Does Internet Speed Matter?

Impact of Internet Speed on E-Applications Adoption by Firms in Luxembourg

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Draft

Abstract

The aim of this paper is to examine the impacts of broadband connection type, and Internet speed on e-activities (e-commerce, e-administration, e-tendering, e-invoicing, etc.) among Luxembourgish firms. Our paper shows how the speed of Internet connection affects the intensity of Internet use (measured by the number of e-activities adopted). Using an ordered logit model we show that a higher Internet speed is positively related to the probability that the firm will engage in a greater number of e-activities. Our work uses data from the 2013 survey of Information and Communication Technologies (ICT) usage and e-commerce, among enterprises in Luxembourg (STATEC, 2013). The dataset covers firms with at least 10 employees in manufacturing and services (excluding financial services). This results in a representative sample of 1,869 firms. We found five main results. First, e-commerce is linked to Internet speed. Firms are more likely to engage in e-commerce if their Internet connection speed is higher than 30 Mbits. Second, firms with broadband and mobile connections are more likely to engage in e-activities compared to other firms, all else remaining constant. Third, being part of a very competitive market increases the probability to adopt three or more e-practices by 2 percentage points. Fourth, we found that large firms and some knowledge intensive firms are more likely to engage in e-activities which is in line from with the findings from previous univariate analyses. Fifth, we found no evidence of a rank effect. Large and small firms are equally likely to use e-applications especially in the presence of high Internet speeds and both broadband and mobile connections.

JEL Classification: L21, O31, 033

Key words: E-commerce, Broadband, Internet use, Ordered logit model,

1. Introduction

The Internet is becoming the lifeblood of business. It enables firms' engagement in a variety of e-activities such as e-commerce, e-training, e-procurement, e-learning, e-tendering, etc. It facilitates online research, customer interactions via social media forums, and wikis, and provides virtual platforms allowing workers to better coordinate their work. Although most businesses use the Internet, it is not uncommon for firms to have insufficient Internet connections. Few firms are aware of what connection level is appropriate for their needs. How much bandwidth they need depends on what they are doing, and how many people are involved.

Broadband infrastructure is supposed to improve both the quality and speed of Internet access, which, in turn improves the firm's productivity (Grimes et al. 2012), enhances efficiencies (Greenstein and Prince 2007), reduces costs, enables the production of more goods and services, and fosters innovation. Broadband has been described as the last General Purpose Technology (GPT)[1] (Bertschek et al. 2013). Broadband provision is considered a potential source of economic growth, and is an important part of economic development policy (OECD, 2008).

Since its introduction in Canada in 1997, deployment of broadband has been supported by several waves of technological innovation. For example, dial up Internet based on copper-wire infrastructure was based on Asymmetric Digital Subscriber Line (ADSL) technology which was overtaken by fibre optic cable.[2] In matter of mobile market, we have 3G, 4G, 4G+ and many other technologies allowing mobile broadband access. These technological innovations have increased Internet speed and the quality of the connection. Nevertheless, firms and individuals continuously demand higher speed and better Internet connectivity. The provision of the most up-to-date technology is supposed to increase firm performance and extend firms' markets.

Given these properties, broadband provision and its economic impact have been at the heart of extensive economic debate since the mid 2000s. There is a large literature on the impact of broadband on worldwide economic growth (Qiang and Rossotto, 2009; Czernich et al. 2011; Atif et al., 2012), employment (Grandall et al. 2007, Lehr et al. 2006), innovation and efficiencies. Several authors have examined its micro-economic impacts and how the use of high speed Internet is boosting productivity (Grimes et al. 2012), cutting costs (Allen Consulting Group, 2002), and resulting in the re-design of economic activities to improve the innovativeness of firms (Bertschek et al. 2013).

The literature mostly considers broadband under the umbrella of Internet, Internet speeds, and types of Internet connections. According to the OECD, broadband allows speeds of at least 256Kbps. Currently, depending on the available technologies, firms can get connection speeds of between 256Kbps and more than 100Mbps. This wide range has several implications for the economic activities of firms which have been rather overlooked by the literature. Few studies (see Grimes et al. 2012) focus on how the shift from one type of connection to another may result in better firm performance, and can enhances the firm's productivity.

[1] Bresnahan and Trajtenberg NOT IN REFS (1995) and Helpman anNOT IN REFSd Trajtenberg (1998) provide a good discussion of GPTs.

[2] ADSL (Asymmetric Digital Subscriber Line) provides data transmission speeds of at least 256 Kbps, consistent with the OECD (2002) definition of broadband.

Cloud computing is providing flexible computing in relation to hardware, software and servers, with very small initial expenditure and for given periods of time (Martson et al. 2010). ICTs are available on demand and on a metered pay per use basis. Cloud computing is cutting costs (Wilson, 2011, Jackson, 2011) and increasing firms' innovativeness (Sultan, 2014). Some authors consider cloud computing to be a game changer for industry and services (Etro, 2009; Xu, 2012). However, firms adoption and quality of cloud computing services are limited by their connection speeds.

Against this background, the present paper aims to contribute to the debate on the economic impacts of broadband by examining how the speed of the Internet connection impacts on the e-activities engaged in by firms. The connection speed has implications for the intensity of ICT use measured as the number of the firm's e-activities. This paper uses data from the 2013 survey of ICT usage and e-commerce in enterprises in Luxembourg (STATEC, 2013). The dataset includes all firms with at least 10 employees, in manufacturing and services (excluding financial services). This provides a representative sample of 1,869 firms.

Luxembourg is a small country with a competitive economy and keenness to adopt the latest generations of ICT; however, there are differences related to firms' sectors and size. Luxembourg has a database providing detailed information on ICT use based on the 2013 survey, which was the first to investigate the impact of new ICT projects among a representative sample. However, as can be seen in Figure 1, in 2012, it had some of the lowest broadband median and average advertised download speeds among the OECD countries. Investigating the link between demand for Internet speed and e-activities seems more appropriate in Luxembourg than in some other countries (i.e. Denmark) where nearly all firms have access to high speed Internet.

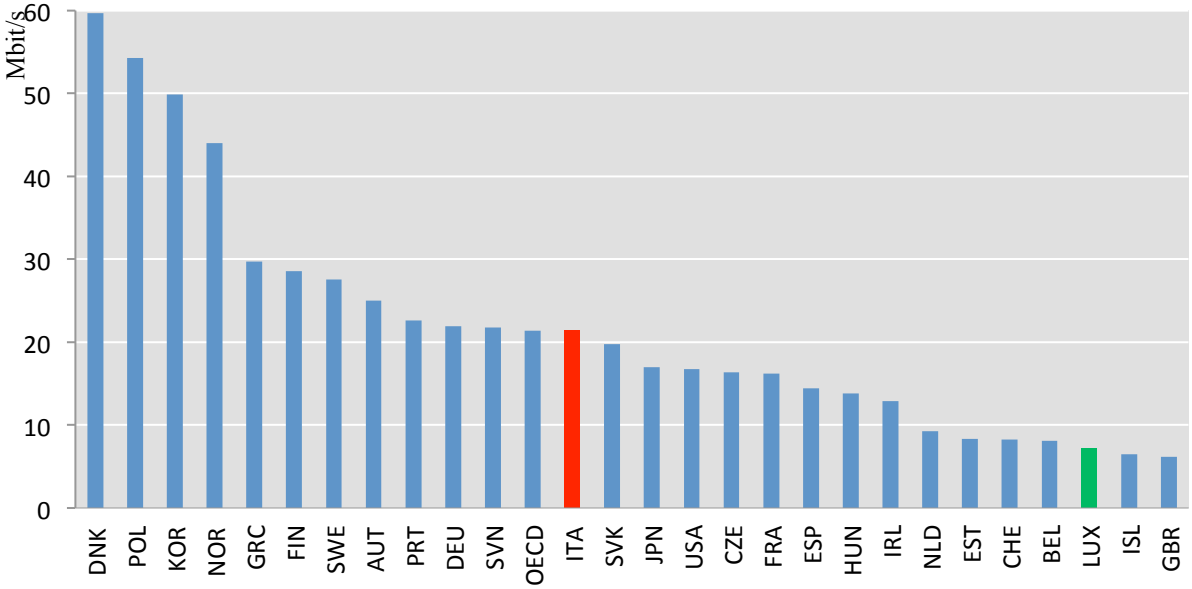


Figure1. Internet connection speed (September 2012): Source: OECD (2013).

Our paper provides two novelties. First, the existing literature focuses on the effects of broadband adoption without distinguishing Internet speeds. Broadband connection can involve the use of various technologies with speeds varying between 1Mbit and 100 Mbits per second. Internet speed is an important determinant of Internet usage. We focus on speed as an explanatory variable of e-applications usage.

Second, most studies consider only fixed broadband connections. As mobile phone use has increased worldwide, the demand for mobile broadband increased rapidly even in developed

countries. Our data tale account of mobile broadband and its impact on firm performances, or the 'mobility dividend' (Kathuria et al. 2009). We find that firms are more likely to engage in e-commerce if their connection speed is higher than 30 Mbits. We find also that firms with broadband and mobile connections are more likely to adopt e-activities than those without them, everything else remaining constant. We find also that e-commerce is linked to the speed of Internet.

The paper is structured as follows. Section 2 reviews the literature; 3 describes the data, and the sample characteristics; Section 4 presents the descriptive statistics and the univariate analysis; Section 5 describes the econometric model; and Section 6 discusses the results, Section 7 concludes the paper.

2. Literature survey

The economic literature focuses mainly on the impact of broadband on economic performance at the macroeconomic and microeconomic levels. There is a strand in the literature that examines the impact of broadband deployment at the macroeconomic level.[3] Endogenous growth theory predicts that broadband will accelerate economic growth by facilitating the development of innovative processes and increasing access to information. Broadband, along with computers and the Internet, is considered a GPT. It is changing economic activities and increasing efficiency in all sectors. Qiang and Rossotto (2009) use the Barro (1988) cross-sectional growth model to analyse the impact if broadband on long-term economic growth rates over the period 1980 to 2006. They find a robust and important growth divide based on broadband access in developed countries. A 10% increase in broadband penetration yields a 1.21% increase in economic growth in developed countries, and 1.38% increase in developing countries. Czernich et al. (2011) use an instrumental variable model to estimate the effect of broadband infrastructure on economic growth in a panel of OECD countries during 1996-2007. They find that a 10% increase in broadband penetration raises annual per capita growth by 0.9-1.5 percentage points. Atif et al. (2012) use a basic macroeconomic model using static fixed effects estimators in a dynamic model (Basic Linear Dynamic Model), for a panel of 31 OECD countries during 1998 to 2010. Their results suggest that broadband penetration has a positive impact on economic growth. An 10% increase in broadband penetration increases economic growth per employee by approximately 0.035 percentage points.

Alternatively, some scholars have tried to estimate the effect of broadband on employment. Grandall et al. (2007) estimate the effects of its adoption on employment and output at state level for 48 US states during the period 2003-2005. They find that, in the private, non-farm sector, for every 1% increase in broadband adoption, employment increases by 0.2%-0.3% per year. Lehr et al. (2006) finds similar results supporting the hypothesis that broadband penetration enhances economic activity with significant effects on firm growth and employment growth. They find also that broadband penetration has a positive effect on wages.

These studies confirm the positive impact of broadband on economic growth and employment and underlines the need to examine how broadband improves firms' microeconomic performance.

There is a body of work on the effects of broadband adoption on the performance of firms. Most studies examine how broadband enhances firm performance using such indicators as cost savings, productivity and output. A study conducted by Allen Consulting Group (2002) in Australia, indicates that businesses achieve cost savings of around 6.3% from adoption of broadband (compared to 1.5% for dial-up Internet). Since Internet speeds are constantly increasing, one can expect these cost savings also to increase. Grimes et al. (2012), for a panel

[3] For a survey, see Holt and JNOT IN REFSamison (2009).

of 6,060 New Zealand firms in 2006, show that the shift from a standard connection to a broadband connection boosted firms' productivity by 7%-10%, and that this effect is unrelated to the firm's location and the knowledge intensity of the sector. Polder et al. (2010) adopt a firm-level perspective to analyse the role of ICT and R&D in innovation success and firm productivity in the Netherlands. They find that use of broadband Internet is particularly important for services firms where broadband is positively related to both product and process innovation and organizational innovation. In contrast, in the manufacturing sector, broadband is significant only for product and organizational innovations. In the case of process innovation, e-commerce plays a significant role. Bertschek et al. (2013) find that broadband Internet enables firms to reorganize and reshape their business processes, and to improve their products and services. This innovation activity induced by broadband usage will likely translate into productivity gains in later periods.

While this body of literature contributes to validating the positive impacts of ICT on firm performance at the macro and micro levels, it has several limitations. First, it pays little attention to Internet speed. Most papers do not differentiate between the several available broadband speeds. Second, little is said about the

There is another set of studies that studies the use of e-applications especially in Luxembourg, but does not include differences in speeds as an explanatory variable. Chaibi et al, (2015) find causal links between e-skills, use of ICT, and firm performance, for a sample of Luxembourg manufacturing and services firms. They found a positive effect of e-applications (ICT use) on the probability of implementing successful new projects, and an asymmetric effect of e-commerce and e-administration. However, they do not discuss the sensitivity of their findings to the speed of Internet. Ben Youssef and Pelletier-Ben Aoun (2015) find that the use of e-applications has different effects on short and long-term performance. Using the latest generation of ICTs increases firm revenues (short term returns) especially if ICT is used to customize services and products, and if firms have the dedicated IT staff. They show also that using the latest generation of ICTs provides long run returns if they are used intensively, for example, to provide online catalogues, e-commerce solutions and customized websites.

The present paper adds to the literature by investigating how Internet connection speed affects firms' variety of ICT use. The literature shows that the variety of use has short-term and long-term impacts on firm performance including innovation performance.

3. Data, sample and sample characteristics

The data set used for this study is based n the 2013 Survey on ICT Usage and e-Commerce in Enterprises in the case of Luxembourg (STATEC, 2013). The survey provides information on ICT adoption and use. While the survey has been administered since 2003, the 2013 wave was the first to ask about the type of speed of the Internet connection . The dataset covers firms with at least 10 employees in manufacturing and services excluding financial services. This provides a representative sample of 1,869 firms (3,651 firms if weighted by firm size and economic activity).

We reduced the sample to firms with a broadband connection. Figure 1 shows that this excludes very few enterprises (less than 1% of the population of firms). We exclude only companies with a dial-up/ISDN or mobile connection from our analysis.

4. Descriptive statistics

Our sample shows that 97% of the firms have a broadband connection. Rather than comparing this population to the rest of the population of firms (3%) with no broadband connection, we focus on the firms using broadband with 10 or more workers.

Figure 1 shows that 36% of companies have only a broadband connection, and 64% have broadband, and a mobile connection or ISDN. Almost two out of ten firms in our population (18%) have broadband as well as ISDN and mobile connections.

It could be argued that focusing on broadband connection focuses only on fast connections. This is true in absolute terms, but there are large differences in connection speeds (see figure 2) with almost half the sample of firms having speeds of less than 10Mbit/s and only 28% of firms with speeds equal to or greater than 30 Mbit/s in 2013.

4.1. Type of connection

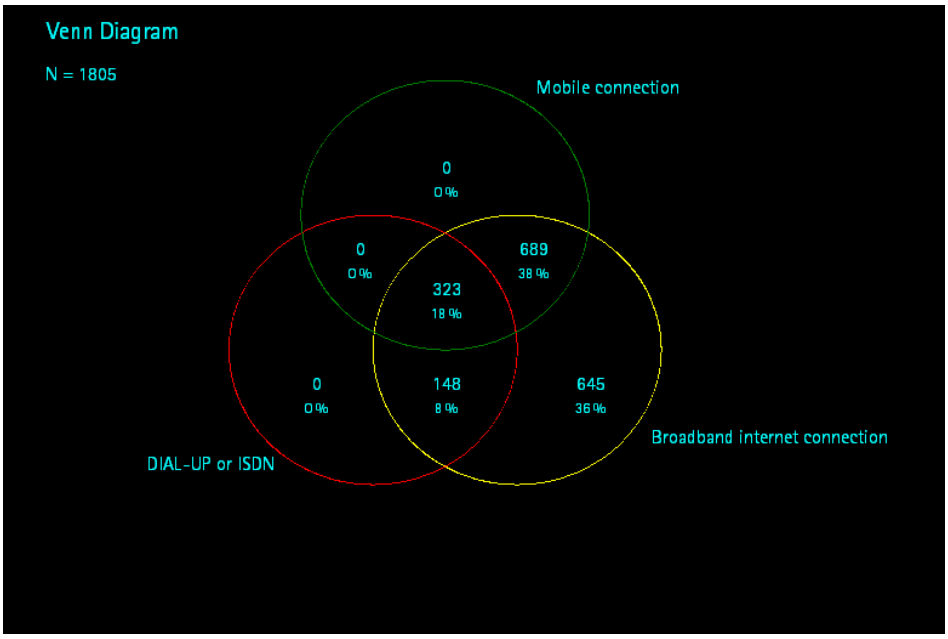


Figure 1. Type of connection

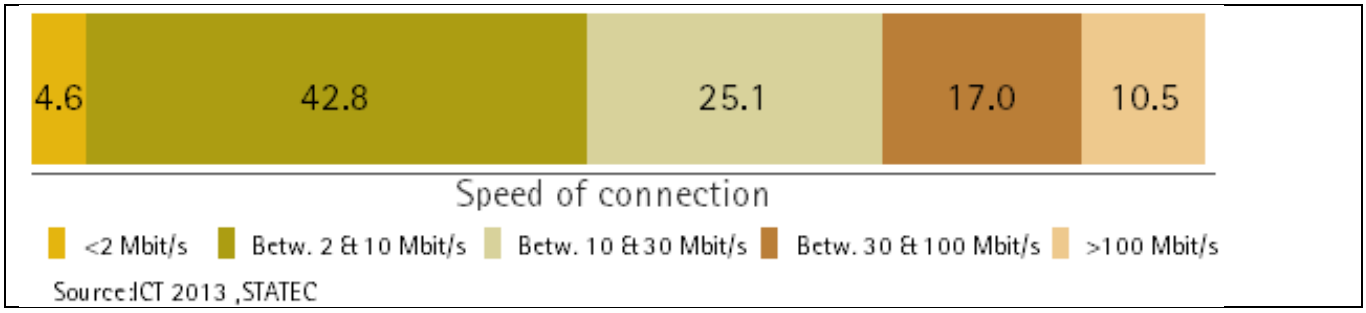
4.2. Internet connection speed

Figure XXX shows that 36% of companies have only a broadband connection, while 64% prefer to combine it with a mobile connection or ISDN. In total, 2 firms out of 10 in our population (18%) will even pair it with both ISDN and mobile connection.

It could be argued that focusing on broadband connection is synonym on studying fast connection, in absolute terms it is true but there are large differences in terms of connection speed (see figure 2). Indeed, almost half of the firm has a speed less than 10Mbit/s and only 28% of the firm has in 2013 a speed equal or greater than 30 Mbit/s.

Figure XXX shows that speed of Internet adoption varies among firms. The need for higher speeds may depend on the firm's activities.

Figure 2. Share of firms by connection speed



Important here is that the type of Internet connection is linked strongly to the connection speed. Figure 2 shows that 52.1% of the firms with a broadband connection receive speeds 2Mbits and 10 Mbits per second, and among these 52.1% of firms 40.2% have broadband and dial-up/ISDN connection types. The first with broadband and dial-up/ISDN connections are the proportion of firms enjoying the lowest speeds (less than 2 Mbits per second). Among those firms with broadband and mobile connections, 19.8% have speeds of between 30 Mbits per second and 100 Mbits per second and another 13% of enjoy speeds of over 100 Mbits per second.

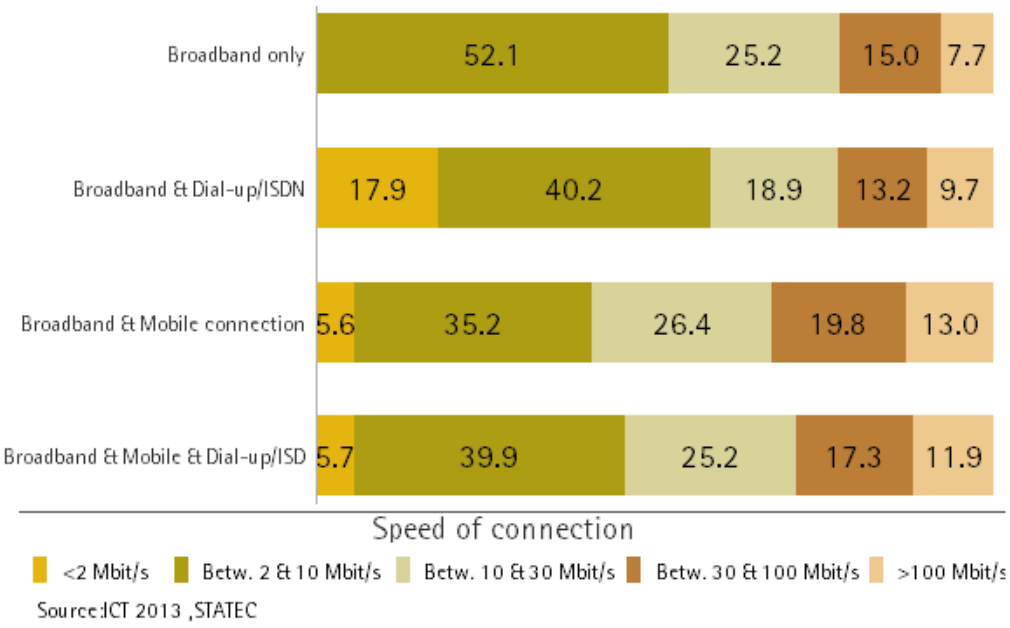
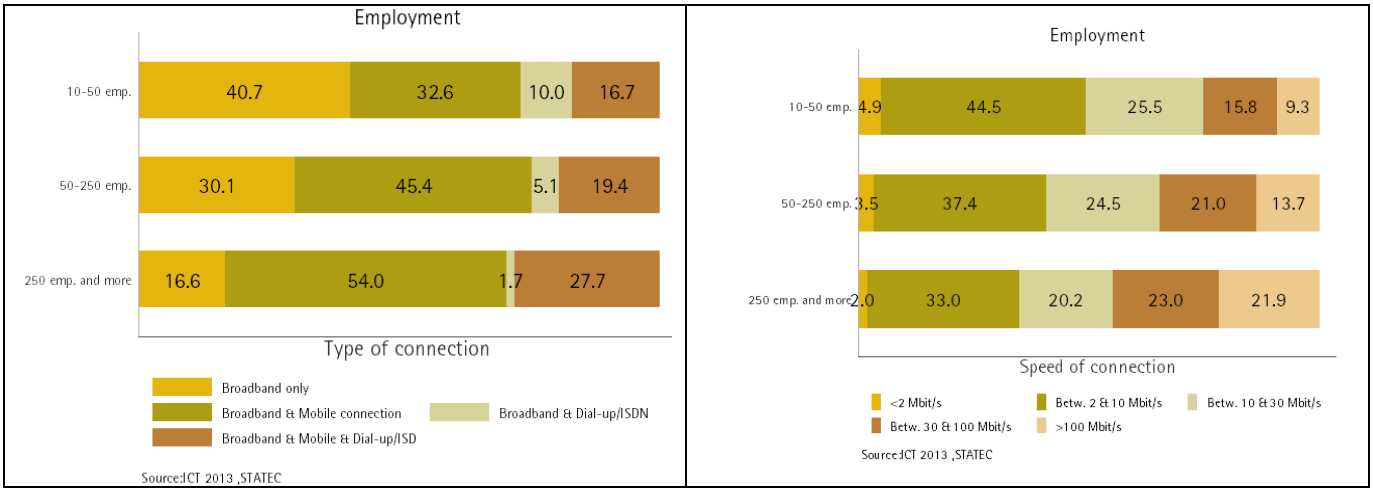


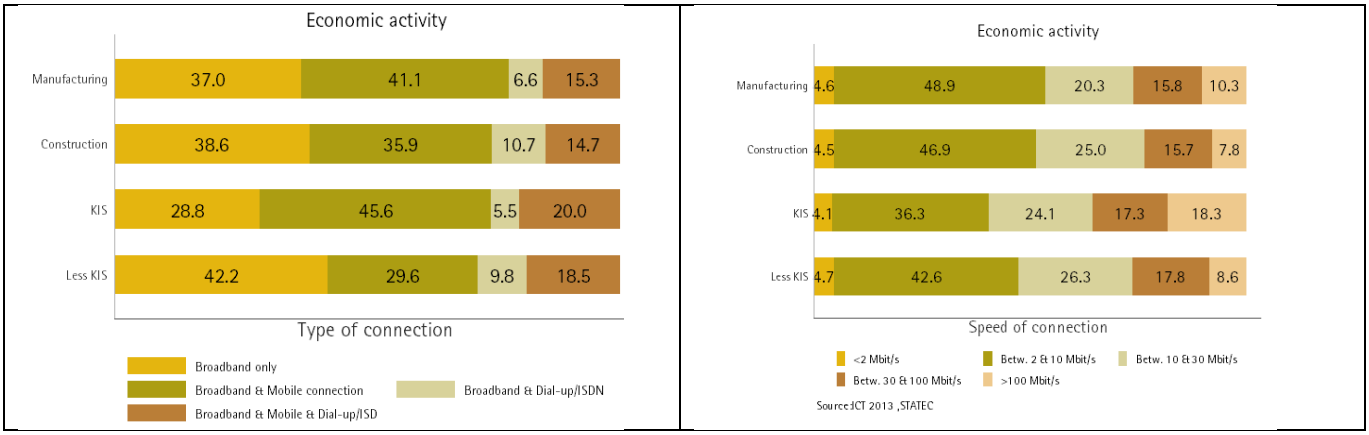
Figure 3. Type of connection by speed of connection

4.3. Type of connection, speed of Internet by size and economic activity of the firm

Descriptive statistics by size and main economic activity confirm existing literature where large firms adopt more often faster connection and combine their broadband connection with mobile connection. Thus, Knowledge Intensive Services are more prone to adopt very fast Internet; their share is double compare to their counterparts (18% versus an average 9%). Moreover, they combine more often broadband and mobile connection than in construction and in less intensive services.

Figure 4. Type of connection, speed of Internet by size and economic activity of the firm





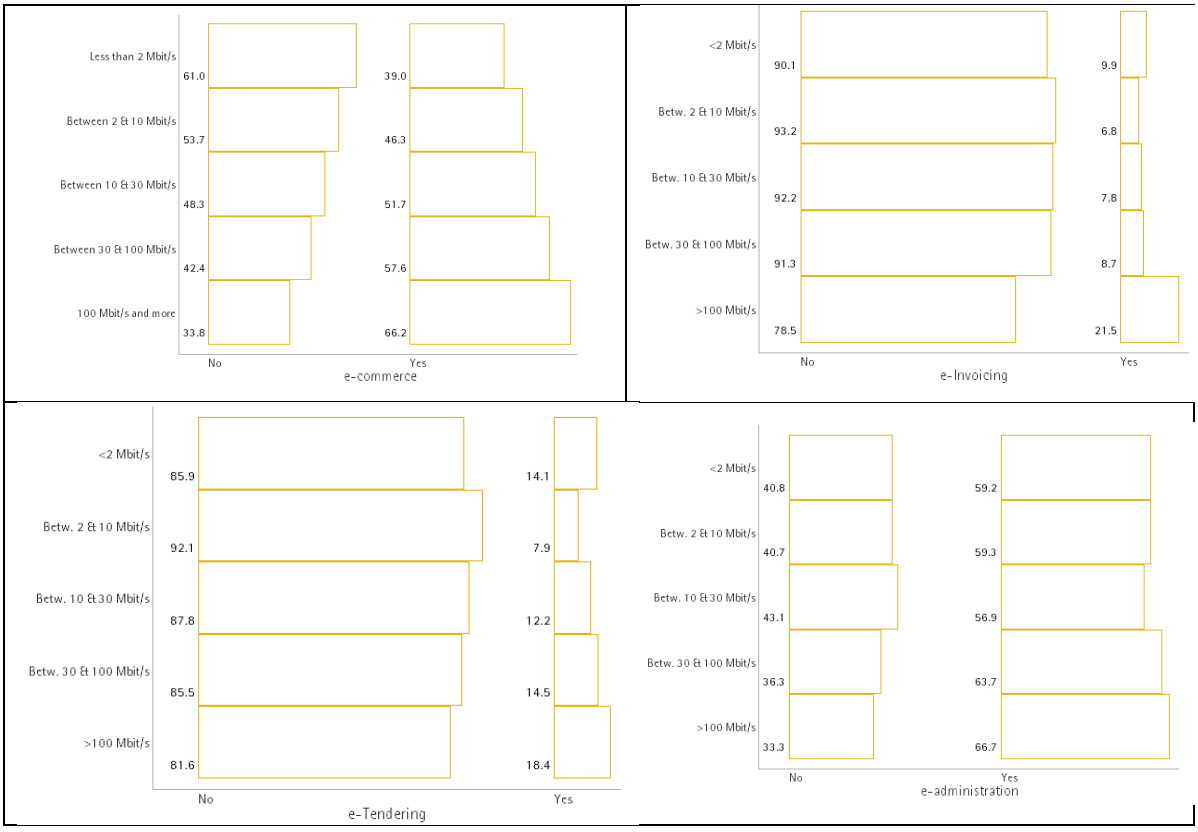
We are interested here in the link between the Internet speed, type of Internet connection, and the activities undertaken by firms based on four types of activities:

e-Activities::

- E-commerce: selling or buying via the Internet;
- E-invoicing: electronic invoicing
- E-administration (digital procedures for various services including e-VAT);
- E-tendering: provision of goods or services as part of an electronic tendering procedure.

We use descriptive statistics to identify the link between these practices and the firm's connection speed.

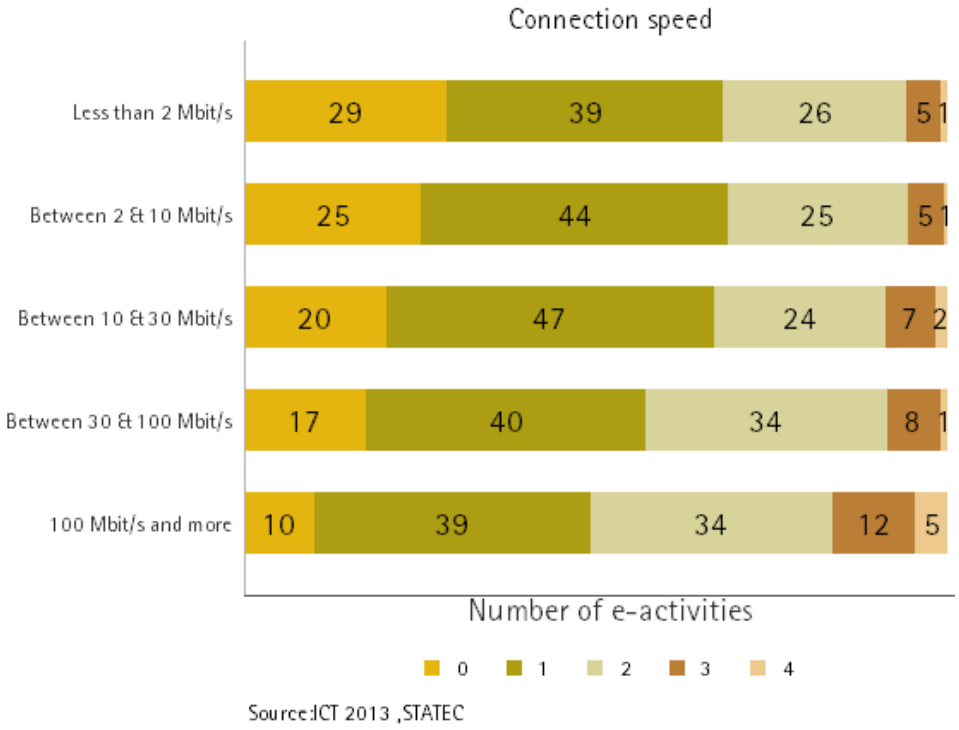
Figure 5. Connection speed and e-activities



The univariate analysis shows that there is an apparent and statistically significant link between some e-practices and the Internet connection speed. There is a positive relationship between connection speed and E-commerce, 66% of companies with a minimum speed of 30Mbt/s adopt E-commerce compared to only 4 in 10 companies with speeds of less than 2Mb/s. Use of e-Invoicing and e-Tendering shows a U-shaped curve.

For administrative procedures the difference is significant depending on the connection speed. We would suggest that e-administration is subject to more stringent legislation which is penalizing companies with slow Internet connections. The companies involved in the highest number of Internet enabled activities are those with faster connections, and vice versa.

Figure 6. Connection speed and intensity of e-activities



Source:ICT 2013 ,STATEC

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5. Econometric Model

5.1. Dependent variables

We define five dependent variables for the relationship between Internet connection speed and e-practices. The first four refer to whether the firm engages in the practices listed above. They are dummy variables which take the value 1 is the firm has adopted the practice and 0 otherwise.

The fifth dependent variable is for the intensity of e-practices and takes values between 0 and 4. Figure 5 shows that very few firms have adopted all four e-practices; Thus, our maximum category is described as adoption of three or more e-practices. Firms not involved in any of the e-activities considered, score 0 , while companies involved in all of these practices score 4. There is no weighting of activities; some may be aimed at reducing costs and others at increasing turnover.

5.2. Explanatory variables

In line with the large literature on the determinants of innovation and the diffusion of ICT, we explore four types of variables. The first two are : (a) firm size in order to test the rank effect, and (b) intensity of competition and the market position in order to test the competition effect. The third focuses on the Internet speed. We broke this down into : less than 2Mbits, between 2 and 10 Mbits, between 10 and 30 Mbits, between 30 and 100 Mbits, and over 100 Mbits. The fourth category is type of connection: broadband only, broadband and dial-up/ISDN, broadband and mobile connection, and broadband and mobile and dial-up/ISDN.

5.3. Model Specification

This study has two objectives. In the first step we focus on the relationship between the four e-practices and Internet connection speed; in the second step we discuss the link between Internet connection speed and intensity of e-practices. We use a logit specification, implemented by an ordered logit.

5.3.1. Probit specification

To estimate the probability of adoption for each e-practice we use the well-known probit estimation. For each practice we observe a binary outcome according to whether the firm has adopted it or not.

$$Y=1 \text{ if } Y^* = X + \beta\, \varepsilon>0 \text{ with } \varepsilon \sim N(0,1)$$

$$Y=0 \text{ Otherwise}$$

Y is an indicator for the latent variable, in our case: the firm adopts Internet if its utility is greater than non-adopting. The probability is equivalent to:

$$\text{Prob}\,(Y=1 \mid X) = \Phi\,(X'\beta)$$

5.3.2 Ordered probit specification

To estimate the probability of the intensity of e-practices, which here is measured by an ordered qualitative, we estimate the following ordered probit model (Greene, 1997):

$$Y^* = X + \beta\, \varepsilon$$

where $\varepsilon \sim N(0,\sigma\varepsilon)$. The latent variable Y* indicates the level of e-practices. The corresponding variable is the score for five categories from 0 to 4. The vector X contains all the previously described variables which might explain adoption of e-practices.

β is the parameter vector. Then the probabilities are:

$$\text{Prob}\,(Y = 0) = \Phi\,(-X\beta)$$

$$\text{Prob}\,(Y = 1) = \Phi\,(mu1 - X\beta) - \Phi\,(-X\beta)$$

$$\text{Prob}\,(Y = 2) = \Phi\,(mu2 - X\beta) - \Phi\,(mu1 - X\beta)$$

$$\text{Prob}\,(Y = 3) = 1 - \Phi\,(mu2 - X\beta)$$

6. Econometric Results

The ordered logit model gives the following results (Table 1).

Table 2. Determinants of e-practices adoption: Probit estimates.

VARIABLES	e-commerce	e-Invoicing	e-administration	e-Tendering
	-0.013	0.019	0.086***	0.028
Group	-0.03	-0.01	-0.03	-0.02
Market position (*ref: follower*)				
Challenger	0.018	-0.002	0.043	-0.029
	-0.04	-0.02	-0.04	-0.03
Leader	0.092**	0.02	0.06	-0.031
	-0.04	-0.03	-0.04	-0.03
Competition (*ref: limited*)				
Intense	0.083*	-0.002	-0.033	0.041*
	-0.04	-0.03	-0.05	-0.02
Very intense	0.076*	-0.003	-0.02	0.076***
	-0.05	-0.03	-0.05	-0.02
Internet speed (ref: <2 Mbit/s)				
Between 2 & 10 Mbit/s	0.071	-0.008	0.053	-0.064
	-0.06	-0.03	-0.06	-0.05
Between 10 & 30 Mbit/s	0.136**	-0.009	0.002	-0.014
	-0.06	-0.03	-0.07	-0.05
Between 30 & 100 Mbit/s	0.162**	-0.01	0.056	-0.01
	-0.07	-0.03	-0.07	-0.05
100 Mbit/s and more	0.220***	0.074*	0.077	-0.007
	-0.07	-0.04	-0.07	-0.05
Type of Connection (*ref: Broadband only*)				
Broadband & Dial-up/ISDN	0.013	0.007	-0.031	0.033
	-0.05	-0.02	-0.05	-0.03
Broadband & Mobile connection	0.193***	0.036**	0.086***	0.032*
	-0.03	-0.01	-0.03	-0.02
Broadband & Mobile & Dial-up/ISDN	0.162***	0.079***	0.096**	0.037
	-0.04	-0.02	-0.04	-0.02
Employment *(ref : less than 50 emp.)*				
50-250 emp.	0.002	0.043***	0.219***	0.048**
	-0.03	-0.02	-0.03	-0.02
250 emp. and more	-0.045	0.190***	0.254***	0.078*
	-0.06	-0.05	-0.06	-0.04
Economic activity *(ref : Manufacturing)*				
Construction	-0.087*	-0.051**	-0.035	0.043*
	-0.05	-0.02	-0.05	-0.02
Knowledge Intensive Services	0.085*	-0.015	0.015	0.104***
	-0.05	-0.02	-0.05	-0.03
Less Knowledge Intensive Services	-0.004	-0.016	-0.014	0.054**
	-0.04	-0.02	-0.05	-0.02
Observations			**3148**	

Notes: Probit estimations: coefficients are estimates of marginal effects (∂F/∂xk), i.e. the marginal effect on Pr(y=1) given a unit increase in the value of the relevant (continuous) regressor (xk), holding all other regressors at their respective sample means. The discrete change in the probability is reported for binary regressors .
Standard errors, adjusted for potential regional clustering, in parentheses.
* p<0.10 ** p<0.05 *** p<0.01.

Table 3. Determinants of intensity of e-practices adoption: Ordered Probit estimates

VARIABLES	None	One	Two	Three and more
Group	-0.041 **	-0.013 **	0.032 **	0.022 **
	(0.016)	(0.005)	(0.013)	(0.009)
Market position (ref: follower)				
Challenger	-0.012	-0.003	0.009	0.005
	(0.023)	(0.005)	(0.018)	(0.011)
Leader	-0.051 **	-0.018 **	0.041 **	0.028 **
	(0.025)	(0.009)	(0.020)	(0.013)
Competition (ref: limited)				
Intense	-0.031	-0.007	0.024	0.015
	(0.029)	(0.005)	(0.022)	(0.013)
Very intense	-0.045	-0.011 **	0.034	0.022 *
	(0.029)	(0.006)	(0.022)	(0.013)
Internet speed (ref: <2 Mbit/s)				
Between 2 & 10 Mbit/s	-0.025	-0.004	0.018	0.01
	(0.042)	(0.005)	(0.031)	(0.016)
Between 10 & 30 Mbit/s	-0.043	-0.008	0.033	0.018
	(0.043)	(0.006)	(0.032)	(0.017)
Between 30 & 100 Mbit/s	-0.073 *	-0.02 **	0.058 *	0.036 **
	(0.043)	(0.009)	(0.032)	(0.018)
100 Mbit/s and more	-0.118 ***	-0.051 ***	0.096 ***	0.073 ***
	(0.043)	(0.016)	(0.033)	(0.023)
Type of Connection (ref: Broadband only)				
Broadband & Dial-up/ISDN	-0.003	0.001	0.002	0.001
	(0.037)	(0.001)	(0.026)	(0.011)
Broadband & Mobile connection	-0.121 ***	-0.036 ***	0.098 ***	0.058 ***
	(0.019)	(0.007)	(0.016)	(0.009)
Broadband & Mobile & Dial-up/ISDN	-0.128 ***	-0.041 ***	0.105 ***	0.064 ***
	(0.022)	(0.012)	(0.019)	(0.014)
Employment (ref : less than 50 emp.)				
50-250 emp.	-0.094 ***	-0.048 ***	0.08 ***	0.062 ***
	(0.014)	(0.01)	(0.013)	(0.011)
250 emp. and more	-0.131 ***	-0.09 ***	0.114 ***	0.108 ***
	(0.021)	(0.028)	(0.019)	(0.03)
Economic activity (ref : Manufacturing)				
Construction	0.053 *	0.01	-0.04 *	-0.023
	(0.029)	(0.008)	(0.023)	(0.014)
Knowledge Intensive Services	-0.055 **	-0.027 **	0.046 **	0.036 **
	(0.026)	(0.012)	(0.022)	(0.016)
Less Knowledge Intensive Services	-0.002	-0.001	0.002	0.001

	(0.026)	(0.008)	(0.021)	(0.014)
Observations		**3148**		

Notes: Probit estimations: coefficients are estimated marginal effects (∂F/∂xk), i.e. the marginal effect on Pr(y=1) given a unit increase in the value of the relevant (continuous) regressor (xk), holding all other regressors at their respective sample means. The discrete change in the probability is reported for binary regressors .

Standard errors in parentheses.

* p<0.10 ** p<0.05 *** p<0.01.

Average predictions

0	1	2	3
0.203	**0.429**	**0.283**	**0.084**

6.1. Internet Speed and adoption of e-activities

Estimates of whether firms have adopted e-commerce, e-invoicing, e-administration and e-tendering are shown in Table 2. It shows that there is a competition effect, and confirms the existence of a relationship between type and speed of Internet connection and use of e-applications in Luxembourgish firms. The results in columns (1)-(4) show big differences for the determinants of adopting specific e-practices.

6.1.1. Competition effect works

To investigate the impact of the market on e-practices, we distinguish between market position and market competition. Market position mostly does not influence the propensity to adopt e-activities except for the case of e-commerce. Being a market leader increases the probability of engaging in e-commerce by 9% point compared to being a market follower, other things being equal. This confirms previous findings on the adoption of innovations. Firms in a leader position try to maintain their advantage by adopting new technological innovations. The second aspect of the competition is its intensity. Our results show that firms facing stronger competition are more willing to practice e-commerce or e-tendering. In economic sectors where competition is particularly fierce, firms try to differentiate practices and products. E-commerce provides a way to differentiate practices and enlarge the scope of their market. At the same time, e-tendering is supposed to decrease the cost of inputs (saving on paper, increased speed of process, and more competitive prices) and result in higher profit. In the case of Luxembourg, it is not surprising that competition seems not to influence e-administration adoption since many administrative activities are already on line.

6.1.2. Speed and type of connection matter

For speed of Internet connection, our results show that speed does not matter for e-applications related to government (e-Administration, e-Tendering). Policy requires these practices to be accessible to all firms and e-applications developed by government are not elaborate (e.g. filling in a web form). However, for e-commerce and e-invoicing, connection speed matters. If the connection speed is at least 10Mbits, it is likely that the firm will adopt e-commerce practices. In the case of e-invoicing, speed matters more: the highest speed (over 100Mbt/s) increases the probability of e-invoicing by 7% points. E-tendering is considered a sophisticated practice reserved to innovative firms.

Our results suggest also that the type of connection combined especially with use of mobile connection, increases the probability of all e-practices including e-tendering. Table 2 shows that adoption of broadband and mobile connections is a predictor of e-commerce, e-invoicing and e-administration compared to firms with only a broadband connection. There is no

statistical difference between firms with broadband only and firms equipped with broadband and dial-up ISDN connection in terms of e-practices. Our results have direct implications for economic policy by indicating that higher speed connections and mobile connections would foster adoption of e-commerce in Luxembourg. .

6.1.3. Control variables

Another finding is that being part of a group has an impact on adoption of e-administration to avoid duplication of effort and resources which might explain its adoption bymulti-plant firms

6.2. Intensity of Internet connection and e-activities

The second part of our analysis examines the relationship between connection speed and intensity of e-activities (see Annex Table 3 for full results). We find a positive relationship.

6.2.1. Rank effect

We found no evidence of a rank effect. Firm size is an important determinant of intensity of adoption of e-applications. Our results show that there is a difference between small and big firms in intensity of use of e-applications. This confirms the results in the literature; most economics studies show evidence of a rank effect. Big firms are more likely to adopt new ICT innovations. Our results show that they are also able to adopt the fastest Internet connections which increases their use.

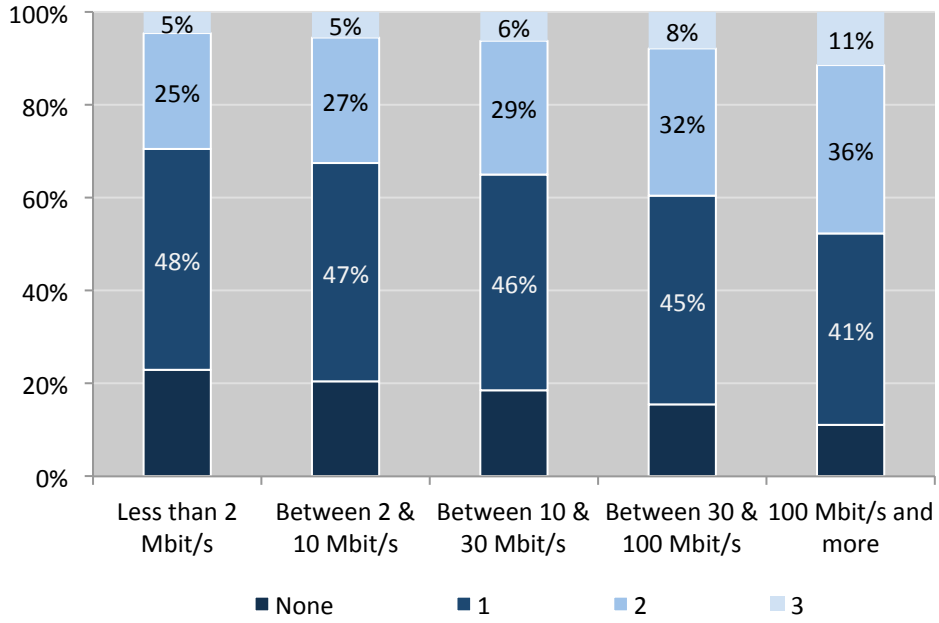
6.2.2. Market structure

We have shown that being a leader has an impact on the number of Internet practices. Leaders are more reluctant to not engage in e-activities or in only one kind of e-activity. However, the strength of the competition in the market affects intensity only in the case of very strong competition. In this case, the leading firms are more likely to adopt all the e-practices examined. This might be due to competitive pressure and cost reduction strategies. Being part of a very competitive market increases the probability of adopting three or more e-practices by 2% point, and decrease, it is small in absolute term but important considering the small share of enterprises that have adopted at least three type of e-activities. Being a leader on the market has a relatively equivalent impact.

6.2.3. Internet speed and intensity of use of e-practices

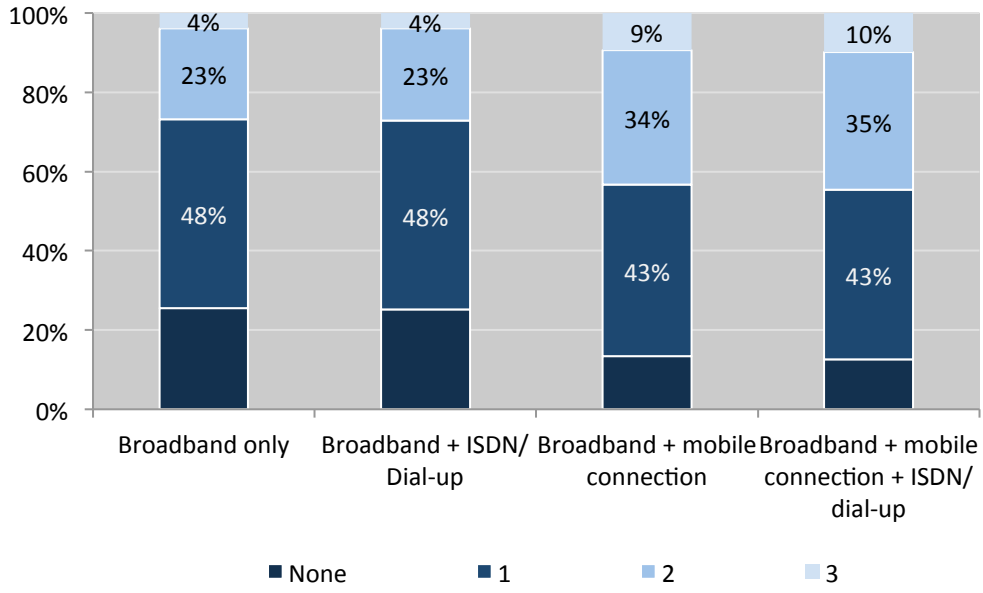
There is no statistical difference between the intensity of e-practices and firms with Internet speeds of less than 30 Mbits. However our results show a clear relationship between the intensity of adoption of e-applications and Internet speeds higher than 30 Mbits compared to firms with less than 2Mbt/s. The faster the speed the larger the number of e-practices adopted. Our results confirm that Internet speed is a major determinant of the intensity of use of e-applications. As e-solutions proliferate, the adoption of high speed Internet increases the probability of their use. **In addition, we observe** a negative sign of the marginal effects for the category no or only one Internet activity, and a positive sign for the other two categories. A connection of between 30Mbit/s and 100 Mbit/s increases the probability of two different types of Internet activities (among those defined previously) by 6% point compared to the slowest connection. Figure 6 depicts this result.

Figure 6. Predicted probabilities by speed of connection.



Another important result of this part of the analysis is the importance of a mobile connection to e-activities. Figure 7 shows that firms with broadband and mobile connections are more likely to adopt a larger number of Internet activities than other firms, ceteris paribus.

Figure 7. Predicted probabilities by type of connection



Based on the characteristics of the firm, we can confirm the main assumption that firms involved in a group, firms with higher numbers of employees and knowledge intensive firms are more likely to adopt more e-activities as suggested by the univariate analysis and by the previous literature.

Our econometric results confirm the intuition that Internet speed has an important impact on the scope and the intensity of use of e-applications by firms. There are numerous e-

applications available to firms; however, our study shows the existence of this link focusing only on four types of e-applications.

7. Concluding remarks

The aim of this paper was to examine the impact of the type of broadband connection and the speed of the Internet connection on uptake of e-activities, based on e-commerce, e-administration, e-tendering, e-invoice) among firms in Luxembourg. Our paper found a clear link between Internet connection speed and type and use of e-application and intensity of Internet use (measured by the number of e-activities adopted). Using an ordered logit model we showed that the faster the Internet speed, the higher the probability that the firm will adopt more e-activities.

We also found that adoption of e-commerce is linked to the speed of the Internet. Firms are more likely to undertake e-commerce when the connection speed is higher than 30 Mbits. Our findings suggest that in order to foster e-commerce in Luxembourg (and probably other European countries), public policies aimed at increasing Internet connection speeds are vital. Also, for higher speeds, use of e-applications becomes more sophisticated. In our case, we found that e-tendering is used especially by firms with connection speeds of more than 100Mbits.

Mobile connection is an important lever for increased use of e-applications. Our results show that firms with broadband and mobile connections are much more likely to adopt e-activities than other firms, everything else constant. Mobility is increasing the need for coordination among employees via new e-applications. As they use these applications, their e-skills increase which increases the likelihood of adoption of other e-applications especially for administration purposes. Applications that have a direct impact on revenue and costs are more likely to be adopted than e-administration activities (considered as less cost-cutting) except for firms that are part of a group.

We found that the classical arguments for competition effects hold. The more intense the competition, the more firms adopt new applications (especially e-commerce). At the same time, the market leaders try to maintain their position in the market by greater adopt of technological innovations compared to followers. Finally, our results show that large firms and knowledge intensive services firms are more likely to adopt more e-activities

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