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Use and intensity of electronic invoices in firms: The example of Sweden

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ABSTRACT

Electronic (e−) invoices potentially enhance environmental sustainability in several stages from production of paper to its usage. This study investigates empirically to what extent a set of firm characteristics and external factors associate with the probability to send e-invoices and with the intensity of usage, based on a representative survey of approximately 1500 Swedish firms. An invoice is considered electronic when it is exchanged in an automated system between the buyer and the seller. The analysis includes firms with one employee or larger across all industries except, agriculture, fishery, forestry, public administration and defence. Descriptive statistics show that 42 per cent of the firms in 2016 send e-invoices. By use of a two-part model, estimation results reveal that both internal and external factors are associated with the e-invoice behaviour. The probability of adoption is significantly higher for firms with government sector clients and a large number of invoices. The intensity estimation exhibits a reverse pattern, where the number of e-invoices is most strongly associated with the invoice pattern. Another internal factor of importance for the extent of e-invoices is the level of labour productivity. Construction firms have the highest probability to adopt e-invoices and manufacturing firms scale-up the usage. Besides this, neither industry affiliation nor size-class is crucial. When size-class is estimated separately, it appears that medium-sized and large firms strongly associate their invoice adoption with type of client, while the extent of the activity is solely related to internal factors. For micro enterprises and small firms, kind of client is the most important aspect at all.

1. Introduction

Aggregate and conceptual analyses point to a number of possible benefits with electronic (e−) invoices, not least for the environment through reduced used of paper, but also for the economy and society due to increased efficiency and simplicity (Capgemini, 2009; Sandberg et al., 2009; European Commission, 2009; Korkman et al., 2010; Moberg et al., 2010; Keifer, 2011; Ollo-López and Aramendia-Muneta, 2012; Koch, 2016; Yip and Bocken, 2018). Despite the fact that systems for automated data interchange were available long before the internet (Hsieh and Lin, 2004) and that there are potential direct advantages such as reduced costs and increased efficiency of operations, many firms are still sceptical. Across the European Union (EU 28), only one out of four firms with ten or more employees sends e-invoices to their clients in 2017.[1] Directive 2014/55/EU is an attempt by the European Union to support sustainability by introducing a European norm for e-invoices that all contracting public authorities have to accept. Although not yet fully implemented, it may nevertheless affect usage.

The aim of this study is to investigate empirically to what extent a set of common firm-specific characteristics (size, industry, invoice pattern and productive capacity) as well as external factors (kind of clients and access to advanced information and communication technology, ICT, infrastructure) relate to the use of e-invoices in firms. Both the probability to send e-invoices and the intensity of usage (measured as the number of e-invoices sent) are estimated

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[1] Source: Eurostat community survey on ICT usage and e-commerce in enterprises; http://ec.europa.eu/eurostat/data/database/isoc_eb_ics.xls.

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by aid of a two-part model. An invoice is considered electronic when it is issued, transmitted and received in a structured data format which allows for automatic and electronic processing, as defined in Directive (2014)/55/EU. Thus, this definition excludes pdf-invoices sent by e-mail. The empirical analysis is based on a unique representative country-sample of approximately 1500 Swedish firms with more than one employee in 2016. Validation of the results include separate estimations of five broad industry groups and two size-classes.

Research on ICT adoption in general is vast (Dholakia and Kshetri, 2004; Hollenstein, 2004; Oliveira and Martins, 2010a, Oliveira and Martins, 2010b, for example), although studies beyond specific infrastructures and applications (broadband and e-commerce) are rare (Bertschek and Fryges, 2002; Hong and Zhu, 2006; Eriksson et al., 2008; Goldmanis et al., 2010; Colombo et al., 2013; Haller and Lyons, 2015, 2019; Sila, 2013, 2015; Hagsten, 2016). A small sample of mainly descriptive studies reveals that the decision to use e-invoices is primarily related to firm specific characteristics, but also to external factors like the available ICT infrastructure and customer requests (Edelmann and Sintonen, 2006; Penttinen and Hyytiainen, 2008; Sandberg et al., 2009; Elkelä, 2011; Hernandes-Ortega, 2012; Veselá and Radiměřský, 2014; Poel et al., 2016). There are also few examples of how ICT relates to environmental sustainability by digitisation of production and internal processes in firms and organisations, which a text mining analysis by Schober et al. (2018) reveals. Exceptions include the environmental impact of online retailing, the dematerialisation of processes in firms as well as public administrations and digitisation of business models (Mirabella et al., 2013; Bocken et al., 2014; van Loon et al., 2015; Arnfalk et al., 2016; Yip and Bocken, 2018).

Swedish firms are at the forefront of applying ICT, such as fixed broadbands and mobile connections (99 and 86 per cent of firms with ten employees or larger (source: Statistics Sweden). Paradoxically, the general development of ICT usage does not pertain to e-invoices, although a stimulus was introduced already in the early 2000s in connection with central government procurement, making the buyer responsible for providing certain technical applications (Ministry of Finance, 2000). The proportion of firms sending e-invoices is moderate (approximately two out of five firms), lower than in similarly ICT-intensive countries such as Denmark and Finland and grows slowly.[2]

This study adds to the scarce empirical literature on adoption of specific ICT applications as well as to research on dematerialisation of production and internal processes as means to increase environmental sustainability. Another novelty is the simultaneous estimation of factors related to the probability of sending e-invoices as well as to the extent of usage. This allows separate interpretations of what is vital for the different stages. A further important aspect is the representative dataset linked to official statistics, which includes a broad coverage of industries, different clients as well as a substantial proportion of micro firms, otherwise seldom available.

The study proceeds as follows: Next sections encompass the conceptual background and the empirical approach. These are ensued by a description of the dataset and some stylised facts. Finally, the estimation results are presented, and some concluding remarks offered.

2. Conceptual background

Conceptual analyses suggest that the use of e-invoices is directly beneficial for firms, in that it potentially increases their efficiency, reduces their costs and makes them less geographically dependent (Korkman et al., 2010; Keifer, 2011; Koch, 2016). Indirectly, a transition to e-invoices may also lead to reduced greenhouse gas emissions in several stages, from production to usage, if for instance, the invoices are not printed and the digital systems do not require a higher consumption of energy than how they were administrated before (Moberg et al., 2010, Mirabella et al., 2013; Pohl et al., 2019). Despite the presumptive advantages and clear policy ambitions of both the European Commission and European governments for increased sustainability, many firms are still hesitant.[3] These ambitions include not only Directive 2014/55/EU on government sector procurement and harmonised standard for electronic invoices, but also amendments of certain VAT and accounting regulations to pave the way for increased e-invoice usage (Ministry of Finance, 2018). Possibly, the resistance to e-invoices relates to how they are perceived and who will benefit from usage (for instance, Hernandez-Ortega, 2012). According to Capgemini (2009), the gains are broad, but potentially highest for the demand side, that is the buyers, while the environmental advantages may appear abstract.

Given their vast and positive impacts, several ICTs are defined not only as innovations but also as general purpose technologies (computers, internet, for instance) (Brynjolfsson and Hitt, 2003; Basu and Fernald, 2007; Cardona, Kretschmer and Strobel, 2013), although complementary applications integrating the internal processes of the firms with the commercial system (such as e-invoicing and e-commerce) are more vaguely conceptualised in literature. E-commerce applications, for instance, are commonly defined theoretically either as independent innovations (Bertschek and Fryges, 2002; Zhu et al., 2003; Zhu and Kraemer, 2005; Battisti and Stoneman, 2005; Hollenstein and Woerter, 2008), as a cluster of innovations or applications related to the internet (Wilson et al., 2008; Colombo et al., 2013) or as advanced computer networks over internet (Forman et al., 2012; Colombo et al., 2013; Gallego et al., 2014; Falk and Hagsten, 2015; Loukis et al., 2017).

No general theoretical framework exists for e-invoices. E-invoices may be embedded within the concept of diffusion of innovations (Edelmann and Sintonen, 2006; Penttinen, 2008), which assumes that progress appears in several stages (Rogers, 2010). Hernandez-Ortega (2012) uses a mix of the innovation and the Technology Acceptance models as the theoretical starting point (Davis, 1989). The latter theory is based on key factors of importance for accepting a new technology such as perceived usefulness and easy-to-use.

If systems for e-invoices are considered as technological innovations, they would develop in several steps until a general diffusion is reached (Hall, 2004; Rogers, 2010). OECD (2004) employs a similar theoretical framework specifically for ICT innovations, where three different stages are identified: i) readiness, ii) intensity and iii) impact. Readiness relates to the ability of a firm to adopt an ICT innovation, intensity (or use) measures the proportion of firms that adopt and the extent of use. Impact relates to changes in behaviour, economic structure or performance as a result of use.

The low level of e-invoice adoption in Sweden could imply that the diffusion is still at the early stage of the process, where factors that prohibit firms from using e-invoices dominate, for instance

[2] Source: Eurostat community survey on ICT usage and e-commerce in enterprises. A high proportion of e-invoice usage in Denmark can partly be explained by the experience of mandatory e-invoices in public procurement since 2005, https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/eInvoicing+in+Denmark.

[3] Source: Eurostat community survey on ICT usage and e-commerce in enterprises.

high costs, lack of systems compatibility, soaring error frequency and organisational inertia (Haag et al., 2013; Marinagi et al., 2015). Although some of these aspects are difficult to quantify, it is obvious that transmissions over XML-based open standards (internet) hold both economic and practical advantages over the costly, complicated and bilateral EDI exchange systems previously used (Penttinen and Hyytiainen, 2008; Tanner and Richter, 2018). Cost reductions are otherwise often seen as important explanations behind the rapid diffusion of certain ICTs (Goldfarb and Tucker, 2019).

Despite the opportunity to transmit easier and cheaper, the lack of progress in recent years might imply that factors other than costs are central for firms or that the diffusion of automated invoice usage does not necessarily follow the expected pattern of an innovation. Evidence originating from the sparse empirical literature indicates that besides costs, size of firm, systems compatibility, customer requests, error frequency, usability, information (deficit), skills, efficiency as well as the underlying ICT-infrastructure are crucial factors for the adoption of e-invoices (Edelmann and Sintonen, 2006 for Finland; Sandberg, Wahlberg and Pan, 2009 on Sweden; Elkelä, 2011 for 16 European countries; Hernandez-Ortega, 2012 on Spain; Haag et al., 2013 for Germany; Veselá and Radiměřský, 2014 on the Czech Republic; Poel et al., 2016 for Belgium). Arendsen and van de Wijngaert (2011) conclude that Dutch firms conducting businesses with governmental organisations are more prone to use e-invoicing systems and by targeting this group of firms, governments could help to accelerate the implementation.

In a qualitative study, Tanner and Richter (2018) emphasise the importance of understanding the needs (not the least the legal frameworks) of the business partners and involving them when new systems solutions are developed, since there is no universal solution for all or over time. Elkelä (2011) reasons that an e-invoice in the stricter sense is not necessarily what is most functional for the firm, and that it is possible to maintain a digital chain even without full automation (by use of pdf-invoices, for instance), as long as the invoice is not printed on paper. An alternative interpretation is that e-invoices, rather than being innovations, are advanced complementary applications, relying on an underlying innovation (internet). This means that diffusion is not independent, but also that it could follow an alternative pattern, where full saturation is not necessarily reached. Unfortunately, literature gives no clear information about the strength of different quantitative variables associated with adoption or what drives the scaling-up of e-invoice usage. Hernandez-Ortega (2012) examines the perceived usefulness, compatibility, ease-of-use and security for the choice to adopt as well as to continue the use and finds that the weight of these variables differs between the two choices in a sample of approximately 1200 Spanish firms. Compatibility and usefulness are the most important aspects related to the adoption, while perceived usefulness is vital for continuous use.

Available studies are difficult to compare because of variations in methods (estimation, descriptive analysis) and representativeness (sample sizes, firm sizes and industries included), factors (size, industry, invoice pattern, experience and efficiency) as well as external aspects (client request and the underlying ICT infrastructure) motivate the e-invoicing behaviour of firms. Larger firms may have a higher need to simplify their internal and commercial systems and are expected to bear possible economic burdens of adoption more easily than smaller firms (Penttinen, 2008; Poel et al., 2016). E-invoicing may also be more attractive for firms with many or increasing numbers of invoices (Hernandez-Ortega, 2012). Potential unmeasured firm heterogeneity, such as differences in production technology and skills of staff becomes visible in a measure of productivity (Bartelsman and Doms, 2000; Syverson, 2011). This means that those who manage to use their production capacities efficiently are more likely to send e-invoices. In addition, firms with experience from e-invoicing, specific client requests and mature ICT infrastructures (access to high speed broadband) are assumed to engage in this to a larger extent (Penttinen and Hyytiainen, 2008; Arendsen and van de Wijngaert, 2011; Hernandez-Ortega, 2012; Hernandez-Ortega and Jimenez-Martinez, 2013; Poel et al., 2016). External pressure like client requests and upcoming regulations may be more strongly associated with the decision to adopt e-invoices, while the intensity to a larger extent relates to the internal operations of firms.

Unfortunately, there is no information available on separate firm-level costs for e-invoices, although recent internet-based systems are assumed to be far less costly than what was available earlier (Penttinen and Hyytiainen, 2008). Qualitative information in the dataset at hand indicates that costs are not a strong motivating factor for adopting e-invoices (Source: Statistics Sweden), implying that this can be considered a constant in the analysis. The same response is valid for environmental concerns.

Based on the interpretation of e-invoice systems as advanced complementary applications to underlying innovations, the following hypotheses (H) are formulated:

H1) E-invoicing relates to both firm-specific (internal) and external factors.

H2) External factors such as client request are expected to be most crucial for e-invoice adoption.

H3) Internal factors are envisaged to relate more strongly to the scaling-up of e-invoicing.

3. Empirical approach

In the absence of research on drivers of e-invoice usage, the empirical approach mirrors the literature on e-commerce adoption, typically estimated by Probit or Logit models (Bertschek and Fryges, 2002; Zhu and Kraemer, 2005; Battisti et al., 2007; Hollenstein and Woerter, 2008; Oliveira and Martins, 2010a, 2010b; Walker et al., 2016; Pascucci et al., 2017).

Given that the majority of firms does not send e-invoices, a model is required that can account for a large number of zeros. Particularly useful in such situations is the two-part model developed by Cragg (1971). This estimator makes it possible to jointly investigate the probability of a firm sending e-invoices and if so, to what extent (the number of e-invoices). Since the dataset at hand encompasses information on the actual choice of firms, that is, either or not sending e-invoices, typical sample selection models are less suitable (Blundell and Meghir, 1987; Madden, 2008; Humphreys, 2013; Belotti et al., 2015).[4] Once adopted, usage follows and the probability of a firm sending e-invoices and its actual usage are modelled as Logit and OLS equations, respectively, the latter with a log-link. Consequently, the probability P that firm i is sending e-invoices at time $t = 2016$ is specified as follows:

[4] The Heckman Selection Correction Model (Heckman, 1976) may be used for simultaneous estimations of propensities and intensities, although it is designed for situations when the dependent variable is censored or truncated, which is not the case in this analysis. Identification of the Heckman model is also hampered by the frequent absence of appropriate exclusion restrictions.

$$ln\left(\frac{P_{it}}{1-P_{it}}\right)=\alpha_0+\alpha_1 lnEFFICIENCY_{it-1}+\alpha_2 lnINVOICES_{it}+\alpha_3 B2B_{it}+\alpha_4 B2G_{it}+\alpha_5 BROADBAND_{mt-1}+\sum_{s=1}^{3}\delta_s SIZE_{it}^{S}+\sum_{ind=1}^{9}\delta_{ind} INDUSTRY_{it}^{ind}+\varepsilon_{it} \quad (1)$$

where *m* means municipality and *ln()* is the natural logarithm. The underlying dependent variable, *e-invoice*, is binary and takes on the value of 1 if a firm sends e-invoices and 0 otherwise. Variable *EFFICIENCY* measures turnover per employee and is expected to reflect the firm-heterogeneity in the production process and *INVOICES* is the total number of invoices sent, independent of kind. Client request is represented by its proportion in different segments: *B2G* (business to government) and *B2B* (business to business). The ICT infrastructure is illustrated by the share of work places with fibre broadband supply *BROADBAND* nearby (at the municipality level) and *SIZE* denotes the number of employees in three classes: 10–49, 50–249 and 250+ employees, with micro firms (1–9 employees) as the reference category. Industry affiliation is controlled for by a set of nine broad industry dummies, *INDUSTRY* (Appendix, Table A2). The variables *BROADBAND* and *EFFICIENCY* are lagged one year to account for the possibility of delayed reactions. This means that a proper underlying infrastructure is expected to be in place before advanced ICT applications can be used and that the relationship between e-invoicing and efficiency is not instantaneous.

The second part of the model is conditional on those firms who actually send e-invoices and thus is solely estimated for a subset of firms. This specification mirrors the first, except for the inclusion of a variable reflecting experience with sending e-invoices, *EXPERIENCE*, and a different dependent variable. The latter now appears as the number of e-invoices sent, *number_e − invoices:*

$$E(number\_e-invoices_{it})=g(X\text{ß}), \quad (2)$$

where g is the density function applicable to positive non-zero observations of the e-invoice intensity and *X* is a vector containing the same covariates as in the Logit part.

$$E(\ln(number\_e-invoices_{it}))=\beta_0+\beta_1 \ln EFFICIENCY_{it-1}+\beta_2 lnINVOICES_{it}+\beta_3 B2B_{it}+\beta_4 B2G_{it}+\beta_5 BROADBAND_{mt-1}+\sum_{s=1}^{3}\theta_s SIZE_{it}^{S}+\sum_{ind=1}^{9}\theta_{ind} INDUSTRY_{it}^{ind}+\sum_{exp=1}^{2}\theta_{exp} EXPERIENCE_{it}^{exp}+\mu_{it}, \quad (3)$$

Since the left-hand variable is measured as level, the natural logarithm (ln) transformation is used to allow the coefficients to be interpreted as elasticities or semi-elasticities. Because high speed broadband access is measured at the municipality level, clustered-adjusted standard errors are used. To account for possible heterogeneity in the relationship, separate estimations are provided for five broad sub-sectors and two size-classes.

4. Data sources and descriptive statistics

Data originate from a stratified random sample of 4,000 Swedish firms, conducted in 2016 by Statistics Sweden and the Swedish Agency for Economic and Regional Growth, with the purpose to identify the extent to which firms in different industries and size-classes send e-invoices and their motivation behind this. The survey encompasses all industries except agriculture, fishery, forestry, public administration and defence in accordance with NACE rev. 2 (Appendix, Table A1) and is stratified by size-class and broad industry sector. Size of firms is represented by four classes of employees (1–9, 10–49, 50–249 and 250+). Besides information on invoicing behaviour, experience, motivation and clients, background data on employment and turnover in the last 3 years as well as geographic location (municipality) is sourced from the Structural Business Statistics and the Business Registers at Statistics Sweden.

The response rate of the survey on e-invoice adoption is 40 per cent. Given difficulties to receive high response rates in non-mandatory surveys, the sample was "over-drawn", that is, more firms were selected than the absolute minimum amount needed for representativeness. This means that all sub-sectors still have a representation in the dataset. The non-responding firms were also analysed based on the background information, resulting in no apparent indications of a systematic distribution. This means that the sample available for analysis can be considered random.

Information on geographic location allows the dataset to be augmented by data on broadband infrastructure, measured as the proportion of workplaces with fibre broadband supply on the premises or within 50 m, for each of the 290 municipalities in Sweden. This information originates from The Swedish Post and Telecom Authority (www.pts.se). Alternative variables describing the technological infrastructure of firms could be the extent to which they use different business systems such as enterprise resource planning, supply chain management or customer relationship management. Although information on usage of automated systems is available in the EU-harmonised survey on ICT usage in enterprises, this is not linked to the dataset at hand.

In 2016, Swedish firms sent about 864 million invoices to their clients, of which B2B is the largest group. On average, this means around 3,000 invoices per firm, although the spread is large. A majority of the invoices are in the traditional paper format, delivered by post. Sending e-invoices is the least common alternative; on average 12 per cent of them is exchanged in a fully automated way (Fig. 1A).

The ability to receive e-invoices is not limited to the business or government sectors, even consumers are enabled platforms for this, via online bank services. In 2018, four out of five persons aged 16–85 years use internet for bank businesses.[5] The proportion of e-invoices sent varies by broad industry group and size-class.

[5] http://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__LE__LE0108__LE0108D/LE0108T16/table/tableViewLayout1/?rxid=08cd1111-af61-47f5-9cdf-74a88f7c6359#.

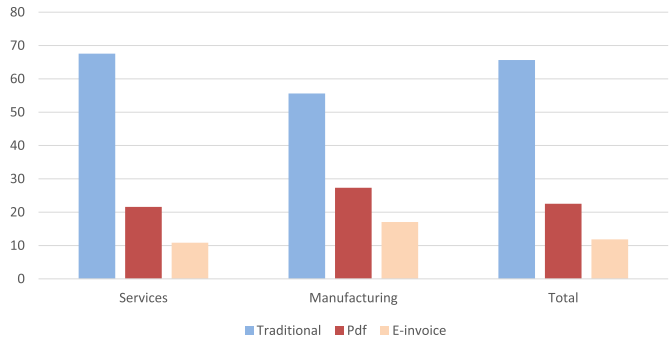
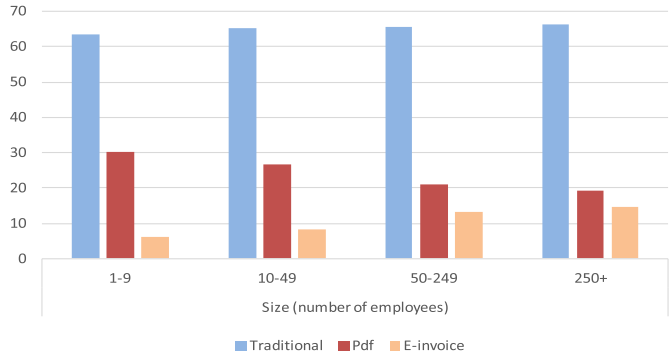


Fig. 1a. Kind of invoice by broad industry (per cent).



Note: Values grossed-up by sample-weights. The proportion of invoices within each group sums up to 100 per cent.
Source: Statistics Sweden and own calculations.

Fig. 1b. Kind of invoice by size-class (per cent).
Note: Values grossed-up by sample-weights. The proportion of invoices within each group sums up to 100 per cent. Source: Statistics Sweden and own calculations.

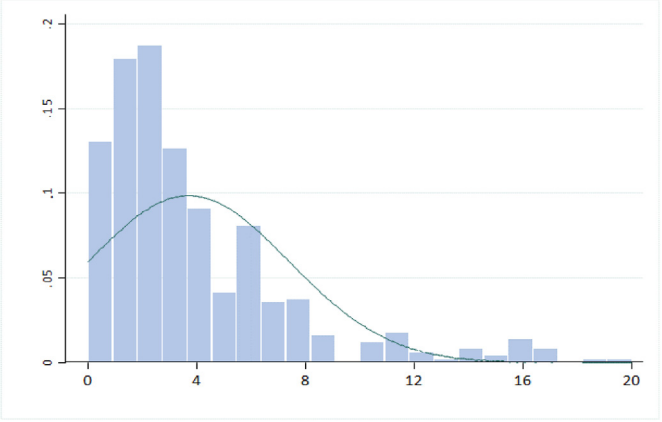


Fig. 2. Experience of e-invoice usage in firms (number of years).
Source: Statistics Sweden and own calculations.

Manufacturing firms and large firms are predominantly prone to use this application (Fig. 1A and B). Micro firms use the pdf-format more frequently than other size-classes (almost every third invoice). The survey also includes questions on why the firms send e-invoices. The main motivation behind this relates to requests of the clients and efficiency, rather than to costs, environmental concerns, standards in the industry or accounting models (Source: Statistics Sweden). Efficiency in this case means that it suits the product or service in question.

Descriptive statistics for the estimation sample, (unweighted values) are available in Table A1 in the Appendix. In this sample, 42 per cent of the firms send e-invoices, while the average proportion of e-invoices is twelve per cent. The proportion of public sector clients (B2G) is 13 per cent and the business clients amount to 65 per cent. Somewhat more than one out of four firms has fewer than ten employees and the average turnover (t-1) per employee is SEK 1,380,000 in 2015, equal to EUR 152,000 (given the exchange rate on 31.12.2015). The share of workplaces with fibre broadband supply nearby in 2015 (t-1) is 70 per cent on average and close to 100 per cent in the larger cities. Among the firms in the sample, integrated systems for e-invoices are quite young phenomena (Fig. 2). Half of the firms has experience of sending e-invoices that goes back no longer than to 2013 (3 years).

5. Empirical results

The estimation of the two-part model by Logit and OLS shows that both firm specific (internal) and external factors are significantly positively related to the probability of sending e-invoices and to the intensity of usage. The proportion of B2G clients and the overall number of invoices are the two most distinct variables (Table 1). In the adoption equation (Specification i), the B2G client coefficient is largest (but B2B is also clearly significant), while the opposite appears in the intensity estimation (Specification ii). The marginal effect of 0.45 on average means that a rise in the share of government sector clients by 10 percentage points is associated with an increased probability of sending e-invoices to this sector by 4.5 percentage points.

A coefficient of 1.06 for invoices (Specification ii), indicates that the number of e-invoices sent increases slightly disproportional to the number of total invoices. Size-class is not important at all, or merely weakly significant for sending e-invoices, while the efficiency (turnover per employee) is distinctly positively significant in the intensity estimation. Industry affiliation is only important for the e-invoicing behaviour to a certain extent. The probability to send e-invoices is highest for construction firms (NACE rev. 2 Section F) and lowest for wholesale and retail (G), in comparison with the reference group manufacturing and energy and water supply (B and C). Firms in manufacturing as well as in energy and water supply appear to have the strongest relationship with the number of e-invoices.

When variables for experience are added to the intensity equation, it becomes clear that early e-invoice adopters are more keen users than those who introduced this at a later stage (Specification iii). This indicates that firms find ways to benefit from sending e-invoices, once getting accustomed to them. A drawback with this variable is that it reduces the sample size by 20 per cent, since not all firms managed to provide information about when they started to send e-invoices.

By calculating a one standard deviation change of the variables (coefficient x standard deviation), their different scales can be neutralised and the most important factors identified. This measure confirms that kind of client (B2G) and number of invoices are indeed the most important factors for both the probability of sending e-invoices (3.1 and 1.3) and for the scaling up (0.7 and 2.8). The significance of kind of client, particularly articulated by B2G, is not completely unexpected, both the upcoming EU regulation and earlier standards for procurement in the central government sector includes attempts to facilitate usage. Besides the broadband variable, several others have been excluded from the final main specifications because they are not significant at conventional level. These include geographic dependency (location) type of municipality (large city, suburb, small city et cetera) and past turnover growth.

Thus, it may be concluded that none of the hypotheses put forward can be rejected: Internal as well as external factors relate to adoption as well as to scale-up, the probability to adopt is most pronounced for firms with B2G clients and the intensity of usage associates strongly with the internal pattern of invoices. These results coincide with fragments highlighted in other studies on

Table 1
Factors related to the use of e-invoices, two-part model.

	Logit estimation of probability						OLS estimation of ln number of e-invoices					
	(i)						(ii)			(iii)		
	Coeff.		z-stat	dy/dx		z-stat	Coeff.		z-stat	Coeff.		z-stat
Proportion of B2B clients	0.890	***	3.97	0.159	***	4.06	0.423	*	1.93	0.523	**	2.31
Proportion of B2G clients	2.510	***	7.89	0.449	***	8.67	0.567	**	2.02	0.815	***	2.69
ln number of invoices	0.497	***	13.00	0.089	***	16.82	1.055	***	27.73	1.054	***	24.77
10-49 employees (ref. 1–9)	−0.112		−0.54	−0.020		−0.54	−0.462	*	−1.93	−0.484	*	−1.90
50-249 employees	−0.153		−0.70	−0.027		−0.70	−0.201		−0.83	−0.366		−1.43
250+ employees	−0.495	*	−1.94	−0.089	*	−1.94	−0.321		−1.13	−0.626	**	−2.03
ln turnover per employee, t-1	0.087		1.48	0.016		1.48	0.154	***	2.75	0.136	**	2.09
Dummy D+E (ref cat B+C)	0.251		0.62	0.045		0.62	−0.205		−0.64	−0.277		−0.75
Dummy F	0.595	***	2.90	0.106	***	2.93	−0.426	**	−2.25	−0.292		−1.42
Dummy G	−0.324	*	−1.70	−0.058	*	−1.70	−0.515	***	−3.08	−0.386	**	−2.16
Dummy H	−0.599		−1.15	−0.107		−1.16	−1.380	**	−2.26	−2.298	***	−5.45
Dummy I	−0.096		−0.25	−0.017		−0.25	−0.539		−1.20	−0.339		−0.64
Dummy J	0.184		0.56	0.033		0.56	−0.145		−0.49	−0.128		−0.37
Dummy KtM	−0.301		−1.33	−0.054		−1.33	−0.380		−1.63	−0.259		−1.04
Dummy N	0.235		0.91	0.042		0.91	0.035		0.17	0.201		0.86
Dummy PtS	0.249		0.70	0.045		0.70	−0.386		−1.16	−0.033		−0.09
Early adoption≤2009										0.852	***	4.98
Adoption between 2009 and 2012										0.440	***	2.96
Constant	−5.419	***	−9.95				−3.395	***	−6.30	−3.560	***	−5.96
Number of observations	1490						623			488		
Pseudo R^2/Adjusted R^2	0.22						0.77			0.78		

Note: Asterisks ***, ** and * denote significance at the 1, 5 and 10 per cent levels. The Stata command "twopm" with the log link is used to estimate the e-invoices equation.
Source: Statistics Sweden and own calculations.

reasons for using or not using e-invoices (Edelmann and Sintonen, 2006; Elkelä, 2011; Hernandez-Ortega, 2012; Haag et al., 2013; Veselá and Radiměřský, 2014; Poel et al., 2016), implying that firm-specific as well as external factors are crucial, even if the relative importance of these variables has not been estimated before in a similar setting. In contrast, the results do not fully support suggestions made by Arendsen and van de Wijngaert (2011), that the sellers, rather than the buyers should be targeted in attempts to increase the use of e-invoices. This might have some degree of effectiveness for the scale-up among firms who already send e-invoices, but for the probability to adopt kind of client is more important. Findings by Capgemini (2009) and Tanner and Richter (2018) are in line with this, in that the buyer is expected to gain the most from e-invoices and that the needs of the business partners are central.

To validate the results in relation to firm heterogeneity, five subsectors are estimated separately: i) Manufacturing, electricity, gas, steam and air conditioning supply, ii) construction, iii) Wholesale and retail trade, iv) Transport, accommodation, personal and public services as well as v) Information, communication and business services.

These results (Table 2) confirm the general findings of the importance of B2G clients for adoption, with the number of invoices also being vital. Strongest relationship to the B2G client appears for wholesale and retail trade. The pattern for the scaling-up deviates somewhat more and the specific clients are of importance only for firms in transportation, accommodation, personal and public services as well as in wholesale and retail trade. The underlying ICT infrastructure, represented by nearby access to fibre broadband, turns out insignificant in most estimations and thus is excluded from the final specifications. A reason behind this could be the generally high level of ICT usage in most industries. There is, however, one exception to this. In a group of service sectors (transport, accommodation, personal and public services) access to fibre broadband is clearly relevant.

Literature indicates that size is of importance for e-invoice behaviour in firms, although it does not turn out significant in the baseline estimations. Because of this, the validity of the results are tested by re-estimating the specification for two separate size-classes: micro enterprises and small firms on the one hand and medium-sized and large firms on the other.

These results partly follow the general pattern where kind of client (B2G) is the most important variable for adoption, but in the case of the smaller firms also relates strongly to the intensity of usage, slightly contradicting hypothesis 3 (Table 3). In the larger firms, all business clients are of importance for adoption, B2G markedly so, although the extent only associates with internal factors. A final robustness check utilises a non-linear specification, where the squared variables of the main determinants are included (B2G and number of invoices). Unreported results show that this exercise only leads to a marginal improvement of the fit.

6. Conclusions

By using a novel and representative country dataset (Sweden), including firms with one employee or larger, this study investigates empirically how firm characteristics (internal) and external factors associate with the probability to send e-invoices and the intensity of usage. An invoice is considered electronic if it is exchanged between the seller and the buyer in an automated system. These activities are still relatively small among firms (12 per cent of total invoices sent), despite a high level of general ICT adoption, early opportunities for the central governments suppliers to voluntary send e-invoices and common expectations that e-invoices are both firm and environmentally friendly through increased efficiency and reduced paper consumption. Manufacturing firms and large firms routinely send e-invoices.

A two-part model is employed to jointly estimate the determinants of both the probability of sending e-invoices and the intensity of this activity (number of e-invoices). The novel results show that the probability of sending e-invoices is strongly related to B2G clients and to the number of invoices in the firm. These are also the two most important factors related to the intensity of usage, but with the opposite order. That is, for adoption external factors are most important, while the extent is more clearly associated with internal aspects, where also efficiency (labour productivity) plays a role. Size class and industry are of lesser importance, although construction firms are most likely to adopt and manufacturing firms

Table 2
Factors related to the use of e-invoices by sector, two-part model.

	Logit estimation of probability						OLS estimation of ln number of e-invoices		
	(i)						(ii)		
	Manufacturing, electricity, gas, steam and air conditioning supply (C & D)								
	Coeff.		z-stat	dy/dx		z-stat	Coeff.		z-stat
Proportion of B2B clients	1.21	*	1.83	0.23	*	1.87	0.36		0.53
Proportion of B2G clients	2.38	**	2.08	0.46	**	2.14	−0.64		−0.67
ln number of invoices	0.65	***	7.46	0.13	***	10.48	1.10	***	11.37
10-49 employees (reference 1−9)	−0.40		−0.79	−0.08		−0.80	−0.51		−0.97
50-249 employees	−0.63		−1.27	−0.12		−1.28	−0.12		−0.24
250+ employees	−1.45	**	−2.51	−0.28	***	−2.59	−0.16		−0.28
ln turnover per employee, t-1	0.06		0.27	0.05		0.50	−0.13		−0.64
Constant	−6.20	***	−3.56				−1.54		−0.84
Number of observations	329						160		
Pseudo R^2/Adjusted R^2	0.19						0.73		
	Construction (F)								
	Coeff.		z-stat	dy/dx		z-stat	Coeff.		z-stat
Proportion of B2B clients	1.21	**	1.97	0.23	**	2.03	0.30		0.40
Proportion of B2G clients	2.36	***	3.00	0.45	***	3.21	0.03		0.04
ln number of invoices	0.48	***	3.89	0.09	***	4.47	0.96	***	9.14
10-49 employees (reference 1−9)	0.64		1.43	0.12		1.46	0.24		0.45
50-249 employees	0.53		1.07	0.10		1.08	0.52		0.79
250+ employees	0.33		0.45	0.06		0.45	0.83		1.07
ln turnover per employee, t-1	−0.02		−0.11	0.00		−0.11	0.16		0.80
Constant	−4.73	***	−2.76				−3.72	**	−1.97
Number of observations	235						112		
Pseudo R^2/Adjusted R^2	0.19						0.65		
	Wholesale and retail trade (G)								
	Coeff.		z-stat	dy/dx		z-stat	Coeff.		z-stat
Proportion of B2B clients	0.78	*	1.90	0.13	**	1.98	0.54		1.35
Proportion of B2G clients	2.74	***	4.05	0.46	***	4.49	1.55	***	2.98
ln number of invoices	0.53	***	7.10	0.09	***	9.71	1.01	***	11.08
10-49 employees (reference 1−9)	−0.46		−1.12	−0.08		−1.12	−0.25		−0.64
50-249 employees	−0.78	*	−1.76	−0.13	*	−1.76	0.22		0.57
250+ employees	−1.24	**	−2.50	−0.21	**	−2.50	−0.15		−0.28
ln turnover per employee, t-1	0.11		0.66	0.02		0.66	0.32	*	1.82
Constant	−5.69	***	−4.83				−5.29	***	−3.85
Number of observations	365						144		
Pseudo R^2/Adjusted R^2	0.25						0.80		
	Transport, accommodation, personal and public services (H, I, N, P to S)								
	Coeff.		z-stat	dy/dx		z-stat	Coeff.		z-stat
Proportion of B2B clients	0.64		1.37	0.11		1.22	0.61		1.17
Proportion of B2G clients	2.36	***	3.83	0.40	***	4.62	1.37	***	2.60
ln number of invoices	0.42	***	8.21	0.07	***	5.45	1.25	***	12.82
10-49 employees (reference 1−9)	0.02		0.03	0.00		0.03	−2.25	***	−2.67
50-249 employees	−0.14		−0.24	−0.02		−0.23	−3.09	***	−3.87
250+ employees	0.06		0.10	0.01		0.10	−3.20	***	−3.16
ln turnover per employee, t-1	0.24	***	3.07	0.04	***	2.61	0.11		1.35
High-speed broadband supply t-1	0.42		0.66	0.07		0.61	1.40	**	2.40
Constant	−5.93	***	−6.76				−4.59	***	−3.47
Number of observations	283						117		
Pseudo R^2/Adjusted R^2	0.25						0.80		
	Information, communication and business services (J, K to M)s								
	Coeff.		z-stat	dy/dx		z-stat	Coeff.		z-stat
Proportion of B2B clients	0.31		0.67	0.05		0.67	−1.01	**	−2.03
Proportion of B2G clients	2.57	***	2.99	0.40	***	3.14	−0.23		−0.39
ln number of invoices	0.37	***	4.87	0.06	***	5.45	0.83	***	9.43
10-49 employees (reference 1−9)	−0.20		−0.39	−0.03		−0.39	−0.22		−0.37
50-249 employees	0.50		1.00	0.08		1.01	0.27		0.44
250+ employees	0.51		0.86	0.08		0.86	0.37		0.58
ln turnover per employees, t-1	−0.01		−0.07	0.00		−0.07	0.11		1.52
Constant	−4.06	***	−4.38				−0.79		−0.70
Number of observations	278						90		
Pseudo R^2/Adjusted R^2	0.23						0.77		

Note: Asterisks ***, ** and * denote significance at the 1, 5 and 10 per cent levels. In the sample transport, accommodation, personal and public services the z-values are based on cluster-adjusted standard errors at the municipality level to account for the different aggregation level of the fibre broadband variable. Industry classification is available in Appendix, Table A2.
Source: Statistics Sweden and own calculations.

Table 3
Factors related to the use of e-invoices by size-class, two-part model.

	Logit estimation of probability						OLS estimation of ln number of e-invoices		
	(i)						(ii)		
	Micro and small firms (1–49 employees)								
	Coeff.		z-stat	dy/dx		z-stat	Coeff.		z-stat
Proportion of B2B clients	0.43		1.45	0.07		1.46	0.45		1.24
Proportion of B2G clients	1.71	***	3.77	0.30	***	3.94	1.02	**	2.37
ln number of invoices	0.39	***	6.87	0.07	***	7.70	0.86	***	11.36
ln turnover per employee, t-1	0.16	*	1.68	0.03	*	1.68	0.16		1.00
Constant	−4.80	***	−6.25				−2.62	**	−2.22
Number of observations	712						210		
Pseudo R^2/Adjusted R^2	0.14						0.54		
	Medium-sized and large firms (>50 employees)								
	Coeff.		z-stat	dy/dx		z-stat	Coeff.		z-stat
Proportion of B2B clients	1.27	***	3.77	0.22	***	3.92	0.41		1.53
Proportion of B2G clients	3.22	***	6.56	0.57	***	7.42	0.63	*	1.76
ln number of invoices	0.57	***	10.50	0.10	***	15.44	1.13	***	26.63
ln turnover per employee, t-1	0.06		0.74	0.01		0.74	0.13	**	2.25
Constant	−6.86	***	−7.85				−4.23	***	−6.14
Number of observations	778						413		
Pseudo R^2/Adjusted R^2	0.24						0.77		

Note: Asterisks ***, ** and * denote significance at the 1, 5 and 10 per cent levels. Source: Statistics Sweden and own calculations.

scale-up. Fibre broadband supply nearby is not a common determinant of neither adoption nor the number of e-invoices, although it is crucial for the extent of usage in certain service firms. An explanation behind this could be variations in sensitivity to the quality of the underlying ICT infrastructure despite the generally high level of access.

When different size-classes are estimated separately, results demonstrate that the proportion of B2G clients is strongly associated with both adoption and intensity of e-invoice usage in micro enterprises and small firms, while the former is only (and vastly) important for the adoption in large firms, where the extent is solely associated with internal factors.

The results partly coincide with previous literature in that factors both internal and external to the firm are of importance for the e-invoice behaviour, but also contradicts the idea to target the sellers, rather than the buyers, in attempts to improve environmental sustainability by an increase of the number of adopting firms. Instead, policy measures (beyond Directive, 2014/55/EU) may need to focus on conditions that primarily stirs demand. Among those who already send e-invoices, stimulus that affect internal factors could be more successful. It is also important to consider that increased use of e-invoices is only environmentally beneficial if it does not introduce more energy consumption or emissions than the traditional handling.

Given the random sample of firms, and that Sweden is a small country dependent on international trade, many firms are already internationally assimilated. Thus, the results are assumed to be applicable also on firms in other countries with similar levels of ICT maturity but where e-invoicing is not yet a full legal requirement. This study focusses on the definition of an e-invoice as stated by the European commission, that is, fully automated. A broader definition, including pdf-invoices, would imply that a larger group of firms engage in this and that systems costs are possible kept down, without necessarily causing more damage to the environment, if that is the main target of the policy level for pushing for this change.

Although the analysis provides clear evidence on the importance of both firm features and external factors, the study has some limitations. For instance, firm specific ICT infrastructure could not be taken into account due to data deficits, instead this is approximated by the supply of high-speed broadband at the local level. There is also no information available about firm-level costs for sending e-invoices. Given that the qualitative information supplied by firms does not point to costs as important motivation, this is not expected to distort the results. Another limitation is the use of cross-sectional data that only makes it possible to estimate associations rather than causal relationships. There are several avenues for future research: One is to estimate the determinants of the year of adoption of e-invoice systems, another is to carry out an update of the survey. The latter makes it possible to explain the dynamics of e-invoicing. Comparisons with other countries would also be useful. Alternatively, the data could be linked to information on organisational and human capital, for a more in-depth investigation of these factors.

Disclaimer

The conclusions drawn in this study are solely those of the authors and should not be confused by official views of their institutions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Eva Hagsten: Conceptualization, Project administration, Supervision, Methodology, Formal analysis, Investigation, Software, Data curation, Visualization, Writing - review & editing. **Martin Thomas Falk:** Methodology, Formal analysis, Investigation, Software, Data curation, Visualization, Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2020.121291.

Appendix

Table A1
Descriptive statistics estimation sample

		Total sample			
		Mean	Std. dev	Min	Max
Number of e-invoices	1,490	22253.38	317972.20	0.00	8000000.00
Proportion of B2B clients	1,490	0.65	0.38	0.00	1.00
Proportion of B2G clients	1,490	0.13	0.25	0.00	1.00
ln number of invoices	1,490	7.22	2.64	0.00	16.81
ln turnover per employee, t-1	1,490	7.23	1.33	−3.55	12.27
1-9 employees	1,490	0.28		0.00	1.00
10-49 employees	1,490	0.30		0.00	1.00
50-249 employees	1,490	0.23		0.00	1.00
250+ employees	1,490	0.19		0.00	1.00
Experience 1996 to 2008	488	0.13	0.34	0.00	1.00
Experience 2009 to 2012	488	0.25	0.43	0.00	1.00
High speed broadband access	1,486	0.70	0.23	0.04	0.99
Industry CD	1,490	0.20			
Industry DE	1,490	0.02			
Industry F	1,490	0.16			
Industry G	1,490	0.24			
Industry H	1,490	0.02			
Industry I	1,490	0.04			
Industry J	1,490	0.06			
Industry KM	1,490	0.13			
Industry N	1,490	0.07			
Industry PS	1,490	0.06			
	Manufacturing, electricity, gas, steam and air conditioning supply (C&D)				
		Mean	Std. dev	Min	Max
Number of e-invoices	329	19614.74	131485.50	0.00	1792000.00
Proportion of B2B clients	329	0.85	0.28	0.00	1.00
Proportion of B2G clients	329	0.06	0.16	0.00	1.00
ln number of invoices	329	8.03	2.28	1.61	15.67
ln turnover per employee, t-1	329	7.64	0.75	3.40	9.87
1-9 employees	329	0.12			
10-49 employees	329	0.20			
50-249 employees	329	0.37			
250+ employees	329	0.30			
	Construction (F)				
		Mean	Std. dev	Min	Max
Number of e-invoices	235	1030.02	4120.26	0.00	35400.00
Proportion of B2B clients	235	0.63	0.32	0.00	1.00
Proportion of B2G clients	235	0.17	0.26	0.00	1.00
ln number of invoices	235	6.54	1.94	1.61	13.12
ln turnover per employee, t-1	235	7.40	0.83	4.26	11.10
1-9 employees	235	0.23			
10-49 employees	235	0.38			
50-249 employees	235	0.25			
250+ employees	235	0.14			
	Wholesale and retail trade (G)				
		Mean	Std. dev	Min	Max
Number of e-invoices	365	28774.42	399901.90	0.00	7605000.00
Proportion of B2B clients	365	0.56	0.40	0.00	1.00
Proportion of B2G clients	365	0.09	0.18	0.00	1.00
ln number of invoices	365	7.72	2.87	0.00	16.79
ln turnover per employee, t-1	365	7.84	0.91	2.89	11.06
1-9 employees	365	0.22			
10-49 employees	365	0.28			
50-249 employees	365	0.30			
250+ employees	365	0.20			
	Transport, accommodation, personal and public services (H, I N, P to S)				
		Mean	Std. dev	Min	Max
Number of e-invoices	283	14552.36	199908.60	0.00	3360000.00
Proportion of B2B clients	283	0.47	0.41	0.00	1.00
Proportion of B2G clients	283	0.26	0.36	0.00	1.00
ln number of invoices	283	6.92	2.62	1.10	16.30
ln turnover per employee, t-1	283	6.10	1.81	−3.55	9.93
1-9 employees	283	0.14			
10-49 employees	283	0.23			
50-249 employees	283	0.28			
250+ employees	283	0.35			
	Information, communication and business services (J, K to M)				

(*continued on next page*)

Table A1 (*continued*)

		Total sample			
		Mean	Std. dev	Min	Max
	# obs	Mean	Std. dev	min	Max
Number of e-invoices	278	42594.45	520816.20	0.00	8000000.00
Proportion of B2B clients	278	0.75	0.37	0.00	1.00
Proportion of B2G clients	278	0.09	0.20	0.00	0.99
ln number of invoices	278	6.47	2.86	0.00	16.81
ln turnover per employee, t-1	278	6.97	1.35	−0.14	12.27
1-9 employees	278	0.32			
10-49 employees	278	0.32			
50-249 employees	278	0.25			
250+ employees	278	0.12			

Source: Statistics Sweden.

Table A2
NACE 2 Industry classification (Svensk näringsgrensidelning, SNI, 2007)

Section	Description
A	Agriculture, forestry and fishing
B	Mining and quarrying
C	Manufacturing
D	Electricity, gas, steam and air conditioning supply
E	Water supply; sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	Transportation and storage
I	Accommodation and food service activities
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M	Professional, scientific and technical activities
N	Administrative and support service activities
O	Public administration and defence; compulsory social security
P	Education
Q	Human health and social work activities
R	Arts, entertainment and recreation
S	Other service activities
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	Activities of extraterritorial organisations and bodies

Source: Statistics Sweden. (https://www.scb.se/dokumentation/klassifikationer-och-standarder/standard-for-svensk-naringsgrensindelning-sni/T)

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