The independent variables are:

- CMMI: it takes the value 1 if the company has CMMI in the studied year and 0 otherwise. This variable allows us to study the effect of CMMI certification on the firm performance.
- CMMI Level: if the company has CMMI in the studied year it takes the value of the CMMI certification level and 0 otherwise. This variable allows us to study the effect of CMMI certification level on the firm performance.
- LAG CMMI: if the company has CMMI in the previous year it takes the value 1 and 0 otherwise. It may be possible that the effect of CMMI in the firm performance is not immediate. This variable allows studying the effect of CMMI on the firm performance 1 year after its implementation.
- LAG2 CMMI: if the company has CMMI in the two previous years it takes the value 1 and 0 otherwise. This variable allows studying the effect of CMMI on the firm performance 2 years after its implementation.

We use the number of employees and the foundation year as control variables.

We introduce LAG CMMI and LAG2 CMMI independent variables to distinguish the implementation period and the post-implementation identified in our research hypothesis. We identify when the company adopted CMMI since CMMI will take the value 1 and LAG CMMI and LAG2 CMMI the value 0.

We analyze if CMMI has influence in the interannual variation of the economic and financial performance, and on the absolute economic and financial performance of the firm. As a robustness analysis, we repeat the analysis dividing the sample into two periods. We choose 2010/2011 as breaking point since, in the descriptive analysis, we found that the firms with and without CMMI had a similar performance during the first three years. However, during the second period, the performance of the firms with CMMI was quite worse than the ones without it.

We consider that the regressions are significant if Prob>F is less than 0.05 and that the variable is significant if P>|t| is less 0.05. We have to notice that when the regression has only one variable Prob>F is equal to P>|t|.

4.2.1. Study of the Interannual Variation of the Firm Performance

We study the impact of CMMI on the variation of the firm performance. We analyze 12 statistical regressions to relate Dif ROA, Dif ROC and Dif ROE to our independent variables (CMMI, CMMI Level, LAG CMMI and LAG2 CMMI) in an individual manner. We use the number of employees as a control variable. We find that none of these regressions is significant.

Table 6. Variation on the firm performance vs the implementation of CMMI.

	CMMI		CMMI Level		LAG CMMI		LAG2 CMMI	
	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|
Dif. ROA	-3.26	0.407	-1.25	0.375	-2.41	0.540	-4.13	0.390
Dif. ROC	-16.77	0.308	-6.41	0.311	14.87	0.362	-5.02	0.800
Dif. ROE	-21.13	0.274	-8.67	0.231	12.91	0.507	-10.95	0.650

We repeat the study without the employee number to check if this variable is distorting our results. However, we also find that the regressions are not significant as shown in Table 6.

4.2.2. Study of the Firm Performance

We repeat the study to analyze the effect on the firm performance. We related ROA, ROC, and ROE to the independent variables (CMMI, CMMI Level, LAG CMMI and LAG2 CMMI) individually. We use the number of employees and the foundation year as control variables.

We find that both the adoption and level of CMMI affects negatively to the ROE and ROC as shown in Table 7. The other regressions are not significant, but all of them pointed out the same negative relation.

We repeat the analysis removing the foundation year and the foundation year and a number of employees. We get the same conclusion.

4.2.3. Study of the Firm Performance. Sample Divided in Two Periods

We repeat the study to analyze the effect on the firm performance dividing the time period into two slots as explained above. We related ROA, ROC, and ROE to the independent variables (CMMI, CMMI Level, LAG CMMI and LAG2 CMMI) individually. In this case, we do not use control variables, as the effect of this variables was tested in the previous regression without dividing the time period.

The regression results are shown in Table 8. During the first period, we do not find any significant regression. LAG2 CMMI column is empty because we do not have enough data to calculate the regression. During the second period, we find that both the adoption and level of CMMI affects negatively to the ROE and ROC

5. Discussion and Conclusions

Based on the results presented in section 4, we only found two significant variables to explain the performance of the firm based on the implementation or not of CMMI. These two variables are CMMI (i.e. the existence or absence of CMMI in the firm) and CMMI Level (i.e. the level of CMMI the company has implemented). Both variables are negatively related to the performance of the firm. When we divided the sample into two time periods, we found that these variables only are significant between 2011 and 2013.

CMMI is a maturity model that provides a set of best practices to improve the firm processes, especially in software companies. Looking at CMMI website

Table 7. Firm performance *vs.* the implementation of CMMI.

	CMMI			CMMI Level		
	Coef.	P>|t|	Prob > F	Coef.	P>|t|	Prob > F
ROA	-5.37	0.036	0.1700	-1.99	0.049	0.2100
ROC	*-36.30*	*0.001*	*0.0039*	*-16.76*	*0.000*	*0.0007*
ROE	*-31.64*	*0.019*	*0.0320*	*-13.85*	*0.015*	*0.0260*
	LAG CMMI			LAG2 CMMI		
	Coef.	P>|t|	Prob > F	Coef.	P>|t|	Prob > F
ROA	-4.82	0.104	0.364	-3.20	0.353	0.8000
ROC	-24.40	0.058	0.160	-14.87	0.303	0.6500
ROE	-14.73	0.358	0.310	-12.73	0.474	0.7093

Table 8. Firm performance *vs.* the implementation of CMMI. Period 2008-2010 and 2011-2013.

	CMMI		CMMI Level		LAG CMMI		LAG2 CMMI	
2008 - 2010	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|
ROA	1.330	0.798	0.508	0.804	1.16	0.865	*	*
ROC	-5.000	0.815	-2.260	0.788	1.20	0.969	*	*
ROE	-2.625	0.930	-1.390	0.907	2.50	0.949	*	*
2011 - 2013	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|	Coef.	P>|t|
ROA	-7.40	0.065	-2.41	0.112	-6.40	0.129	-3.56	0.450
ROC	*-53.94*	*0.001*	*-25.70*	*0.0001*	-17.37	0.316	-13.78	0.456
ROE	*-48.72*	*0.017*	*-20.02*	*0.011*	-11.55	0.589	-11.78	0.645

we find which companies have adopted this maturity model and when.

Based on the literature, we established a positive relation of the application of CMMI and the firm performance (Goldenson & Gibson 2003; Gibson *et al.,* 2006). However, CMMI has also been criticized for its difficulty to put the model in practice (Reifer 2000; Sun & Liu 2010).

Dynamic Capabilities are defined as the capacity to organize, integrate and develop new capabilities (Teece *et al.,* 1997). Teece (2014) considers that Dynamic Capabilities are inimitable; they should be built and learned. On the other hand, Eisenhardt & Martin, (2000) consider them as replicable processes. Following this view, CMMI may help to develop Dynamic Capabilities (Lee & Wu 2007).

CMMI implementation triggers a complex change in the organization. It requires an investment of time and other resources. This kind of changes may carry economic losses in the company in the short term (Mellert *et al.,* 2015). This is also the case when implementing CMMI (Shih *et al.,* 2013). This statement has been validated by our empirical study; however, we do not consider six year is a short time period.

We were not able to validate our research hypothesis 1 "*The performance of a firm is likely to increase after the process of CMMI implementation*". We found a negative relationship between the use of CMMI and the performance of the firm.

We neither could validate research hypothesis 2 "*The performance of a firm is likely to decline during the process of CMMI implementation*" since LAG CMMI and LAG2 CMMI variables were not significant. To be able to validate this second hypothesis LAG CMMI and LAG 2 CMMI should have been positively correlated to firm performance since these variables show if the firm has just implemented CMMI, it has been implemented in the company for one year (LAG CMMI) or for two years or more (LAG2 CMMI).

These results should be understood as a preliminary study and they must be put in the right context. The time period under study belongs to the economic crisis, which had a special impact in Spain. Moreover, the number of companies that use CMMI is relatively small compared to the total sample. We know the results of the CMMI appraisal; however, we do not know the commitment of the company with CMMI. We also need to take into account that the firms with CMMI grew significantly during the time period under study. So, this growth may also be a cause for its economic and financial recession.

To drive general conclusions, this study should be replicated in other countries and during longer time periods. Moreover, other variables, such as the commitment of the company to CMMI or the reason for implemented CMMI should be included.

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