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Choosing the right amount of healthcare information technologies investments

Rodolphe Meyer [a,c,*], *Patrice Degoulet* [b,c,1]

[a] *University Hospitals of Geneva, Geneva, Switzerland*
[b] *Université Paris Descartes & HEGP, Paris, France*
[c] *INSERM - U729, Paris, France*

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ABSTRACT

Objectives: Choosing and justifying the right amount of investment in healthcare information technologies (HITECH or HIT) in hospitals is an ever increasing challenge. Our objectives are to assess the financial impact of HIT on hospital outcome, and propose decision-helping tools that could be used to rationalize the distribution of hospital finances.
Design: We used a production function and microeconomic tools on data of 21 Paris university hospitals recorded from 1998 to 2006 to compute the elasticity coefficients of HIT versus non-HIT capital and labor as regards to hospital financial outcome and optimize the distribution of investments according to the productivity associated with each input.
Results: HIT inputs and non-HIT inputs both have a positive and significant impact on hospital production (elasticity coefficients respectively of 0.106 and 0.893; R^2 of 0.92). We forecast 2006 results from the 1998 to 2005 dataset with an accuracy of +0.61%. With the model used, the best proportion of HIT investments was estimated to be 10.6% of total input and this was predicted to lead to a total saving of 388 million Euros for the 2006 dataset.
Conclusion: Considering HIT investment from the point of view of a global portfolio and applying econometric and microeconomic tools allow the required confidence level to be attained for choosing the right amount of HIT investments. It could also allow hospitals using these tools to make substantial savings, and help them forecast their choices for the following year for better HITECH governance in the current stimulation context.
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1. Introduction and objectives

It has become almost impossible to make a strategic decision without involving information technology (IT) in modern hospitals [1]. For example, the new 2009 American Recovery and Reinvestment Act (ARRA) regarding Health Information Technologies (HITECH or HIT) gives strong incentives concerning high technology investments and especially electronic health records (EHRs) in US hospitals [2]. However, HIT continues to increase expenditure on lines for which nearly all decision makers believe that clear profitability has not been demonstrated [3]. Difficulties in capturing the impact of IT in national economies have first been expressed by Economy Nobel Prize winner Robert Solow's in a New-York Times 1987 interview: "*You can see the computer age everywhere but in the productivity statistics*". If there is widespread agreement about the importance of health information systems (HIS), the per-

* *Corresponding author at*: University Hospitals of Geneva, Service of Medical Informatics, 24, rue Micheli-Du-Crest, CH-1211 Genève 14, Switzerland. Tel.: +41 0 22 30 55 878.
E-mail addresses: rodolphe.meyer@sim.hcuge.ch (R. Meyer), patrice.degoulet@egp.aphp.fr (P. Degoulet).
1 Address: Université Paris Descartes & HEGP, Laboratoire SPIM, 15 rue de l'école de Médecine, 75006 Paris, France.
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ceived lack of financial benefits raises the recurrent problem of justifying the associated investments and deciding on the appropriate amount of money to spend on IT. The result is that IT investments will inevitably be too low in the opinion of chief information officers (CIO) and always too high for chief executive officers (CEO). It has as a consequence become essential to quantify accurately the added value of appropriate IT investments in the healthcare sector [4].

Relationships between IT and hospital activities are indeed complex and the economic impact of new IT investments is difficult to grasp. To perform this task, the most common tools available are accounting methods like cost benefits analysis, net present value and internal rate of return [3,5–10]. These return-on-investment (ROI) methods can be applied to almost every investment project of any kind. Cost-benefit analyses [4,11–13] mainly emphasize the indirect earnings (e.g., quality and continuity of care, users' satisfaction, and process optimization) transformed into a monetary value of implementing a particular clinical information system component (e.g., computerized physician order entry (CPOE), clinical decision support systems (CDSS) or picture archiving and communications systems (PACS)) [1,3,14–18]. To achieve the best results these methods have to accumulate an exponentially increasing number of variables which might result in them failing as they become overly complex. In most cases, as the accuracy required increases, the amount of effort needed to feed the method rather than working the project also increases. Furthermore, all these financial methods, when used to evaluate a future investment, tend to be systematically biased against innovation [5,19]. As Christensen said in the January 2008 Harvard Business Review about their exclusive use "*they divert resources away from investments whose payoff lies beyond the immediate horizon*" [20]. In addition, all studies using accounting ROI reach their limits by focusing only on specific, identified and targeted types of benefits, neglecting the overall added value of the project on a strategic level. Only a handful of studies have attempted to measure overall earnings resulting from the integration of the different HIS components into a global portfolio or strategic approach [13,6,21,22]. Isolating and trying to measure the value added by a single project, like a PACS acquisition and deployment, is akin to assessing the value contributed by the cheese to a pizza. As Computer world columnists pointed out "*the idea that there are IT projects must be abandoned. There are only projects targeted at improving business processes, developing new products or services, delivering more efficient customer service or improving some other aspect of business performance*" [23].

Thus, many decision makers rely only on classic financial techniques that do not necessarily capture all the business benefits of their IT investment [24] and the contradictory results of some of these studies frequently lead hospital managers to make decisions solely on the basis of expected indirect benefits and/or empirical evidence.

A complementary approach to respond to this issue is provided by the set of tools emerging from econometric research. Econometrics is concerned with the development and application of quantitative and statistical methods to the study and elucidation of economic principles [25,26]. These methods can be extended from the macroeconomic level to the level of individual businesses to analyze the overall impact of particular investments in a global portfolio perspective as validated in prior research on industrial business [5,22]. In a preliminary study of 17 French acute-care hospitals, we observed a positive and significant relationship between IT investment (including capital and labor) and hospital productivity over an 8-year period (1998–2005) [21]. The results also showed that the expected benefits from the investments made were directly related to the integration level of the HIS: the higher the integration level, the greater the benefits. Another econometric study, based on a much larger but heterogeneous set of two thousand US hospitals, showed that higher levels of IT investment correlate with improved hospital cost performance [22]. This study also showed that IT acquisitions are cost-additive until a "critical mass" is achieved, at which point the relationship becomes neutral for a period of time but ultimately turns positive. Another interesting result is that there is a natural lag between technology implementation and the emergence of benefits. Cost reductions can be made in the same year as the IT acquisition, but generally it took 2–5 years to break even [22].

This paper explores the relationships between hospital financial outcomes and IT and non-IT inputs in a longitudinal study of 21 university hospitals. The objectives are (1) to assess the respective links between IT and non-IT inputs and hospital outcomes; (2) to assess the predictive capacity of an econometric model in an homogenous group of structures; (3) to measure the technical substitution relationship between IT and non-IT investments; and (4) to compute the optimized proportion of IT inputs versus non-IT inputs to get the best incomes for an hospital.

2. Materials and methods

2.1. Production functions

The economic approach of capital efficiency is generally represented by the ratio of production divided by capital expenditure [26]. A large ratio indicates better capital efficiency, leading to a greater output [27–29]. In the econometric field, sensitive data on this efficiency are provided by the utilization of a production or cost function. A production function links the growth and productivity of an enterprise to the elements, or production factors, used to generate products or services [30]. A mathematical relationship is established between the production (output) and the factors put together to obtain it (inputs). The American economist Paul Douglas and the mathematician Richard Cobb made a major step forward by proposing a non-linear function linking yearn or output (Y), capital (K) and labor (L) [30,31]. The initial studies with this function undertaken in 1930 particularly concerned the industrial sector, and since then it has been applied in all economic sectors seeking efficiency. In 1956, Nobel Prize winner Robert Solow enhanced the function by introducing a new factor known as the Solow residual (A) that is traditionally regarded as a marker of technology level [32]. The Solow production function can be expressed as

$$Y = AK^{\alpha}L^{\beta} \quad (1)$$

where Y represents the output (or yearn) observed; K is the capital stock modulated by a depreciation factor depending on the nature of the investment; and L is the quantity of labor expressed as a monetary value. Alpha and beta are called elasticity coefficients and represent the share of each input explaining the output Y.

The classical Cobb-Douglas functions assume constant elasticity of substitution of the inputs (i.e., $\alpha + \beta = 1$) an assumption that economists also call constant return to scale [31]. We choose to assume the same constant elasticity in this study. Knowing the value of the output (Y) and of the inputs (K, L), the value of the elasticity factors α and β can be calculated to estimate the contribution of each input to the observed output [33].

Studies aiming to compute the impact of information technologies traditionally regroup IT capital and IT labor in a third variable called T still assuming the constant elasticity of substitution of the inputs (i.e., $\alpha + \beta + \gamma = 1$) [5,21]:

$$Y = AK^{\alpha}L^{\beta}T^{\gamma} \tag{2}$$

The mathematical properties of the function can be used to adapt it to study the effects of IT in comparison to those of other inputs. For this purpose, the capital and labor are combined and then separated between what is associated with IT and what is not. This leads to the following equation:

$$Y = A(\overline{IT})^{\alpha}(IT)^{\beta} \tag{3}$$

where $\overline{IT}$ represents the amount of non-IT capital and labor investments (called non-IT inputs); and IT represents the same capital and labor investments restricted to the IT field (called IT inputs). The constant return to scale (i.e., $\alpha + \beta = 1$) can also be assumed for this function. The most interesting property of the constant elasticity of substitution of the inputs lies in its definition. It assumes that it is possible to substitute non-IT inputs with IT inputs to achieve the same production. This allows evaluation of the proportion of an input that can be substituted with the other.

2.2. *Marginal rate of technical substitution*

The marginal rate of technical substitution (MRTS) is the rate at which an enterprise is able to substitute one input for another while keeping a constant level of output [34,35]. For our context of non-IT versus IT input, the MRTS corresponds to the supplementary amount of IT input needed to maintain the production level when a unit of non-IT is eliminated. Mathematically, the MRTS is the ratio of the production function derivatives:

$$dY(\overline{IT}, IT) = \frac{\partial Y}{\partial \overline{IT}} d\overline{IT} + \frac{\partial Y}{\partial IT} dIT \tag{4a}$$

$$\text{MRTS}\,(\overline{IT}, IT) = \frac{\partial Y/\overline{IT}}{\partial Y/IT} \tag{4b}$$

$$\text{MRTS}\,(\overline{IT}, IT) = \frac{A\alpha(\overline{IT})^{\alpha-1}(IT)^{\beta}}{A(\overline{IT})^{\alpha}\beta(IT)^{\beta-1}} \tag{4c}$$

2.3. *Average and marginal productivity*

The productivity of an input indicates the influence of this input on the output, given that the other inputs remain constant. The average productivity (AP) of an input represents the total output produced divided by the quantity of a specific input:

$$AP_{\overline{IT}} = \frac{Y(\overline{IT}, IT)}{\overline{IT}} = A(\overline{IT})^{\alpha-1}(IT)^{\beta} \tag{5}$$

$$AP_{IT} = \frac{Y(\overline{IT}, IT)}{IT} = A(\overline{IT})^{\alpha}(IT)^{\beta-1} \tag{6}$$

The marginal productivity (MP) of an input represents the additional production obtained when adding one unit of that particular input:

$$MP_{\overline{IT}} = \frac{\partial Y(\overline{IT}, IT)}{\partial \overline{IT}} = \alpha A(\overline{IT})^{\alpha-1}(IT)^{\beta} \tag{7}$$

$$MP_{IT} = \frac{\partial Y(\overline{IT}, IT)}{\partial IT} = \beta A(\overline{IT})^{\alpha}(IT)^{\beta-1} \tag{8}$$

The elasticity coefficient of an input is the ratio of the marginal productivity of this input to the average productivity of this same input:

$$\alpha = \frac{MP_{\overline{IT}}}{AP_{\overline{IT}}} \tag{9}$$

$$\beta = \frac{MP_{IT}}{AP_{IT}} \tag{10}$$

2.4. *Output optimization*

These elements make possible further analysis and estimation of the optimal proportion of non-IT versus IT capital investment; in general economy, this is known as cost minimization ($Min_{\overline{IT},IT} C$) under a production constraint ($\bar{Q}$) In our case the hospitals have obvious budgetary constraints:

$$\begin{cases} \underset{\overline{IT},IT}{Min} C(\overline{IT}, IT) = \overline{IT} + IT + f \\ Q(\overline{IT}, IT) = A(\overline{IT})^{\alpha}(IT)^{\beta} = \bar{Q} \end{cases}$$

$$\underset{\overline{IT}}{\text{optimum}} = \left[\frac{\bar{Q}}{A(\beta/\alpha)^{\beta}}\right]^{1/\alpha+\beta} \tag{11}$$

$$\underset{IT}{\text{optimum}} = \left[\frac{\bar{Q}}{A(\alpha/\beta)^{\alpha}}\right]^{1/\alpha+\beta} \tag{12}$$

So knowing the annual budget, the production objectives and the elasticity coefficient of all the inputs it is possible to compute the best proportion of each of them from an economic point of view.

2.5. *Hospital data*

This study concerns 21 of the 37 Parisian university hospitals of the *Assistance Publique Hôpitaux de Paris* (AP-HP)

Table 1 – Sample of data from the 21 hospitals, 2006.

21 hospitals	Nb. beds	Y (*)	$\overline{IT}$ (*)	IT (*)
AMBROISE PARÉ	468	95.96	124.3	4.124
ANTOINE BÉCLÈRE	413	103.8	125.9	3.470
AVICENNE	530	106.7	172.9	3.727
BEAUJON	597	110.2	150.3	5.261
BICÊTRE	929	188.9	260.2	7.174
BICHAT	907	189.1	263.9	7.666
COCHIN	874	258.3	423.6	8.707
HEGP	833	194.1	251.6	11.54
HENRI MONDOR	859	206.7	331.2	10.77
HÔTEL DIEU	484	103.3	136.1	4.097
LARIBOISIÈRE	1008	152.1	225.9	6.941
MOURIER	506	71.19	141.3	3.661
NECKER	602	193.4	259.1	5.540
PITIÉ	1826	381.1	538.4	15.20
POINCARÉ	408	56.04	103.9	4.461
ROBERT DEBRÉ	423	96.26	143.7	5.481
SAINT ANTOINE	779	166.5	254.1	7.812
SAINT LOUIS	569	175.8	215.5	8.294
TENON	672	153.8	201.1	6.157
TROUSSEAU	381	81.18	160.3	3.560
VERDIER	305	71.65	97.01	3.278

(*) Y = output, $\overline{IT}$ = non-IT capital and labor, IT = IT capital and labor in Millions of Euros.

group. The 21 hospitals were selected according to their size (more than 300 beds) and activity (acute, short and mid-term care). The data used covers the period 1998–2006, such that there are 189 complete annual observations. The careful selection of these 21 structures has been done to ensure that the studied data are homogeneous, i.e., that they are comparable and thus useful as input to the econometric model. Table 1 shows a sample of the data for the year 2006. Econometric parameters were estimated using Eviews 6® econometric software and the PASW17® statistical solution.

The output, Y, is the sum of all the hospital revenues from true healthcare activity (based on French diagnosis-related group (DRG) valorization at the exclusion of all other hospital incomes (research, donations, ministry of health funding, commercial activities, etc.). The IT field is constituted by the addition of the IT assets and the dedicated work force (labor). IT assets include the IT capital value and investments directly related to IT (hardware, software, maintenance, support, etc.). IT capital on year y is defined as the accumulated assets and infrastructure investments of the previous years, modulated by a depreciation factor that runs over a 5-year period according to the AP-HP cost-accounting system [21]. IT capital does not include embedded systems such as scanners, MRI and other diagnostic systems. The IT work force, expressed in Euros, includes all the human resources appearing on the HIS teams payrolls.

The same construction was made for non-IT capital and non-IT work force. The non-IT capital was defined as the accumulated assets and property investments of the previous years, modulated by a depreciation factor depending on the nature of the investment. For example, equipment is depreciated over 5–10 years, most furniture is depreciated over a 10 years and transportation related materials are depreciated over 6 years.

3. Results

3.1. *Share of factors*

Table 2 presents the values of output (Y) and inputs (K, L, K_{IT}, L_{IT}, etc.) during the 9-year study period. IT inputs made up, on average, 2.64% of the total inputs over these years.

These values of input and output can be used to compute the elasticity coefficient of the production function for these hospitals.

The Solow residual is 1.022, the elasticity coefficient for the non-IT inputs (α) is 0.893, and the elasticity coefficient for the IT inputs (β) is 0.106 with a p-value far under 0.001 and R^2 and adjusted R^2 equal to 0.92 (see Table 3).

3.2. *Outcome prediction*

Table 4 presents the forecasting results obtained by our model. In 2006, IT inputs for the 21 hospitals were set at almost 137 million Euros, and non-IT inputs were set at 4.5 billion Euros. The elasticity coefficients obtained from the 1998 to 2005 dataset allow the computation of a theoretical output prediction for 2006 of 3.175 billions of Euros which is 0.61% above the true output for 2006 (3.156 billion Euros).

3.3. *MRTS and productivity*

Table 5 presents the results of the MRTS evaluation: 0.252 unit of IT is needed to maintain the production level if one unit less of non-IT input is used. Average productivity (AP) of IT is 23.57, and the additional production obtained when adding one unit of IT (marginal productivity of IT) is 2.50.

Table 2 – Input and output values over the study period (1998–2006) in Millions of Euros.

21 hospitals	Y	K	L	$\overline{IT}$	K_{IT}	L_{IT}	IT	$K_{IT}/(K+K_{IT})$	$L_{IT}/(L+L_{IT})$	$IT/(IT+\overline{IT})$
1998	2251	1193	2145	3339	49.34	32.75	82.10	3.97%	1.50%	2.40%
1999	2332	1251	2199	3450	55.64	34.02	89.67	4.26%	1.52%	2.53%
2000	2419	1321	2294	3616	61.64	33.37	95.01	4.46%	1.43%	2.56%
2001	2543	1412	2369	3781	67.69	36.97	104.6	4.57%	1.54%	2.69%
2002	2714	1480	2490	3970	69.38	32.74	102.1	4.48%	1.30%	2.51%
2003	2876	1530	2622	4153	80.61	23.71	104.3	5.00%	0.90%	2.45%
2004	3159	1642	2665	4308	96.82	29.72	126.5	5.57%	1.10%	2.85%
2005	3125	1698	2810	4508	105.9	24.92	130.8	5.87%	0.88%	2.82%
2006	3156	1702	2878	4581	111.0	25.91	136.9	6.12%	0.89%	2.90%

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Table 3 – Computation results for elasticity coefficients (A: Solow residual, α: non-IT ($\overline{IT}$) elasticity coefficient, β: IT elasticity coefficient).

	Value	p	t-Statistic	Std. error
A	1.022	<0.001	9.289	0.110
α	0.893	<0.001	30.63	0.029
β	0.106	<0.001	30.63	0.029
R^2	0.92		Adjusted R^2	0.92

Table 4 – Predicting 2006 values from 1998–2005 data ($\overline{IT}$: non-information technology input, IT: information technology input, Y: output, B€: billion Euros).

$\overline{IT}$ 2006 value (B€)	4.581
IT 2006 value (B€)	0.136
Y 2006 value (B€)	3.156
Y predicted with 1998–2005 dataset (B€)	3.175
Prediction difference	+0.61%

Table 5 – Marginal rate of technical substitution and productivity results (MRTS: marginal rate of technical substitution, AP: average productivity, MP: marginal productivity).

	Value (2006)
MRTS ($\overline{IT}/IT$)	0.252
AP ($\overline{IT}$)	0.704
AP (IT)	23.57
MP ($\overline{IT}$)	0.629
MP (IT)	2.500

Table 6 – IT versus non-IT inputs optimization results.

	2006 values (B€)	Optimal values (B€)
Y	3.156	3.156
$\overline{IT}$	4.581	3.870
IT	0.136	0.459
$\overline{IT} + IT$	4.718	4.329
Economy	–	0.388

3.4. *Optimum input distribution*

Table 6 presents the results obtained using the cost optimization technique. The real output is taken as the optimal value to achieve in any case. Based on the elasticity coefficient, the marginal productivity and the results of optimization formulae, the optimal value of non-IT inputs appears to be 3.870 billion Euros (15.5% lower than the 4.581 billion Euros observed). The optimal value of IT inputs could be multiplied by 3.35 from 137 million Euros to almost 459 million, which is 10.6% of total input for the 21 hospitals in 2006.

Adding these two new values gives a theoretical input of 4.32 billion Euros, which is 388 million Euros less that the observed total input for 2006.

4. Discussion and conclusion

Our analysis using an overall approach reveals a highly significant correlation between IT inputs, non-IT inputs and the output, consistent with the findings of several industry studies including healthcare [5]. The elasticity coefficient of IT investment is 0.106 which highlights the importance of IT in an homogeneous group of hospital production. Another issue addressed by our study was the prediction of next year's outcome for the hospitals considered. The computed model approach seems to have good forecast abilities. The 2006 forecast based on the analysis of data for the years 1998–2005 predicted an income only 0.61% higher than what was achieved that year in reality. Confirming the importance of IT, our results also suggest that IT has a major average productivity of 23.57 and a marginal productivity of 2.5. In the model we developed, one additional Euro invested in IT returns 2.5 Euros. When analyzed with the results of the MRTS (0.251) these findings indicate that IT inputs are currently far too low in comparison to non-IT spending. Finally, we were able to compute the appropriate proportion of IT inputs versus non-IT inputs using our formulae. The results indicate that the AP-HP hospitals studied could achieve the same output by decreasing non-IT inputs by 15.5% and by multiplying IT inputs 3.4 times; this moreover is expected to lead to an 8.2% economy in overall input (i.e., 388 millions of Euros).

There are however possible limitations to this approach. First, the AP-HP University hospitals selected do not represent all aspects of hospital activity. Size (number of beds) also will have to be taken into account and may lead to computations involving investment-per-bed-ratios. Secondly, the time period we had at our disposal is relatively short from an econometric perspective. This was partly a consequence of the recent introduction of HIS into the AP-HP group. Nevertheless, our results are statistically relevant but a longer period of study would improve the quality of our model. The accounting methods used to evaluate output within the AP-HP group are subject to regular changes. Consequently, short period studies are appropriate to minimize the influence of these changes and also to avoid the need to adjust prices for inflation [21]. Thirdly, the very nature of our choices when constructing our variables needs to be considered. The boundary between what is IT and what is not can be ill-defined. A new PET-Scanner (and related imaging devices like MRI and traditional scanners) could be classified as part of the IT stock, considering the apparatus as merely a new networked image producing device, especially in hospital with substantial IT structuring and integration. Professionals working with these devices could also be re-classified from non-IT labor to IT labor. Further studies incorporating this conceptual issue are required. We also choose to assume the constant return to scale of the inputs in this work; more work could be done assuming an inconstant elasticity of substitution.

In this spirit, the variable Y reflects only the cash flow generated by clinical activity (DRG), and other cash incomes could also have been included, for example hospital subsidies, private donations, and French Ministry of Health valorization for research or specific expensive general interest clinical activities (MERRI & MIGAC in the French system).

Conventional financial or economic approaches do not integrate the less intangible impacts of IT inputs such as improvements in quality, potential increased employee productivity and greater customer satisfaction [11,12]. They also have the hazardous tendency to underestimate some IT capital "real world" aspects. An example is the frequent underestimation of IT capital because hardware and software are frequently used past their accounting depreciation life, and this affects the results of studies in which the IT hardware value is aggregated.

IT inputs may be correlated with improvement in quality of care [4,14,22,36–38]. Such observation constitute a good argument to convince CEOs to invest in IT and therefore in quality. Further work on the consequences of IT investment on quality of care could be conducted using quality markers and econometric correlations to detect the level of quality return-on-investment that could be expected.

Our results suggest that it would be beneficial to increase IT inputs from the current 2.99% to 10.61% of all inputs. However, this finding must be interpreted with great caution because 10% is far above the observed set of input values, and Thomas Malthus' law of diminishing returns – stating that each additional unit of variable input yields less and less output – applies to this domain. As IT input increases, the output will also increase but presumably at a decreasing rate. So, the more a hospital invests in IT, the less the marginal productivity of IT is expected to be until it reaches zero: this point will indicate the real optimized percentage of IT inputs to attain. It will have to be computed in future work, but the evidence is still clear that IT inputs are far too low in the 21 hospitals we studied. Note that current IT inputs in finance, banking and the tertiary sector more generally can be up to 16% of capital stock [39]; no hospital in the dataset is in this range so IT inputs of this magnitude cannot be assessed in this context.

Previous studies have given prominence to the lag between the time at which IT inputs are made and the first benefits obtained [14,15,22]. This point is particularly relevant for return on input studies (using cost-benefit analysis or net present value) because they focus on the IT project they intend to evaluate. In our econometric approach, this time lag is taken into account in a global IT portfolio perspective because the approach covers previous inputs and cumulative depreciation of each variable component on a 5–10 years period.

Various directions need to be explored for further analysis. This work could be extended to different sets of hospitals in France and also in other countries with different levels of IT investments (see above). Further studies should include non-acute hospitals, psychiatric hospitals, army hospitals, medium- and long-term-care hospitals, etc. Private and semi-private institutions should also be involved, especially because a greater IT influence has been observed within private structures [22]. The social and organizational impacts of a new investments distribution policy should also be taken into account, especially if, over a certain a period of time, increasing IT inputs could cause a decrease in non-IT inputs and in particular non-IT labor.

Evidence of the benefits of IT to hospitals is still limited. This work indicates the substantial positive effects of IT inputs on hospital production. Considering IT inputs (assets and labor) from a portfolio perspective could lead to the utilization of a constructed econometric dynamic simulation model based on a production function to predict the output that the hospital management could expect from their present investment policy. The portfolio approach merges the appreciation of the two roles that IT can play in a hospital: the production technology enhancing role and the coordination technology enhancing role [40]. Once understood, the model is not difficult to build and use, relatively inexpensive, not excessively time consuming, and has the advantage over many other accounting models of not being based on assumptions [5]. It also takes into account frequently neglected costs when implementing HIS, like the loss of productivity and the cost of organizational changes and redesigning workflows [40–42]. The model is also a reflection of the interactions with external systems (other healthcare organizations, suppliers, consumers and regulatory systems) also known as spillover effect [40].

Applying economic principles on the basis of this econometric model could lead to the computation of the best IT versus non-IT ratio for investments in the hospitals. This could rationalize the choices by IT managers and hospital managers for better IT governance in healthcare. Our study also suggests that the implementation of the computed recommendations may stimulate the adoption of HIT projects and provide substantial savings that could be invested in various other projects aiming to improve efficiency, quality and safety of care.

Authors contribution

Rodolphe Meyer: conception and design of the study, acquisition of data, analysis and interpretation of data, writing of the article.

Patrice Degoulet: conception and design of the study, revising the article critically for important intellectual content, final approval of the version to be submitted.

Summary points

"What was already known on the topic"

- HIT investments add value to the hospital production.
- Traditional ROI methods doesn't give sufficient incentives of the IT production results.
- Econometric methods can be used to assess the added value of HIT.

"What this study added to our knowledge"

- Econometrics can be used to forecast hospitals production.
- Econometrics allow the computation of the optimal amount of HIT investments.

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