Does Information Technology improve the productivity of the health care system?

Information and IT in health care

Traditionally the health sector has been perceived as lagging behind other industries with respect to its use of information technology (IT). This is surprising given the centrality of information exchange in the care process and for purposes of management, accountability, research and for financial transactions.

Health care provision is characterised by complexity and uncertainty. In most circumstances patients lack the ability to make an accurate diagnosis or to decide on an appropriate course of action on the basis of their symptoms. Instead patients usually seek diagnostic information from a health professional, to whom they also delegate decisions about how to organise and co-ordinate their care requirements. The successful outcome of such interaction depends (at least partially) on how information is shared between the patient and their delegated representative, and between different health professionals as they assume responsibility for parts of the care process. Any failure in communication between any of these parties may result in poor decisions being made which may impact adversely on the eventual outcome of the course of treatment. There is an obvious role for IT systems in recording pertinent data about the patient and in facilitating data exchange among those involved in the care process, subject to necessary ethical safeguards.

Accurate information is also essential for the management, monitoring and regulation of the health system as a whole. Smith and Häkkinen characterise information as enabling three important functions in the health system (Smith and Häkkinen, 2006). First, information is essential to accountability, allowing politicians to monitor the performance of the health system and citizens to assess stewardship. Second, information facilitates research into general patterns of system and organisational performance, so that sound evidence can be obtained about best practice. Third, information enables management to undertake comparative analysis of organisations and individuals, and thereby assess the effectiveness and efficiency of how they are fulfilling their functions. Adding to this list, information is essential to accountability, allowing politicians to monitor the performance of the health system and citizens to assess stewardship. Second, information facilitates research into general patterns of system and organisational performance, so that sound evidence can be obtained about best practice. Third, information enables management to undertake comparative analysis of organisations and individuals, and thereby assess the effectiveness and efficiency of how they are fulfilling their functions.

Given the centrality and diverse uses of information, IT systems that ensure timely...
and accurate collection and exchange of information are likely to foster more efficient use of health care resources. But empirical evidence about the contribution of IT to the productivity and efficiency of health care is limited. Identifying the impact of IT on productivity is difficult for a number of reasons. A particular problem in the health sector is that there is no measure of performance analogous to profits for private sector firms, and health care organisations tend to pursue multiple objectives. Investments in IT may be made to support any of these objectives. For instance, a computerised booking system may be implemented to boost patient throughput by optimising theatre use; financial performance may be improved via a reduction in transactions costs brought about by investing in technology to enhance billing arrangements. But other investments might be made to improve the quality of service provision and patient experience, and such objectives are notoriously difficult to measure and value.

This article outlines the methodological approaches taken to measure the impact of IT on productivity, summarises the available evidence, and makes recommendations as to where future research effort might be best directed.

## Defining IT resources

A key requirement for analytical work is a clear definition of what constitutes IT resources. First of all, international comparisons require appropriate price indices. IT resources have been subject to continuous and rapid technical improvements over the last few years, which have led both to enhanced quality and to reductions in price. These technical improvements make it difficult to measure IT resources over time, because it is necessary to estimate a “true” price change that is not contaminated by the change in quality. A number of methods are available to do this, and countries differ in the approach adopted (Schreyer, 2002). The US applies hedonic methods to measure the price of IT resources, which consider how the mix of characteristics of a good change over time and identify the proportion of price change that is related to each of these characteristics. The alternative methods used elsewhere are thought to lead to underestimate of IT output and investment growth in the countries that employ these methods (Inklaar et al., 2005).

Secondly, the IT resources themselves need defining and measuring. Official sources of data promise consistent definitions of what constitutes IT (Pilat, 2004). But in many countries, IT resources are poorly accounted for in the national accounts and official productivity statistics (Pilat, 2004). For example, Oulton argues that official Office of National Statistics estimates of the level of software investment in the UK during the 1990s is only a third of the actual level (Oulton, 2002).

The Groningen Growth and Development Centre’s 60-industry database (http://www.ggdc.net) defines six asset types, of which three refer to IT goods: computers, software, telecommunications equipment (Inklaar et al., 2005). (The non-IT goods in the GGDC data are transport equipment, machinery, equipment, and non-residential structures (Inklaar et al., 2005).) Clearly these broad categories contain a great deal of variation. For instance, while hardware (computers) may be fairly standardised, software is likely to be written for specific purposes and not easily transferred from one context to another. This finer level of detail will be missed when making international comparisons.

Organisational analyses usually rely on accounting returns by the organisations under consideration, and these returns may be subject to reporting error (Menon and Lee, 2000). The data advantage that firm-level studies have over aggregate or sectoral studies is that it is sometimes possible to identify the labour input associated with IT as well as the capital input. In theory, case studies should provide the most accurate information about IT resources, but in their review Chaudhry et al found that IT systems were incompletely described and data on costs or inputs were rarely reported, which makes it difficult to assess their net impact and to assess financial effects (Chaudhry et al., 2006).

## Industry-level analyses

A number of studies have employed growth accounting methods to investigate the contribution of IT to productivity growth for the economy as a whole or for sectors within the economy. Taking the economy as a whole, the relationship between the growth in aggregate output and growth in inputs can specified as (Jorgenson and Griliches, 1967, OECD, 2001):

\[
\Delta Y = \phi_0 + \phi_1 \Delta K^{IT} + \phi_2 \Delta K^{OT} + \Delta TFP
\]

(1)

Where \(\Delta Y\) is aggregate output growth, measured as the sum of growth for each type of output, weighted to reflect their shares in nominal GDP. Input growth measures the rate of growth for each input type, here defined as labour \(L\), non-IT capital resources \(K^{OT}\), and IT capital resources \(K^{IT}\). These inputs are weighted by the proportion \(\phi\) of income attributable to each input as a proportion of nominal GDP, under an assumption of constant returns to scale, \(\phi + \phi^{IT} + \phi^{OT} = 1\). Capital investments need to measured in real terms, hence the need to deflate (depreciated) capital stocks using a price index that corrects for quality change (Schreyer, 2002). Finally, the growth of total factor productivity (or technical progress), \(\Delta TFP\), is the amount by which output increases as a result of improvements in methods of production. TFP growth occurs when output increases for the same inputs.

Instead of considering the contribution of IT to overall output growth, a number of studies consider its impact on labour productivity (Timmer and van Ark, 2005, Inklaar et al., 2005). Studies of US labour productivity growth have ascribed virtually all of the acceleration that occurred in the late 1990s to investment in IT (Jorgenson and Stiroh, 2000, Oliner and Sichel, 2000). But the US experience was not mirrored elsewhere, despite the fact that IT products are traded internationally in competitive markets (Schreyer, 2002, Inklaar et al., 2005). These international comparative studies reach broadly consistent conclusions:

- Prior to the 1990s, there were lower levels of IT investment in Europe than the US, hence IT stocks were lower in Europe
- During the 1990s, IT-investment growth accelerated in both Europe and the US
- The contribution of IT capital deepening (ie the amount of capital available per unit of labour input) to labour productivity growth in Europe is about half the contribution that it is in the US
- Unlike the US, Europe experienced a labour productivity slowdown after the mid-1990s which appears unrelated to IT investment but may be partly due to declines in non-IT capital deepening and a lack of acceleration in TFP growth
- TFP growth in Europe and the US has been similar for IT-producing industries but is lower in Europe for IT-using industries

Inklaar et al have used the GGDC database to explore the contribution of IT to 60 indus-
tries and to make industry-level comparisons between the US, France, Germany, the Netherlands and the UK (Inklaar et al., 2005). The health sector is not separately identified in this database, but is incorporated within “Social and Personal Services” which also includes the education sector. Social and Personal Services is identified as a “non-IT” industry in the database, reflecting low expenditure on IT assets.

As yet, no study has used growth accounting methods to assess the contribution of IT to health sector productivity. A number of challenges have to be overcome before such a study can be undertaken, the most fundamental being to better measure of the output of the health sector. As Direct Volume Measurement became the established technique to measure output for the purposes of the official statistics, there is increased potential to explore the relative contributions of different types of input to output growth and to variations in output levels across jurisdictions (United Nations Statistics Division, 1993, OECD, 2001). At present, though, this must remain a longer-term research ambition in the health sector. Many countries have not yet adopted Direct Volume Measurement and, among those that have, there is considerable diversity in practice. This makes it difficult to make valid international comparisons of output levels and growth, let alone of the input factors that contribute to output.

Organisational analyses

In addition to difficulties in quantifying the output of the health system, evaluative challenges include isolating the impact of IT from other, perhaps contemporaneous, technological improvements and organisational initiatives; and recognising that there may be lags between IT investments and benefit realisation (Devaraj and Kohli, 2000). It is difficult to address these challenges using aggregate statistics but organisational analyses might avoid these difficulties (Hempell, 2005).

Roughly speaking, organisational analyses fall into two groups. The first group of studies are based on the standard economic theory of the firm, and comprise regression (econometric) models to estimate either a production or cost function. These studies attempt to identify the contributions of specific factors of production, such as labour, capital or IT input, to observed levels of output or cost. The production function describes the relationship between output and inputs (L, K\(^n\), K\(^{IT}\)) of an organisation i at time t, such that:

\[
y_i = y(L_i, K_{nIT}, K^{IT})
\]

The production function expresses an explicit formulation of the relationship between output and input types and, consequently, lends itself to investigation of the importance of IT investment.

The second group of studies attempt to estimate the relative efficiency of organisations, and these studies can be sub-divided into those that use the regression based technique called Stochastic Frontier Analysis (SFA) and those that employ a linear programming technique known as Data Envelopment Analysis (DEA). SFA involves either estimation of a production or cost function, or analysis of output by considering exogenous constraints on the production process (Jacobs et al., 2006). DEA involves the estimating the ratio of output to inputs (including IT resources), under the straightforward assumption that the higher this ratio, the more productive the organisation (Farrell, 1957).

Despite the very large number of studies that have estimated production or cost functions or applied SFA and DEA in the health sector, only four studies look specifically at the impact of IT in the health care industry. Three of these studies use the same dataset. Devaraj and Kohli estimate a production function to analyse the effect of implementing a decision support system in eight US hospitals, with data covering three years available on a monthly basis (Devaraj and Kohli, 2000). A number of performance measures were considered, including proxies for profitability and quality, and IT expenditures were subdivided into labour, capital and support costs. The authors conclude that IT investments have a positive but not immediate effect on both profitability and quality.

Menon and Lee use a data set spanning 18 years (1976-1994) for 54 general and surgical hospitals in the US state of Washington (Menon and Lee, 2000). They employ panel data techniques to estimate hospital costs as function of IT capital input, IT labour input, non-IT capital input and non-IT labour input. They find that IT investment increased following the change from cost reimbursement to DRG-based funding, and that IT enabled efficient production and substituted for other inputs.

Ko and Osei-Bryson re-analysed the data used by Menon and Lee, arguing that IT investments had a positive impact on productivity in the health care industry (Ko and Osei-Bryson, 2004). However, this study does not improve on that by Menon and Lee and, in fact, contains two fundamental flaws. First, the authors estimated a production function, according to which hospital output is described in terms of patient days. This is a poor descriptor of hospital output, because it implies that hospitals with longer lengths of stay are more productive, whereas reductions in length of stay have long been identified as sources of efficiency gains. Second, they fail to take account of the fact that they observe each hospital numerous times over an extended period, instead treating every annual observation as independent. This means that the estimates of the impact of their explanatory variables, such as the contribution of IT, will be biased, which undermines any inferences that might be drawn about their impact.

Menon et al also analysed their data using SFA techniques, using a similar model specification as in their companion paper (Menon and Lee, 2000) but with a simpler functional form (Menon et al., 2000). Like Ko and Osei-Bryson, though, they also use patient days as a measure of output and do not account for the panel nature of their data.

Case studies of specific examples of IT

The final type of analytical approach into the impact of IT investment takes the form of a case study of a particular type of IT. These studies might be either retrospective evaluations that measure the actual impact of the IT investment or prospective assessments, which are more akin to “business cases” which set out the assumptions on which investment might be justified. The strength of case studies lies in their specificity, offering the promise of detailed information about costs and benefits and about the environmental conditions in which the IT investment has been made. But case studies suffer two weaknesses. First, it is difficult to attribute IT investment to observed effects, because it is usually not possible to apply randomisation or case-control design to the evaluative study. Second, it is difficult to generalise from the particular study to the broader context.

Chaudhry et al reviewed 257 studies that explored the impact of IT, most of which considered decision support systems or electronic health records (Chaudhry et al., 2006). Three main benefits on quality were found: increased adherence to guidelines, better surveillance and monitoring, and decreased medication
errors. IT was not found to have any clear impact on labour input, but did appear to reduce utilisation of care.

The prospective approach makes projections about the future costs and benefits of particular IT initiatives, which is a feature of the study by Stroetmann et al (Stroetmann et al., 2006). But it may be the case that some of the expected impacts are not realised in practice. This is a weakness of the evaluation of NHS Direct Online in the United Kingdom, where benefits were expected to come from this service substituting for visits to general practitioners, and to calls to the NHS Direct telephone service. The national evaluation of the NHS Direct telephone service found no evidence of substitution (Munro et al., 2000), and it is even less likely to have occurred for the online service. Rather, NHS Direct appears to have stimulated previously unmet demand, the value of which is difficult to establish.

The main drawback of case studies is the ability to generalise. Chaudhry et al. highlight this problem, noting that a quarter of the studies they identified emanated from just four institutions, and all sites were more likely to be “leaders in the field” and therefore less representative of usual practice (Chaudhry et al., 2006). On the plus side, the advantage of focussing on exemplar projects is that they may foster replication elsewhere. But there is a bias against reporting unsuccessful applications, consideration of which may alter the conclusions drawn about the contribution of IT to productivity. The ambitious but controversial attempt to introduce an electronic patient record in the NHS is a high-profile example, which had already cost the NHS £12.4bn (£18.3bn) by December 2006 (Brooks, 2007). The need for electronic patient records is not clear-cut, and the programme has provoked opposition from health professionals and patient groups who are particularly concerned about confidentiality. The installation of the new hospital administration systems is behind schedule, and there is growing evidence that the transfer from old to new systems has compromised patient care. It is an open question whether this system will ever be subject to formal evaluation, and when and how its impact will be accounted for in official statistics. Examples such as this suggest that Solow’s productivity paradox, whereby IT investments do not lead to productivity gains, has not been resolved (Solow, 1987).

**Conclusions and recommendations for future research**

The health sector has traditionally been a low user of IT but there appears to great potential for wider use of IT resources in the health care sector, given the central role of information in the care process and for governance, management, research and financial purposes.

With regard to the care process, paper-based records have been the normal method of recording details of patient contact with health professionals and personal contact via letters or phone calls has formed the predominant method for data exchange among those involved in caring for patients. It has been argued that the “advantages of health information technology over paper records are readily discernible” (Chaudhry et al., 2006), but implementation of electronic records runs the risk of cost inflation and needs to be sensitive to ethical concerns particularly around patient confidentiality (Smith and Hakkinen, 2006).

Table 1. ASSESSMENT OF DIFFERENT ANALYTICAL APPROACHES AS TO THE IMPACT OF IT

<table>
<thead>
<tr>
<th>Study type</th>
<th>Advantages</th>
<th>Challenges</th>
</tr>
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<tbody>
<tr>
<td>Industry-level analyses</td>
<td>• Offers insight into impact of IT on industry as a whole. • Permits international comparisons.</td>
<td>• Health care output is poorly measured, though recent improvements where direct volume measurement has been introduced. • Quality of output is not taken into account. • IT resources may be poorly measured.</td>
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<tr>
<td>Organisational analyses</td>
<td>• May be able to identify multiple objectives to which IT investment is directed. • Can identify variation among firms.</td>
<td>• Need to compare like-with-like sample of organisations engaged in same production process. • Results sensitive to choice of analytical technique.</td>
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<tr>
<td>Case studies</td>
<td>• Highly specific assessment of particular forms of IT investment.</td>
<td>• Difficult to attribute effects to IT. • Results may not be generalisable. • For prospective studies, assumptions of impact may be ill-founded.</td>
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This article has categorised the analytical approaches that are available to study the impact of IT on productivity, and provided a brief overview of these analytical approaches. A summary of the key advantages and challenges associated with each analytical approach is provided in Table 1.

Research into the impact of IT resources in the health sector is currently limited. No studies have been conducted that explore the impact of IT on the health system as a whole, which is unsurprising given the difficulties in measuring the output of this sector.

There have been few organisational analyses that focus explicitly on the impact of IT in the health sector. This is an area of significant research potential, notwithstanding the challenges involved in specifying production processes, choosing among analytical techniques and making secure inferences about the relative efficiency of organisations. In practical terms, research along these lines requires a dataset about organisations engaged in similar production processes with data about their outputs and input use, including IT, preferably measured over several time periods.

Case studies offer the greatest potential for specific learning about particular cases of IT investment, although much published work makes it difficult to draws conclusions about the cost-effectiveness of implementation.
because reporting tends to focus on measures of benefit without consideration of the financial effects. Case studies offer the best opportunity to gain detailed insight into particular forms of IT investment, which may be particular in the health system, where software is often designed for specific purposes in particular contexts.

The main drawback of a case study approach is that it is difficult to apply rigorous evaluative study design. For instance, randomisation of organisations to particular levels of IT is clearly not possible, and it would be difficult to formulate a “case-control” study. Case studies of single technologies in single sites make it difficult to attribute observed effects to IT input and to make generalisations. Caution should also be exercised in drawing conclusions from published case studies, particularly if poor examples of IT investment are under-reported.

To better understand the contribution of IT to health system productivity, an initial way forward may be to consider a specific example of IT, rather than IT in aggregate. The introduction of the electronic patient record appears a pressing example of where international evaluative effort might be directed, particularly given ethical concerns about this technology, the difficulties in determining whether it substitutes for or adds to existing technologies, and its high cost. Those health systems that are considering the implementation of electronic patient records would likely benefit from experience elsewhere, in the identification of both best practice and potential pitfalls. Such shared learning may help avoid the electronic patient record (or other forms of IT) contributing to a “productivity paradox” in which high levels of investment insufficiently enhance the efficiency of the health system or patient experience.

Referencias


