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THE INFLUENCE OF IT INNOVATION MECHANISMS ON HEALTHCARE PROJECT MANAGEMENT STRATEGIES

Walter AMEDZRO ST-HILAIRE[1], Catherine DE LA ROBERTIE[2]

[1]*University of Ottawa, Canada*
[2]*University of Paris 1 Panthéon-Sorbonne, France*
Corresponding author e-mail: a.st-hilaire@telfer.uottawa.ca

Abstract. Healthcare projects with apparent productivity gaps require all available IT innovation mechanisms. The objective of this study is to investigate the predictors of the development of IT innovation mechanisms to improving healthcare business. This includes the utilization of the panel data in healthcare projects and the analysis of the relationship between IT innovation mechanisms and operational decision-making. The paper indicates that the implementation of innovative IT technology has a significant positive effect on the healthcare project productivity in Canadian hospitals.

Keywords*: Canadian hospitals, healthcare business, healthcare projects, IT innovation mechanisms, operational decision-making, project productivity.*

INTRODUCTION

Owing to a great public support by the government and private organizations alike, healthcare management industry has witnessed a significant influx of IT innovation mechanisms, and it has seen an increased project productivity resulting from the use of IT innovative tools. Today, implementation of IT innovation mechanisms is a standard for managing healthcare projects, and it has a strong effect on various aspects of the healthcare project management practice. This has resulted in the increased productivity as well as improved operational decision-making in healthcare projects.

The evolution and the widespread use of IT innovation mechanisms triggered important changes in Canadian healthcare project management practices. According to Zhou, Q., Zhang, H. L. and Wang (2012) statistical results, almost 1/4 of healthcare project productivity increase resulted from the implementation of IT innovation mechanisms. Overall, it should be noted that the technological advances in the realm of IT and communication contributed to the 8 % increase in project productivity.

Compared to the traditional management practices, IT and knowledge management have stronger impact on operational decision-making in the era of knowledge-driven healthcare project management. Owing to the development of IT infrastructure, Canadian healthcare projects are no longer constrained to a limited number of local projects; rather, they have the potential to become large, country-wide projects.

Owing to the positive initiatives and the support by the public policy makers, new healthcare operational strategies focusing on the active application of IT

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innovation mechanisms have begun to develop. Since 2011, hospital healthcare project revenue and profit have grown by 8.9 percent and 6.1 percent respectively. We can see a sharp increase in healthcare project revenues from the sale of electronic devices, reaching $639 billion, which is above a designated volume; while, at the same time, the average annual growth rate exceeded 15 percent in five years. In other areas of the healthcare project management, the implementation of IT innovation mechanisms has played a positive role in the process of transformation of the healthcare practices.

Mobile applications use in the Identification Phase of hospital projects (the request is clarified, the objectives specified, and the overall project identified with respect to the product or service to be delivered, Constraints and implementation strategy) has reached 74.6 percent on average; the active use of mobile applications in the Definition phase (the content of the project is defined more precisely, a detailed planning is established for its entire duration; timeframes, resources, expenditures, and management policies and procedures are circumscribed) is in the net increase of 38.3 percent, while the computer applications penetration rate in the Implementation phase (the product or service is actually carried out according to the envisaged plan and in accordance with the requirements of the applicant) reached more than 70 percent.

This paper focuses on the relationship between the decision-making factors of innovation strategy and the productivity of the healthcare projects. The data was collected over a period from 2005 to 2015 in a cross section of 31 hospitals in Canada. We applied the Cobb-Douglas production function as the basic model, followed with the Hausman test. We set up the adjustable panel model for the empirical analysis of the impact of innovation factors on productivity. In terms of variables, we selected the innovation productivity index (IPI). We performed an analysis of the healthcare projects in three Canadian provinces (Quebec, Ontario, and Alberta), amongst which there exists a project productivity gap. We studied whether the implementation of the innovative IT mechanisms has had influence on any of the specific districts and their healthcare project productivity. The objective of this study is to investigate the predictors of the development of IT innovation mechanisms to improving healthcare business.

1. CONCEPTS REVIEW

The empirical analysis of the relationships between IT innovation mechanisms and the healthcare project productivity has been divided into two stages. In the analysis of the IT statistics, Stanley and Roach (1987) established that the increased use of computers only did not augment project productivity. Strassman (1997b) researched 292 projects, and, as a result, he found out that there is a significant correlation between the investment in innovative IT infrastructure (computers) and return on investment (ROI). In 1987, Solow suggested that "Computers are everywhere except in the productivity statistics", and called this kind of phenomenon the "productivity paradox". In other words, although companies have invested a large amount of resources in IT innovation, from the productivity perspective, the effects were minor. Oliner and Sichel (1994) researched specific annual data from 1970 to 1992, and discovered that the input of innovative factors exerted little impact on the project productivity and governance.

From then on, scholars have paid close attention to the "Solow productivity paradox". They put forward numerous hypotheses to explain the reasons behind this "productivity paradox". The most representative hypotheses were the "mechanism delay hypothesis" and the "capital stock hypothesis".

David (1990) found out that over forty years the usage of electronic devices has significantly contributed to the project productivity increase; according to him, IT innovation mechanisms would have had a tremendous potential to contribute to productivity increase, and it was just a matter of time. Oliner and Sichel (1994) proposed the "capital stock hypothesis" suggesting that although the implementation of IT application has been rather fast in the process of decision-making, owing to the mechanisms, it will still be limited to make susceptible contributions to the productivity of projects.

The two aforementioned hypotheses explain the productivity paradox, implying that when certain external conditions change (such as time or stock increase), then the investment in IT innovation mechanisms exerts a positive effect on project productivity. In the late 1990s, the recovery of the project economics eventually challenged these hypotheses since various statistics have shown that the development of IT infrastructure started to exert a significant influence on project productivity. Hence, more and more scholars observed that "productivity paradox" was no longer applicable.

Kim (2002) noted that capital investment is not only an important factor for project success in the short run, but it also has a positive effect on the long run productivity increase. The positive contribution of the IT innovation mechanisms to project performance stems from the growth in capital investment, rather than from the increase in business growth. Using the empirical data, Ramirez & Cockburn (2012) have shown that the investment in IT innovation mechanisms has a great impact on the project productivity increase. Rahmah (2011) and Nivikar (2012) explored the long-run relation and the short-run causal dynamics between the implementation of IT innovation mechanisms, increases in financial investment and project productivity with use of the vector-error-correction model.

They concluded that the IT innovation mechanisms are relatively more important than the financial investment for propelling the long-run project productivity. Jorgenson (2002) and Kooshki (2011) indicated that there is a positive relationship between the effectiveness of projects and decision-making. They found that productivity has a higher effect on the performance of project governance. Hossein (2012) suggested that an increase in innovation tools affects the effectiveness of operational decision directly and that the productivity stimulates further innovations.

Referring to project operational decision-making, Maryam & Rahmah (2011) and Nivikar (2012) empirical data analysis indicated that there was an overall positive correlation as well as a low-value and high-value clustering phenomenon between the gross domestic product and the implementation of the IT innovation mechanisms. Significantly (reflected an obvious spatial heterogeneity), the more the projects are in their Closing phase (the product or service is delivered to the applicant, the project is evaluated, and its administrative closure is carried out), the greater the contribution of innovation to productivity. As a result of panel data analysis, they added the IT innovation mechanisms factor to the traditional measures of productivity in the healthcare project management model. Their research suggests that innovation always has a positive impact on the overall project productivity, and that there is a threshold effect. The equilibrium traps exist in project planning as to the innovation to promote the productivity. Jorgenson, Dale W, Mun S. Ho, and Kevin J. Stiroh., (2002) performed empirical analysis of the influence of IT innovation on productivity using the VAR model.

The results show that there is a long-term co-integration between the investment in IT innovation mechanisms and project productivity; in the short term, the implementation of IT innovation mechanisms improved project productivity; in the long term, the investment in IT innovation mechanisms contributed to the productivity by around 40 percent; the productivity stimulated the investment in IT innovation mechanisms, but there was no Granger causality relationship between them.

This paper uses the model based on the traditional Cobb-Douglas production function to assess the technological progress factor, commonly used in most empirical studies. Taking the logarithms of the Cobb-Douglas function, the function can be represented as follows:

$$\ln Y_{it} = \ln A + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln IPI_{it} + \delta \ln openness_{it} + \phi \ln PPI_{it} + u_{it},$$

where *Y* indicates gross domestic product referring to healthcare project productivity, *K* indicates the fixed assets investment, *L* indicates the number of projects, and IPI indicates the IT innovation mechanisms implementation referring to technological progress. *Openness* indicates trade openness, and PPI is a project's price index, which implies the price level. *A* is a constant; $\alpha, \beta, \gamma, \delta, \phi$ are coefficients, i indicates respective hospitals, t indicates time, and u_{it} is an error term.

The error term can be further divided into two parts, and it is shown as follows:

$$u_{it} = u_i + v_{it},$$

where u_i indicates the unobservable specific effects which only change among different individuals, and v_{it} is a pure error term which changes both in time and among individuals.

Panel data can be analyzed in approximately two ways, utilizing either a fixed effect model (FE) or a random effect model (RE). In general, we can use the Hausman test to determine which of the two we should use. The null hypothesis and alternative hypothesis will be:

$$H_0\text{: } \operatorname{cov}(x_{it}, u_i) = 0,$$

$$H_1\text{: } \operatorname{cov}(x_{it}, u_i) \neq 0.$$

If we accept the null hypothesis, either FE or RE will be available and we will find similar results in these two models. However, if we reject the null hypothesis and accept the alternative hypothesis, the estimator of RE will no longer be the consistent estimator, and only FE will be available.

We used annual panel data from 31 hospitals over the period from 2005 to 2015. The data was retrieved from the Canadian National Statistical Office. We used the annual provincial gross domestic product as the indicator of the healthcare project productivity in each hospital, and the total investment in fixed assets (units: billion) was used as the comprehensive indicator of the scale of investment in fixed assets in all the projects. Taking into account the differences between economic growth levels among provinces, we have divided the project geographically to Alberta, Ontario, and Quebec, in order to analyze the relationship between the implementation of IT innovation mechanisms and the healthcare project productivity in each region.

Table 1. Innovation mechanisms index (IPI)

Combined index	Sub-index	Specification
Innovation productivity index	Infrastructure index	Phone ownership rate (/100)
		Television ownership rate (/100)
		Computer ownership rate (/100)
	Industrial technology index	Telecom industry output value per capita
		Invention patent applications per one million people
	Applied project index	Internet penetration (/100)
		Consumption of information per capita
	Knowledge support index	Proportion of the numbers of practitioners in information
		Education index
	Productivity effect index	The added value of information industry accounted for gross domestic product
		The information research and productivity spending accounted for gross domestic product
		Gross domestic product per capita

In order to analyze the impact of IT innovation strategy on healthcare project productivity, we selected a comprehensive indicator to represent the implementation of IT innovation mechanisms in the process of operational decision-making. Previous studies have shown that capital stock or the amount of capital investment was usually used to represent the level of the innovation productivity. This paper applies the additional variable, namely, the innovation productivity index (IPI) in operational decision making to indicate the mechanism factors impacts. Table 1 shows the specific classifications of the innovation productivity index (IPI).

Table 2. Sample data

Provincial health projects	Variable	Mean	Std. dev.	Min	Max	Obs.
All	*GDP*	9894.39	9924.86	162.04	57 067.92	341
	K	5365.05	5467.67	106.58	31 255.98	341
	L	62 076.41	129 626.7	1767	907 427	341
	IPI	0.62649	0.11423	0.388	1.11	341
	openness	$6.81 \cdot 10^7$	$1.39 \cdot 10^8$	130 370	$9.84 \cdot 10^8$	341
	PPI	105.34	47.83	97.7	110.1	341
Quebec	*GDP*	16 089.46	12 817.69	642.73	57 067.92	121
	K	7673.056	6816.243	225.41	31 255.98	121
	L	70 962.95	150 558.5	5321	907 427	121
	IPI	0.71174	0.13103	0.486	1.11	121
	openness	$1.74 \cdot 10^8$	$1.94 \cdot 10^8$	1 866 800	$9.84 \cdot 10^8$	121
	PPI	109.74	80.26	97.7	106.9	121
Ontario	*GDP*	9165.89	5838.23	2324.8	29 599.31	88
	K	5584.04	4572.61	813.36	21 450	88
	L	77 882.36	143 005.7	18 363	876 943	88
	IPI	0.5933	0.05918	0.460	0.763	88
	openness	$1.36 \cdot 10^7$	$1.02 \cdot 10^7$	1 694 470	$5.17 \cdot 10^7$	88
	PPI	102.84	2.285	98.4	107.2	88
Alberta	*GDP*	4701.24	4420.59	162.04	23 872.8	132
	K	3103.38	3322.43	106.58	17 039.98	132
	L	43 393.12	93 125.75	1767	730 821	132
	IPI	0.57046	0.07207	0.388	0.761	132
	openness	7 679 673	9 848 179	130 370	$5.91 \cdot 10^7$	132
	PPI	102.97	2.39	97.9	110.1	132

Table 2 lists the basic statistics of the sample data. The data indicates that the average gross domestic product amongst all analyzed hospitals is 9894.39 billion, which ranges from 162.04 billion to 57 067.92 billion. The average of total investment in fixed assets was 5365.048 billion, ranging from 106.58 billion to 31 255.98 billion. The average number of projects is 62 076, ranging from 1767 to 907 427. The average innovation productivity index (IPI) was 0.626, ranging from 0.388 to 1.11, which is quite a wide gap. Moreover, the average of openness is $6.81 \cdot 10^7$, ranging from 130 370 to $9.84 \cdot 10^8$. The average PPI is 105.34, ranging from 97.7 to 110.1.

2. EMPIRICAL ANALYSIS

In order to select the most appropriate model for our analysis, we first conducted the Hausman test. Function (1) is the estimation without environmental factors, and function (2) is the estimation with environmental factors.

Table 3. Hausman Test

Provincial health projects	Function	*F*-value	Model

All	(1)	195.89***	Fixed effect model
	(2)	185.03***	
Quebec	(1)	61.58***	
	(2)	63.28***	
Ontario	(1)	25.34***	
	(2)	70.00***	
Alberta	(1)	85.71***	
	(2)	84.75***	

*** indicates that adopt fixed effect model at 1 percent significance level.

According to the results of the Hausman test shown in Table 3 all the models reject the null hypothesis which can be used in both fixed effect model and random effect models, under 1 percent significance level. In other words, the fixed effect model can be more precisely estimated than the random effect model.

Based on the results of the Hausman test, we conducted the estimation with the fixed effect model. The results of the estimation (among all provinces) and its operational impact on the healthcare project management are shown in Table 4. All the following estimations are conducted by using the heteroscedasticity adjustment.

Table 4-1. Estimation of all projects

Variable	ln *GDP*			
	(1)		(2)	
	coefficient	*t*-value	coefficient	*t*-value
constant	5.315	16.81***	3.602	11.43***
ln *K*	0.507	18.02***	0.430	10.42***
ln *L*	−0.002	−0.66	−0.001	−0.39
ln *IPI*	1.415	7.23***	1.212	7.47***
ln *openness*	–	–	0.121	3.95***
ln *PPI*	–	–	0.047	3.19***
R^2	0.976		0.980	
F-test	1026.45		733.28	

*,** – significant at 1 percent significance level.

Table 4-2. Estimation of health projects in Quebec

Variable	ln *GDP*			
	(1)		(2)	
	coefficient	*t*-value	coefficient	*t*-value
constant	5.929	14.20***	1.953	2.28**
ln *K*	0.470	−1.08	0.332	6.96***
ln *L*	−0.005	6.33***	−0.008	−1.85*
ln *IPI*	1.561	14.02***	1.050	5.74***
ln *openness*	–	–	0.266	4.54***
ln *PPI*	–	–	0.029	4.95***
R^2	0.971		0.983	
F-test	409.99		1126.47	

**** – significant at 10 percent and 1 percent significance level respectively.

Table 4-3. Estimation of health projects in Ontario

Variable	ln *GDP*			
	(1)		(2)	
	coefficient	*t*-value	coefficient	*t*-value
constant	5.639	10.76***	3.978	3.16**

ln *K*	0.484	11.45***	0.403	7.49***
ln *L*	0.002	0.63	0.002	0.76
ln *IPI*	1.390	3.83***	1.196	3.54***
ln *openness*	–	–	0.120	2.55**
ln *PPI*	–	–	0.063	0.18
R^2	0.9834		0.986	
F-test	534.6		1339.02	

*, *** – significant at 10 percent and 1 percent significance level respectively.

Table 4-4. Estimation of health projects in Alberta

Variable	ln *GDP*			
	(1)		(2)	
	coefficient	*t*-value	coefficient	*t*-value
constant	4.097	9.69***	−1.954	−1.71
ln *K*	0.595	15.02***	0.593	12.27***
ln *L*	−0.002	−0.32	0.004	0.67
ln *IPI*	0.991	3.80***	0.845	3.28***
ln *openness*	–	–	0.010	0.24
ln *PPI*	–	–	1.247	4.01***
R^2	0.981		0.983	
F-test	455.91		784.01	

*** – significant at 1 percent significance level.

According to the results in Table 4-1 regarding the estimation of all projects, in the function (1), when other conditions are unchanged, *K* increases in each by 1 percent, and the performance augments by 0.507 percent; *L* increases in each by 1 percent, and the performance decreases by 0.002 percent; IPI increases in each 1 percent, and the productivity rises by 1.415 percent. In the function (2), when other conditions are unchanged, *K* increases in each 1 percent, and the productivity augments by 0.43 percent; *L* increases in each 1 percent, and the performance decreases by 0.001 percent; IPI increases in each 1 percent, and the performance rises by 1.212 percent; openness increases in each 1 percent, and the productivity increases by 0.121 percent; PPI increases in each 1 percent, and the performance augments by 0.047 percent.

In both functions, all parameters, except for the parameter of projects, reject the null hypothesis with significance level under 1 percent. Hence, fixed asset investment, the sum of export and import, PPI and informatics mechanism have positive effects on the productivity of the healthcare projects. And, in contrast, there are no significant relationships between IT innovation and the productivity of health projects.

Table 4-2, Table 4-3, and Table 4-4 demonstrate the results of the estimation in each province separately: Quebec, Ontario, and Alberta. According to the results in Quebec, Ontario and Alberta, with the estimation in function (1), with other conditions unchanged, *K* increases in each 1 percent, and the performance of project will averagely augment by 0.470 percent, 0.484 percent and 0.595 percent respectively; *L* increases in each 1 percent, and the performance will decrease by 0.005 percent and 0.002 percent in Quebec and Alberta respectively and increase by 0.002 percent in Ontario; IPI increases in each 1 percent, and the profitability will augment by 1.561 percent, 1.390 percent and 0.991 percent respectively. With the estimation in function (2), when other conditions unchanged, *K* increases in each 1 percent, and the satisfaction will averagely augment by 0.332 percent, 0.403 percent and 0.593 percent respectively; *L* increases in each 1 percent, and the performance will decrease by 0.008 percent in Quebec and increase by 0.002 percent and 0.004 percent in Ontario and Alberta respectively; IPI increases in each 1 percent, and the performance will augment by 1.050 percent, 1.196 percent and 0.845 percent respectively; openness increases in each 1 percent, and the satisfaction will augment by 0.266 percent, 0.12 percent and 0.01 percent respectively; PPI increases in each 1 percent, and the performance will rise by 0.029 percent, 0.063 percent and 1.247 percent respectively.

In all functions, *L* does accept null hypothesis with 1 percent significance level, and PPI in Ontario and openness in Alberta do not reject the null hypothesis either. Hence, fixed assets investment and PPI have positive impact on the healthcare project productivity and management in all three districts; a number of projects has had a negative influence on the project productivity (Quebec) – however, it has no significant influence in other two provinces (Ontario and Alberta); trade openness has a positive effect on the healthcare project productivity in Quebec and Ontario, while it has no significant impact on the healthcare project productivity in Alberta.

CONCLUSION

The paper analyzes the relationships between IT innovation mechanisms and healthcare project productivity in three provinces in Canada. Though much research has been done on this topic (Aghion, P., Blundell, R., Griffith, R., Howitt (2009) & Swift (2012)), it is equally true that there is still considerable conflict, and to erase this gap has been an inspiring objective of this study.

To overcome these shortcomings, Panel data was used from a cross section of 31 hospitals over the period from 2005 to 2015. The main conclusions can be summarized as follows: in the static panel model across all provinces, the productivity indexes all have a significant positive effect on the gross domestic product. In other words, IT innovation mechanisms have a positive influence on the productivity of healthcare projects. The impact of the IT innovation mechanisms is higher than other four factors: fixed assets investment, number of projects, trade openness, and PPI.

The contribution of IT innovation mechanisms to the healthcare project productivity in Alberta is relatively lower than in Quebec and Ontario, and this may be the result of a relatively low innovation productivity level in Alberta. Therefore, the findings from this paper suggest that developing IT innovation mechanisms is an important strategy for improving the healthcare project economics. In the era of innovation, more attention should be given to the availability of IT innovation tools and to its even mechanism.

The major limitation of the present paper is its failure to add more control variables to the model. Therefore, future research using more control variables would shed more light on the relationship between IT innovation practices and healthcare project productivity.

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AUTHORS' SHORT BIOGRAPHIES

Walter Amedzro St-Hilaire is a Professor at the University of Ottawa. He has written a number of articles that have appeared in international journals. He also guest edits special editions of various journals devoted to managerial economics and industrial organization.
E-mail: a.st-hilaire@telfer.uottawa.ca

Catherine de La Robertie is a Professor at Paris 1 Panthéon-Sorbonne University. She is the author of numerous scientific publications and communications and the Head of Strategy and Business Economics Division at Sorbonne Management School.
E-mail: catherine.de-la-robertie@univ-paris1.fr