Computers & Education 75 (2014) 173–184

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Does ICT matter for effectiveness and efficiency in mathematics education?

Kristof De Witte [a,b,*], Nicky Rogge [b]

[a] Maastricht University, TIER, Kapoenstraat 2, 6200 MD Maastricht, The Netherlands
[b] Faculty of Business and Economics, Naamsestraat 69, 3000 Leuven, Belgium

ARTICLE INFO

Article history:
Received 13 December 2013
Received in revised form
25 February 2014
Accepted 26 February 2014
Available online 12 March 2014

JEL-classification:
I21
D61

Keywords:
ICT
Effectiveness
Efficiency
Secondary education
Pupil motivation

ABSTRACT

ICT infrastructure investments in educational institutions have been one of the key priorities of education policy during the last decade. Despite the attention, research on the effectiveness and efficiency of ICT is inconclusive. This is mainly due to small-scale research with weak identification strategies which lack a proper control group. Using the 2011 'Trends in International Mathematics and Science Study' (TIMSS) data, we define by a Mahalanobis matching a control group with similar student, teacher, school and regional characteristics. The results indicate that accounting or not accounting for these characteristics, may considerably alter the estimated impact of ICT. This suggests that a correction for characteristics related to the student population, teaching staff, administrative personnel and school management is warranted in the evaluation of the impact of ICT.

1. Introduction

1.1. ICT and education

ICT infrastructure investments in educational institutions (i.e., primary schools, secondary schools, colleges and universities) have been one of the key priorities of education policy during the last decade. Most countries have invested (and still are investing) considerable amounts of public resources in ICT equipment such as computers, whiteboards, connectivity, software, etc. An example of such a country is the Netherlands. In the last three decades, in the Netherlands, large amounts of public resources have been invested in the implementation of ICT infrastructure in primary and secondary education (Haelermans & De Witte, 2012). In a policy document published in 2008 for the parliament, the Education Council recognized that as a result of these investments, most schools have computers, internet connection and educational software at their disposal (Onderwijsraad, 2008). With enormous amounts of public resources being invested in educational technology, an important question is whether this investment has paid off in terms of higher efficiency and effectiveness in school administration, teaching and learning.

More precisely, policy makers and stakeholders in the Netherlands (however, the same question frequently pops up in other countries) ask themselves (1) how the schools are currently doing in terms of implementing the ICT infrastructure in the daily organization (e.g., school management and administration), (2) the implementation of ICT in teaching and (3) whether or not ICT has positively impacted the effectiveness and efficiency of education (see European Schoolnet (2006) for a similar discussion). While effectiveness denotes the extent to which ICT can improve education outcomes, efficiency refers to the extent to which ICT can replace traditional instruction methods (e.g., reduce teaching and administrative time).

* Corresponding author. Katholieke Universiteit Leuven (KULeuven), Faculty of Business and Economics, Naamsestraat 69, 3000 Leuven, Belgium. Tel.: +32 16326566.
E-mail addresses: Kristof.Dewitte@kuleuven.be, k.dewitte@maastrichtuniversity.nl (K. De Witte).

http://dx.doi.org/10.1016/j.compedu.2014.02.012
0360-1315/

First, concerning the impact of technology in school administration and organization, there seems to be a consensus among practitioners and scholars that ICT has benefited efficiency and effectiveness of daily organization. More and more schools use ICT-infrastructure (such as intranets and digital learning environments) to support the administrative personnel in performing administrative tasks (e.g., financial management) and the daily organization of the school (e.g., planning of the rooms). For example, schools use ICT applications to collect pupil test scores, monitor progress in pupils' scholastic achievements, report the pupil education outcomes to the parents, share information among the teaching staff, etc. The belief is that all of these applications have benefited the efficiency and the effectiveness of administrative personnel.

Second, the implementation of ICT in education is visualized in Fig. 1, which indicates the reported computer shortage by grade 4 math teachers in the Netherlands between 2003 and 2011. Being one of the stakeholders most involved in the school and the classroom, we believe that teachers are well-placed to indicate whether or not the considerable investments in ICT implementation in schools have actually resulted in more ICT infrastructure (both hardware and software) being present in the school, in general, and the classrooms, in particular. While the ICT shortage reported by math teachers is only a proxy for general ICT shortage, it is one of the only indicators for ICT implementation. Whereas in 2003 about 39% of the Dutch math teachers reported in the Timms (Trends in International Mathematics and Science Study) 'a lot' or 'some' shortage, only 14% of the teachers reported 'a lot' or 'some' shortage in 2011. Moreover, an increasing share of teachers did not observe any computer shortage between 2003 and 2011 (from 34% in 2003 to 51% in 2011). Other measures of ICT infrastructure confirm this trend (e.g., number of computers available at the school/in the classroom, number of internet connections, presence of WIFI). Similar trends are observed in the OECD Pisa data (Fig. 1b). As computer shortage is nowadays less an issue, for a large majority of the schools, the use of ICT has become a relatively routine part of the everyday practice. Next to using ICT for the more "traditional purposes" as a management and administration tool, it is also increasingly used in the classroom as a supplement or as an alternative to the more conventional teaching methods. Fig. 2 shows the use of computer in Dutch classrooms to discuss math principles. Between 2003 and 2011 we observe in the Dutch TIMSS data an increase of 21 percentage points of the teachers who use computers in about half of the lessons to discuss math principles. However, notwithstanding this positive trend in ICT-usage, recent reports of the European Commission (e.g., European Schoolnet, 2006) show that the heterogeneity in the availability of ICT-infrastructure is still considerable, with large differences between countries and regions as well as between schools within countries and regions.

The third question, concerning the impact of ICT on the effectiveness and efficiency, attracted the attention of (international) public institutions and scholars. Broadly speaking there are two opposite findings in the literature. One group of researchers and teachers advocates the use of ICT in teaching and learning thereby referring to studies that found a positive impact of ICT on teaching effectiveness and pupil learning. They typically reason that the use of ICT in teaching and learning both enhances the educational outcomes of pupils and reduces the educational costs (particularly in the long run). Additional benefits discussed by advocates are, among other things, a greater flexibility and autonomy for pupils in their learning and an increase in the learning attitudes and experiences of pupils. Next to the group of believers, there is also the group of scholars and practitioners who are more critical to the use of technology in teaching and learning. They believe that the return of using ICT in teaching and learning in terms of increasing pupil performances is not significantly positive. Some of the disbelievers even warn that the impact of more ICT in education may very well be negative with the use of ICT-tools in the classroom being more a distraction to pupils than anything else or teachers and/or pupils not having the necessary skills to use computers most effectively in their teaching and learning (see a discussion in van Braak, 2001). To buttress their viewpoint, they refer to the findings of an insignificant impact of ICT on pupil educational achievement reported by (predominantly quantitative) studies.

The paper is organized as follows. The next subsection gives an overview of the literature on the impact of ICT on education. The focus is on the findings of how ICT impacts efficiency and/or effectiveness in school management and organization, teaching and learning. The third subsection discusses the limitations of earlier work, some of which this paper aims to overcome. Section 2 presents the matching procedure employed to study the impact of ICT, while Section 3 describes the TIMSS data and results. The paper concludes with a section which briefly summarizes the main conclusions. It also discusses some limitations of this study and presents some interesting avenues for future research.

1.2. Literature

The study of the impact of ICT use in primary and secondary schools has gained interest in the academic literature during the last two decades. This resulted in a considerable expansion of the number of studies on this topic. In this section, a review of the previous impact

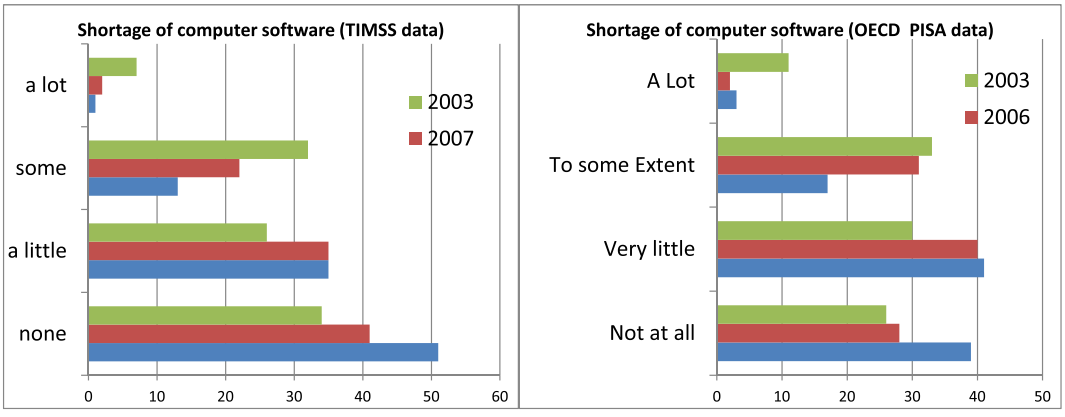

Fig. 1. Experienced shortage of computer software by grade 4 math teachers in the Netherlands between 2003 and 2011, expressed in % (source: left hand side: own calculations based on TIMSS 2003–2007–2011; right hand side: own calculations based on PISA 2003–2006–2009).