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CHAPTER 4

Information and Communication Technologies, Innovation, and Productivity: Evidence from Firms in Latin America and the Caribbean

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Over recent decades, the economic literature has progressively recognized the role of information and communication technologies (ICTs) as a key driver of economic growth. In particular, a large body of research has clearly shown the link between accelerating productivity growth and ICT diffusion in the context of growth accounting (Oliner and Sichel 1994, 2002; Jorgenson 2001).

At the firm level, ICT adoption can improve business performance in various ways: ICTs speed up communication and information processing, decrease internal coordination costs, and facilitate decision-making (Cardona et al. 2013; Arvanitis and Loukis 2009; Atrostic et al. 2004; Gilchrist et al.

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2001). ICTs may also promote substantial firm restructuring, making internal processes more flexible and rational, and reducing capital requirements, by improving equipment utilization and reducing inventory. Moreover, the possibility of developing better communication channels with suppliers, clients, knowledge providers, and competitors may increase innovation capacity.

Nevertheless, ICT-driven productivity gains vary largely among countries and sectors, suggesting that simple diffusion may be not sufficient to take full advantage of the potential of ICTs. Empirical evidence indicates that firm-specific operational and organizational characteristics determine not only the expected benefit of ICT adoption, but also the impact once adopted. Therefore, complementary investment in areas such as organizational change and human capital appear necessary both to increase absorptive capacity and to maximize the real impact of new technologies (Brynjolfsson and Hitt 2000). As a result, ICTs seem to function as an enabling factor that allows firms to use new processes and business practices, which, in turn, improve performance.

A complete understanding of these dynamics is central to designing effective public policies to promote ICT adoption and increase firm productivity. However, the bulk of the literature has focused on developed countries, while evidence from emerging economies is still scarce and fragmented. This chapter aims to fill this knowledge gap by exploring the determinants of broadband adoption and assessing their relationship with innovation and productivity in Latin America and the Caribbean (LAC).

The rest of the chapter is organized as follows. First we describe the main patterns of diffusion of the internet in LAC and the data we use in our empirical analysis. Then we discuss determinants of ICT adoption and explore the relationship between broadband, innovation, and productivity. We review the relevant theoretical and empirical literature, specifying the empirical model employed and discussing the main results. Finally, we provide concluding remarks.

Data and Main Patterns of Internet Diffusion in LAC

The diffusion and use of ICT is still relatively low in LAC. In fact, although ICTs have significantly increased in the region, there is still a notable divide between LAC and developed countries, especially in the most advanced technologies.[1] Using data from the International Telecommunications Union (ITU) for 2014, Fig. 4.1 displays an international comparison for fixed broadband penetration. Western Europe (EUR) and USA–Canada (US-

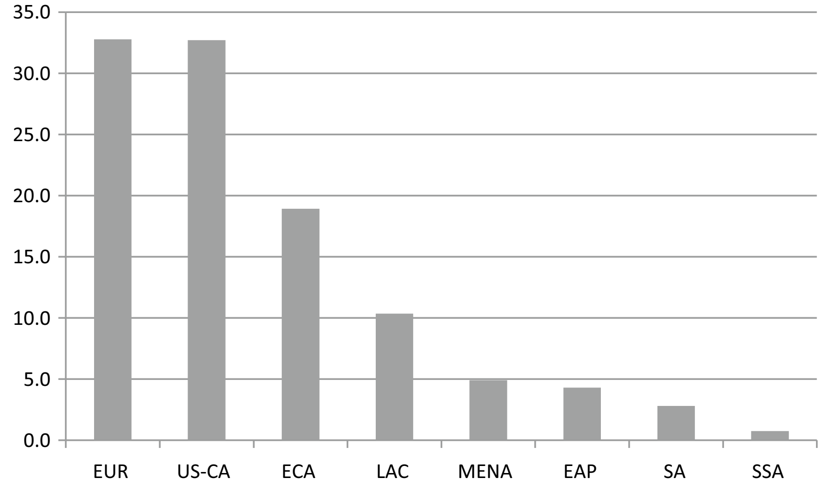

Fig. 4.1 Fixed broadband subscriptions by region (2014)

Source: Authors' elaboration using data from the ITU

Notes: Simple average of available countries in each region. **EUR**: (*Western Europe*) Austria, Belgium, Croatia, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Spain, Sweden, United Kingdom, Norway, and Switzerland; **US-CA**: The United States and Canada; **ECA**: (*Eastern Europe and Central Asia*) Bosnia and Herzegovina, Bulgaria, Czech Republic, Estonia, Hungary, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Moldova, Mongolia, Montenegro, Poland, Romania, Russia, Serbia, Slovak Republic, Slovenia, and Ukraine; **LAC**: Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, St. Kitts & Nevis, St. Vincent & the Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela; **MENA**: *Middle East and North Africa*) Algeria, Djibouti, Egypt, Arab Republic, Jordan, Lebanon, Libya, Morocco, Syrian Arab Republic, Tunisia, and Yemen; **EAP**: (*East Asia and Pacific*) Indonesia, Lao PDR, Micronesia, Philippines, Samoa, Timor Leste, Tonga, Vanuatu, and Vietnam; **SA**: (*South Asia*) Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan, and Sri Lanka; **SSA**: (*Sub-Saharan Africa*) Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Chad, Comoros, Congo, Cote d'Ivoire, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, and Zimbabwe

CA) appear at the top, with 32 connections per 100 people. Eastern Europe and Central Asia (ECA) and LAC are far behind, with 19 and 10 connections per 100 people, respectively. Middle East and North Africa (MENA), East Asia and the Pacific (EAP), South Asia (SA), and Sub-Saharan Africa (SSA) report 5, 4, 3, and 1 connections per 100 habitants, respectively.

With respect to ICT diffusion in firms, an international comparison is much more complicated because it requires precise and comparable data, which is not easy to find. Nevertheless, a first approximation can be made using data from the World Bank Enterprise Surveys (WBES). The WBES have been conducted in various waves across 135 developing countries since 2002, using face-to-face interviews with top managers, covering a broad range of topics relevant to business, including innovation, ICT, access to finance, corruption, infrastructure, crime, competition, and performance measures. However, a full set of ICT-related questions was only introduced in the 2010 round and not in all the surveyed countries.[2]

For this reason, a comparison is possible only among those regions that have enough countries reporting data on ICT access. Fig. 4.2 shows the level of broadband diffusion, email use, and website availability for the surveyed firms, by region.

LAC emerges as the region among the developing countries with the highest level of ICT penetration, with almost 85% of its firms indicating that they have a high-speed internet connection, 90% using email to communicate with clients or suppliers,[3] and 60% having their own website. This analysis shows that, overall, ICT diffusion among firms in LAC appears generally to be higher than in other developing regions, though we are cautious in our assessment of these results. First, the WBES does not provide information about adopting and using more advanced ICTs, only basic technologies that firms in advanced economies take for granted, and thus the resulting picture could be too optimistic. Second, WBES data on ICT diffusion in firms are not always consistent with ITU data on diffusion in society, raising some concerns about data reliability. For example, Fig. 4.3 shows the correlation between the percentage of households with a fixed broadband connection (ITU data) and the percentage of firms with broadband on their premises (WBES data) in LAC. It is clear that in some cases the two indicators substantially differ. For example, Panama shows a high level of household connection (31.6%), much higher than most Central American countries (with the exception of Costa Rica), but has the lowest percentage of firms with a broadband connection, even lower than Nicaragua and Honduras.

Even considering these caveats, the WBES provide excellent observations to empirically study ICT dynamics in LAC firms because they are the first attempt to collect related data with the same questionnaire and sampling across all countries. After data cleaning, the analysis included in this chapter is based on a 2010 cross-section dataset of 10,477 enterprises from 19 LAC countries,[4] with Mexico (13.7%), Argentina (9.6%), and

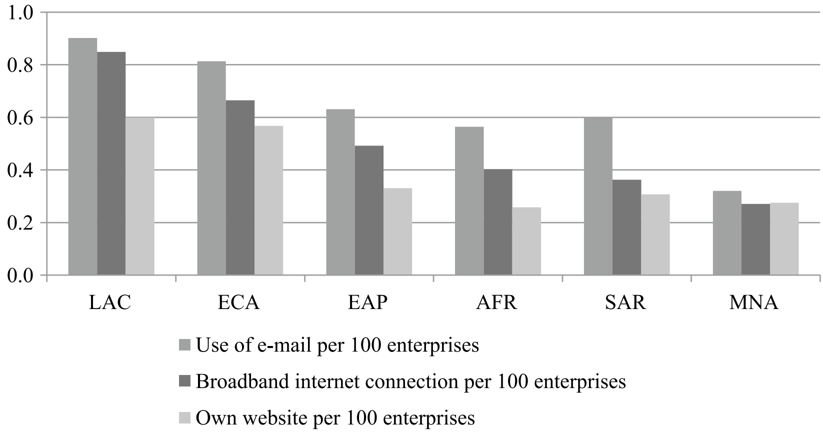

Fig. 4.2 ICT diffusion in enterprises (2009–2010)

Source: Authors' elaboration based on WBES data

Notes: Simple average of available countries in each region. **LAC**: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, St. Kitts & Nevis, St. Vincent & the Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela; **ECA**: (*Eastern Europe and Central Asia*) Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Czech Republic, Estonia, Fyr Macedonia, Hungary, Kazakhstan, Kosovo, Kyrgyz Republic, Latvia, Lithuania, Moldova, Mongolia, Montenegro, Poland, Romania, Russia, Serbia, Slovak Republic, and Slovenia; **EAP**: (*East Asia and Pacific*) Fiji, Indonesia, Lao PDR, Micronesia, Philippines, Samoa, Timor Leste, Tonga, Vanuatu, and Vietnam; **AFR**: (*Africa*) Angola, Benin, Botswana, Burkina Faso, Cameroon, Cape Verde, Chad, Congo, Democratic Republic of the Congo, Eritrea, Gabon, Ivory Coast, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Niger, Sierra Leone, and Togo

Chile (8.6%) being the most represented in terms of observations. The resulting sample includes enterprises of various sizes[5] from both the manufacturing and services sectors. In Table 4.1, we provide the sample's main descriptive statistics.

ICT Adoption

From a theoretical point of view, several models have been developed to explain patterns of ICT adoption among firms, building on the existing body of research on technology diffusion. Karshenas and Stoneman (1995) proposed a general conceptual framework, distinguishing four sub-models: Epidemic, rank (probit), stock, and order.

Table 4.1 Descriptive statistics

Variables	*Mean*	*Standard deviation*	*Minimum*	*Maximum*	*Observations*
Broadband	0.848	0.359	0	1	10,440
E-mail	0.904	0.295	0	1	10,462
Website	0.630	0.483	0	1	10,460
Internet use for purchases	0.626	0.484	0	1	10,440
Internet use to deliver services	0.605	0.489	0	1	10,440
Internet use for research	0.674	0.469	0	1	10,440
Internet for purchases, to deliver services, and for research	0.429	0.495	0	1	10,440
Broadband intensity (scale)	2.752	1.426	0	4	10,440
Log (productivity)	10.426	1.200	4.06	16.34	8431
New product	0.574	0.495	0	1	6155
New process	0.483	0.500	0	1	6147
Log (capital per worker)	8.706	1.546	1.09	14.95	4293
Micro firm	0.219	0.414	0	1	10,440
Small firm	0.394	0.489	0	1	10,440
Medium firm	0.277	0.448	0	1	10,440
Skilled human capital	16.864	21.635	0	100	10,165
Age of firm	25.898	20.036	1	185	10,330
Foreign direct investment (FDI)	0.129	0.336	0	1	10,477
Exporter	0.162	0.369	0	1	10,477
Investment	0.555	0.497	0	1	10,415
Capital city	0.497	0.500	0	1	10,477

Source: Authors' elaboration based on WBES data.

Early research introduced epidemic models based on the concept that the diffusion of a technology depends on information about its availability (Mansfield 1963). These models predict that the diffusion of new technology gradually increases over time, as adoption costs and risks decline, based on learning effects among firms. The process is similar to the spread of epidemics: early adopters disseminate information, then other firms adopt the technology and release further information, and so on until the saturation point. While epidemic models are traditionally based on information spillovers from users to non-users, for ICT another dimension is very relevant: network effects. In fact, the gains that derive from ICT adoption—as well as the opportunity costs of not adopting—increase with the number of users of the technology, causing a snowball effect.

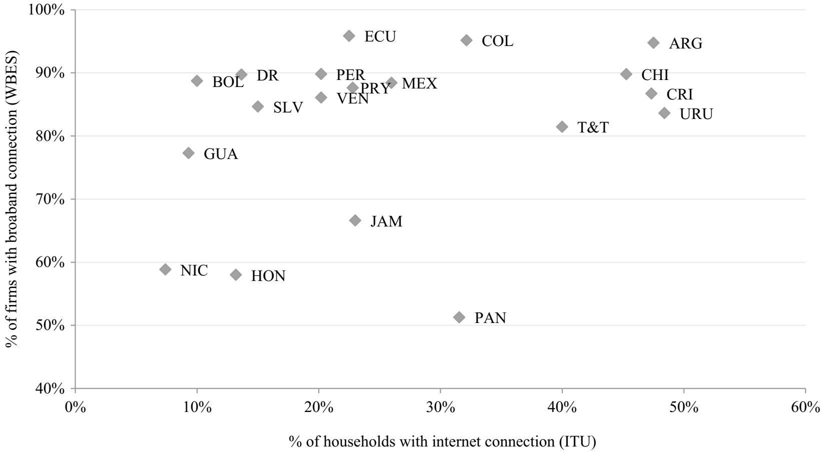

Fig. 4.3 ICT diffusion in LAC (latest available year)
Source: Authors' elaboration based on ITU and WBES data

However, without considering firm heterogeneity, these models are not sufficient to explain fully variations in adoption rates among firms. Another group of theoretical models (rank or probit models) was developed with increasing emphasis on the link between different firm characteristics, differentials in expected or potential returns, and adoption decisions.

Finally, two game theory approaches model the returns on adoption depending on the number of previous adopters and the order of adoption. Stock models are based on the assumption that the benefit of adoption decreases as the number of previous adopters increases. Then, for any given adoption cost there is a number of adopters beyond which adoption is not profitable. On the other hand, order models reflect the advantages of early adopters, assuming that returns on adoption depend on the position of a firm in the order of adoption because of advantages such as obtaining better skilled labor or geographic locations.

It is important to stress that, even if the majority of the literature has focused on the demand side, technology diffusion dynamics are the result of the interaction between demand-side and supply-side factors. The models usually assume declining prices over time, but do not relate it to supply-side forces. Moreover, and quite surprisingly, empirical research has mainly focused on inter-firm diffusion—the access a firm has to a new technology—and has neglected intra-firm diffusion—the extent of technology usage in the firm.

Model Specification and Results

In this chapter, in line with recent literature, we empirically test the validity of the rank and epidemic[6] models in LAC firms, focusing on inter- and intra-firm ICT diffusion. To identify determinants of inter-firm diffusion, we estimate the following equation to model the probability a firm will adopt ICT:

$$\begin{aligned}\Pr(\text{ICTADOPTION}=1)= &\\ &\text{F}(\alpha+\ \beta_0 * \textit{RankEffects}+\beta_1 * \textit{LocationEffects}\\ &+\ \beta_2 * \text{EpidemicEffects}+\ \beta_3 * \text{CountryEffects}\\ &+\ \beta_4 * \text{SectorEffects})\end{aligned} \tag{4.1}$$

To measure inter-firm ICT adoption, we consider two dichotomic indicators: broadband, using the value 1 if a firm has a high-speed internet connection on its premises, and website, using the value 1 if a firm has its own website. Then, we estimate two equations where broadband and website are the dependent variables.

As for rank effects, we first consider the size of the firm, grouping them into four categories: micro (10 or less employees), small (11–50 employees), medium (51–250), and large (251 or more). Size is generally considered relevant to the adoption of new technologies. Given that larger firms have fewer financial constraints and are usually less risk adverse, supposedly they are in a better position to withstand the costs and risks associated with new technologies.[7] Empirical evidence generally supports this hypothesis (Teo and Tan 1998; Fabiani et al. 2005; Haller and Siedschlag 2011; Giunta and Trivieri 2007).[8] We use large firms as our reference group.

We then consider the firm's age as a proxy for its technological experience (age of firm), and we look at the percentage of workers with at least a bachelor's degree as a proxy for human capital (skilled human capital). The relationship between a skilled workforce and ICT adoption is relatively clear in the literature,[9] which shows that a more educated workforce facilitates the early adoption of technologies (Chun 2003) and that the demand for skilled workers increases with the use of new technologies (Bartel and Sicherman 1999); however, the role of firm age is not theoretically straightforward. In fact, on the one hand, older firms are better equipped to assess the risks and benefits of introducing new technologies, while, on the other hand, younger enterprises are believed to be more flexible in dealing with the organizational changes that come with adopting ICTs. The empirical evidence is inconclusive, in general finding either a non-significant (Bayo-Moriones and Lera-Lopez 2007; Giunta and Trivieri 2007) or negative impact (Haller and Siedschlag 2011; Gambardella and Torrisi 2001) of age on ICT diffusion.

The next two variables we consider are exposure to international competition (exporter) and the need to be early adopters of ICT to maintain fluid communication with foreign partners (foreign direct investment, or FDI). Exporter is a dummy variable, taking the value 1 if at least 10% of the firm's sales are exported. FDI is also a dummy variable, taking the value 1 if at least 10% of the firm's capital is foreign-owned. In general, empirical evidence shows that firms that engage in foreign trade are more likely to adopt new technologies (Hollenstein 2004; Lucchetti and Sterlacchini 2004; Haller and Siedschlag 2011), and that those foreign-owned tend to be early adopters, contributing to technology diffusion in the country where they operate (Keller 2004; Narula and Zanfei 2005).

Capital city, a dummy variable that takes the value 1 if the firm is located in a capital or in a city with more than one million inhabitants, controls for location effects. The empirical literature demonstrates the influence of an urban or densely populated location on ICT adoption. Many arguments support this hypothesis, such as the proximity of suppliers, technology prices, and the availability of a qualified labor force (Galliano et al. 2001; Karlsson 1995).

The epidemic variable calculates the percentage of other firms that have adopted a technology (broadband or website) in the same country and sector. This variable tests for the existence of network effects for ICT diffusion, following the hypothesis that existing technology adopters have positive spillover effects on firms considering adoption. In other words, firms operating in more digitally advanced countries and sectors may face reduced costs and increased benefits. Finally, in all estimations we include country and three-digit sector dummy variables to control for unobserved industry- and region-specific effects.

To estimate equation 4.1 for the two indicators (broadband and website), we use a sequential approach. First we apply a probit model, which is a common econometric approach that uses maximum likelihood estimation. This approach is not always fully efficient because it does not consider the correlation between firm choices in adopting broadband and having a website. Therefore, to consider this possible correlation, we complement the probit analysis with a bivariate probit (biprobit) model (Greene 2003).

We show the marginal effects resulting from our estimations with probit in Table 4.2. Columns 1 and 2 present results for broadband connection, while columns 3 and 4 refer to having a website. Columns 1 and 3 correspond to the basic model, while columns 2 and 4 add the capital city and epidemic variables.

Table 4.2 Determinants of broadband connection and using firm website: probit estimations

Variables	*Broadband connection*		*Website*	
	Basic	*Inclusive*	*Basic*	*Inclusive*
	(1)	*(2)*	*(3)*	*(4)*
Micro firm	−0.2718***	−0.2666***	−0.4782***	−0.4697***
	(0.0182)	(0.0182)	(0.0198)	(0.0198)
Small firm	−0.1433***	−0.1403***	−0.3084***	−0.3040***
	(0.0181)	(0.0180)	(0.0195)	(0.0194)
Medium firm	−0.0609***	−0.0588***	−0.1172***	−0.1155***
	(0.0188)	(0.0186)	(0.0203)	(0.0203)
Skilled human capital	0.0022***	0.0022***	0.0023***	0.0023***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Age of firm	0.0007***	0.0007***	0.0014***	0.0014***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
FDI	0.0138	0.0126	0.0612***	0.0594***
	(0.0122)	(0.0122)	(0.0155)	(0.0155)
Exporter	0.0868***	0.0876***	0.1115***	0.1120***
	(0.0146)	(0.0145)	(0.0148)	(0.0148)
Capital city	n.a.	0.0233***	n.a.	0.0458***
		(0.0070)		(0.0094)
Epidemic (broadband)	n.a.	0.1193***	n.a.	n.a.
		(0.0326)		
Epidemic (website)	n.a.	n.a.	n.a.	0.1517***
				(0.0365)
Country dummies	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes
Log likelihood	−3010	−2999	−4880	−4859
Pseudo R-squared	0.278	0.281	0.232	0.236
Observations	9583	9583	9583	9583

Source: Authors' elaboration based on WBES data

Notes: "Inclusive" includes the capital city and epidemic variables. Estimated marginal effects from the probit regression. Delta-method standard errors are in parentheses. * Coefficient is statistically significant at the 10% level, ** at the 5% level, *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. n.a. = not applicable.

We present the biprobit estimates in Table 4.3, with the basic estimations displayed on the left side and those with capital city and epidemic variables included on the right side.

Table 4.3 Determinants of broadband connection and using firm website: biprobit estimations

Variables	*Basic estimations*		*Incl. capital city and epidemic variables*	
	Broadband (1)	*Website (2)*	*Broadband (3)*	*Website (4)*
Micro firm	−0.2656***	−0.4708***	−0.2605***	−0.4625***
	(0.0175)	(0.0192)	(0.0175)	(0.0192)
Small firm	−0.1409***	−0.3041***	−0.1381***	−0.2998***
	(0.0174)	(0.0189)	(0.0174)	(0.0188)
Medium firm	−0.0621***	−0.1161***	−0.0598***	−0.1143***
	(0.0181)	(0.0197)	(0.0180)	(0.0196)
Skilled human capital	0.0021***	0.0024***	0.0020***	0.0024***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Age of firm	0.0007***	0.0013***	0.0007***	0.0013***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
FDI	0.0121	0.0557***	0.0109	0.0538***
	(0.0117)	(0.0150)	(0.0117)	(0.0150)
Exporter	0.0818***	0.1057***	0.0822***	0.1064***
	(0.0141)	(0.0141)	(0.0140)	(0.0141)
Capital city	n.a.	n.a.	0.0226***	0.0454***
			(0.0068)	(0.0092)
Epidemic (broadband)	n.a.	n.a.	0.1073***	n.a.
			(0.0303)	
Epidemic (website)	n.a.	n.a.	n.a.	0.1487***
				(0.0341)
Country dummies	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes
Log likelihood	−7825		−7796	
Rho	0.4448		0.4435	
	(0.0206)		(0.0207)	
/Athrho	0.4779***		0.4766***	
	(0.0257)		(0.0257)	
Observations	9950		9950	

Source: Authors' elaboration based on WBES data

Notes: Estimated marginal effects from the biprobit regression. Delta-method standard errors in parentheses. * Coefficient is statistically significant at the 10% level, ** at the 5% level, *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. n.a. = not applicable

Additionally, to check for sectoral differences, we split the sample between manufacturing and services. In Table 4.4, we report the marginal effects from these disaggregated biprobit estimations.

Overall, the results appear robust for all the specifications and are generally in line with the findings of previous studies. The smaller the

Table 4.4 Determinants of broadband connection and using firm website: biprobit estimations by sector

Variables	*Manufacturing*		*Services*	
	Broadband	*Website*	*Broadband*	*Website*
	(1)	*(2)*	*(3)*	*(4)*
Micro firm	−0.2545***	−0.4702***	−0.2673***	−0.4496***
	(0.0229)	(0.0247)	(0.0271)	(0.0310)
Small firm	−0.1447***	−0.3021***	−0.1233***	−0.2990***
	(0.0227)	(0.0240)	(0.0269)	(0.0307)
Medium firm	−0.0490**	−0.1264***	−0.0699**	−0.0928***
	(0.0240)	(0.0246)	(0.0274)	(0.0325)
Skilled human capital	0.0017***	0.0030***	0.0022***	0.0019***
	(0.0003)	(0.0004)	(0.0003)	(0.0003)
Age of firm	0.0005**	0.0015***	0.0009***	0.0008**
	(0.0002)	(0.0003)	(0.0003)	(0.0004)
FDI	0.0047	0.0141	0.0225	0.1047***
	(0.0166)	(0.0199)	(0.0171)	(0.0225)
Exporter	0.0871***	0.0957***	0.0446	0.1637***
	(0.0151)	(0.0150)	(0.0332)	(0.0408)
Capital city	0.0278***	0.0336***	0.0161	0.0647***
	(0.0087)	(0.0119)	(0.0110)	(0.0148)
Epidemic (broadband)	0.0148	n.a.	0.1586***	n.a.
	(0.0364)		(0.0604)	
Epidemic (website)	n.a.	0.0544	n.a.	0.1576**
		(0.0429)		(0.0612)
Country dummies	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes
Log likelihood	−4645		−3092	
Rho	0.407		0.51	
Observations	6147		3803	

Source: Authors' elaboration based on WBES data

Notes: Estimated marginal effects from the biprobit regression. Delta-method standard errors in parentheses. * Coefficient is statistically significant at the 10% level, ** at the 5% level, *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. n.a. = not applicable firm, the less likely it is to have a broadband connection or a functioning website. The level of skilled human capital appears to be an important determinant of adoption, confirming the importance of having a skilled workforce to increase a firm's capacity to absorb technology. Interestingly, firm age showed a positive and significant—although small—coefficient. This result seems to demonstrate that previous technological experience is more important for ICT adoption by LAC firms than flexibility to organizational changes. These results hold for the entire sample, as well as for both the manufacturing and services sub-samples.

Also, in general, exposure to competition in foreign markets, as measured by the exporter dummy, has a positive impact on the probability a firm will adopt ICTs, with the only exception of broadband adoption in the case of exporters in the services sector. On the contrary, we do not find any significant effect of foreign ownership on broadband connection, although it seemed to be important for having a website, especially in the services sector.

Finally, the estimations show the key role that location and epidemic effects play in ICT adoption. In all the specifications using the entire sample, a firm operating in a country and sector where there is a larger share of firms using ICTs has a bigger probability of adopting them. However, when the sample is split by sector, the epidemic variable loses significance for manufacturing firms, suggesting that epidemic effects can be particularly important for firms in the services sector. Moreover, the firms that are located in a capital or in a city with more than one million inhabitants are, in general, more likely to have both a broadband connection and a website.[10] This may reflect lower technology costs, higher availability of trained human capital, and potential partners (i.e. suppliers and clients) having a higher level of connectivity. If we adopt an extended concept of epidemic effects, not limited to firms operating in the same sector, this result complements the importance of the level of technological assimilation of the environment in which a firm is operating in order to determine its pace of adoption.

The basic model of intra-firm diffusion does not differ substantially from the inter-firm one, given that the level of penetration is supposed to depend on epidemic and rank effects. The first major difference is related to the form of the dependent variables. The WBES collect data on three different categories of internet use: (i) making purchases, (ii) delivering services, and (iii) researching or developing ideas for new products and services. In order to measure intra-firm diffusion, we build an indicator related to the availability of broadband and the number of internet activities performed by a firm. Our dependent variable, intra-firm, is an indicator using values 0, 1, 2, 3, and 4. And, we use an ordered probit model, which is appropriate if the dependent variables are measured on an ordinal scale.

However, this approach fails to take into account the correlation between broadband adoption and intensity of internet use. In fact, broadband adoption entirely determines the extent of use, selecting firms that have the capabilities to perform activities. Therefore, in order to disentangle the determinants of inter- and intra-firm adoption, it is necessary first to complement the analysis with alternative econometric approaches, taking into account this sample selection. Then, we generalize the Heckman sample selection model (Heckman 1979; Van de Ven and Van Praag 1981), specifying an ordered probit with sample selection, where the first stage equation is the broadband inter-firm diffusion equation, including both location and epidemic effects.

Table 4.5 reports the estimated coefficients resulting from the ordered probit model and the ordered probit with sample selection, for the whole sample and disaggregated by sector. In general, the estimates show a similar pattern to those for inter-firm diffusion. Skilled human capital, age of firm, and being an exporter remain important drivers of ICT diffusion in most specifications. However, there are some interesting differences. First, in the ordered probit, firm size is negative and significant only for small and micro-firms, while the coefficient for medium firms is significant only for the services sector. Once we control for the sample selection, for manufacturing, all the size coefficients become smaller and not significant; for services, the coefficients also become smaller, but they lose significance only for medium firms. For manufacturing, size does not seem to matter for intensity of use once broadband is adopted. For services, the result seems to indicate a dimension threshold, above which size does not matter for intra-firm diffusion. Furthermore, we do not find any strong statistical evidence related to being located in a capital city, which suggests that location affects the decision to adopt broadband but not how extensively it is used. Finally, there is some evidence of a negative correlation between foreign ownership and intra-firm diffusion, but only in the manufacturing sector. This result is stronger in the ordered probit with sample selection model, which may be related to the fact that foreign investments in manufacturing in LAC are concentrated in low value-added activities. Therefore, ICTs are especially important for communication with headquarters, but not for research and relationships with providers and clients, the activities used to build the intensity index.

Table 4.5 Determinants of broadband intensity of use: ordered probit and ordered probit with sample selection estimations

Variables	*Ordered probit*			*Ordered probit with sample selection*		
	Whole sample	*Manufacturing*	*Services*	*Whole sample*	*Manufacturing*	*Services*
Micro firm	–0.8623***	–0.8576***	–0.8756***	–0.1545***	–0.1183	–0.2527**
	(0.0476)	(0.0617)	(0.0773)	(0.0596)	(0.0744)	(0.1212)
Small firm	–0.3081***	–0.2928***	–0.3312***	–0.1101**	–0.0565	–0.1993**
	(0.0424)	(0.0543)	(0.0699)	(0.0470)	(0.0600)	(0.0818)
Medium firm	–0.0683	–0.0081	–0.1667**	–0.0368	0.0005	–0.1076
	(0.0418)	(0.0523)	(0.0703)	(0.0456)	(0.0570)	(0.0791)
Skilled human capital	0.0069***	0.0067***	0.0071***	0.0021***	0.0031***	0.0018
	(0.0007)	(0.0010)	(0.0009)	(0.0007)	(0.0010)	(0.0011)
Age of firm	0.0026***	0.0021***	0.0035***	0.0016**	0.0016*	0.0018
	(0.0006)	(0.0008)	(0.0011)	(0.0007)	(0.0008)	(0.0012)
FDI	–0.0649*	–0.1146**	0.0102	–0.0771*	–0.1154**	–0.0194
	(0.0374)	(0.0498)	(0.0570)	(0.0394)	(0.0513)	(0.0621)
Exporter	0.2291***	0.2322***	0.2115**	0.1069***	0.0872**	0.1999**
	(0.0356)	(0.0396)	(0.0913)	(0.0375)	(0.0421)	(0.0947)
Capital city	0.0377	0.0172	0.0644	-0.0385	-0.0852**	0.0307
	(0.0261)	(0.0343)	(0.0412)	(0.0283)	(0.0369)	(0.0455)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes

(*continued*)

Table 4.5 (continued)

Variables	*Ordered probit*			*Ordered probit with sample selection*		
	Whole sample	*Manufacturing*	*Services*	*Whole sample*	*Manufacturing*	*Services*
Thresholds						
	–1.3715***	–1.3274***	–1.9148***	–1.5240***	–1.4638***	–2.0654***
	(0.1029)	(0.1096)	(0.1730)	(0.1291)	(0.1396)	(0.1851)
	–1.1731***	–1.1381***	–1.7011***	–0.6470***	–0.5941***	–1.1625***
	(0.1034)	(0.1105)	(0.1730)	(0.1276)	(0.1376)	(0.1807)
	–0.6678***	–0.6387***	–1.1819***	0.1701	0.214	–0.3148*
	(0.1033)	(0.1104)	(0.1726)	(0.1283)	(0.1387)	(0.1800)
	0.0346	0.0607	–0.4672***	n.a	n.a	n.a
	(0.1032)	(0.1104)	(0.1721)			
Log likelihood	–12,736	–7718	–4984	–12,533	–7613	–4880
Rho	n.a.	n.a.	n.a.	–0.513	–0.571	–0.324
				(0.0783)	(0.0876)	(0.2138)
/Athrho	n.a.	n.a.	n.a.	–0.5669***	–0.6488***	–0.3358
				(0.1063)	(0.1299)	(0.2388)
Observations	9958	6148	3810	9958	6148	3810
Observation censored	n.a.	n.a.	n.a.	1514	865	649
Observation uncensored	n.a.	n.a.	n.a.	8444	5283	3161

Source: Authors' elaboration based on WBES data

Notes: Estimated coefficients from ordered probit regression and ordered probit with sample selection. Robust standard errors in parentheses. * Coefficient is statistically significant at the 10% level, ** at the 5% level, *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. n.a. = not applicable

Broadband, Innovation, and Productivity

The economic impact of ICT has received considerable attention in the literature, and many firm-level empirical studies have identified multiple ways ICT can have a positive effect on performance. For example, Mack and Faggian (2013) stated that ICTs have dramatically changed every aspect of modern life, including business management, which has been revolutionized by the new capacity of finding, sharing, and storing information.

In fact, ICTs have the potential to have substantial impact on the internal communication processes of a firm. For example, it is usually argued that ICTs can help reduce internal communication costs (Jorgenson 2001), allowing quicker information processing, lower coordination costs, fewer supervisors (reduction in labor costs), and easier decision-making (Cardona et al. 2013; Arvanitis and Loukis 2009; Atrostic et al. 2004; Gilchrist et al. 2001). In turn, reduced communication costs can spur additional investments (Colecchia and Schreyer 2002).

Moreover, ICTs may enable development of new processes and new work practices (Mack and Faggian 2013), and facilitate substantial firm restructuring (Brynjolfsson and Hitt 2000), making internal processes more flexible and rational, and reducing capital requirements through better equipment utilization and inventory reduction. These improvements may also allow firms to improve the quality of their outputs.

Also, adopting ICTs opens the possibility of better external communication channels with suppliers, clients, and other firms, facilitating innovation processes, arranging new distribution systems, and prompting knowledge spillovers across firms and regions (Czernich et al. 2011). Cheaper information dissemination can facilitate the adoption of new technologies devised elsewhere. As knowledge is increasingly becoming crucial for economic activity, ICTs have the potential to generate more efficient external collaboration and promote the creation of new knowledge (Forman and van Zeebroeck 2012). From a market perspective, ICT development can contribute to lower entry barriers and promote transparency, fostering competition and development of new products, processes, and business models (Czernich et al. 2011).

ICTs have become a substantial part of the modern business environment (Cardona et al. 2013), allowing factor productivity gains in industries that are ICT intensive. Recent empirical research has found extensive evidence about the impact of ICTs on innovation activities and performance.

Brynjolfsson and Saunders (2010) completed a comprehensive survey of ICT and innovation, and noted that the lower communication and replication costs provided by ICT can help firms innovate through new products. Bertschek et al. (2013) found that broadband exhibited a positive and significant impact on innovation activity in a sample of German firms through the period of expansion of digital subscriber lines (DSL) (2001–2003), and that its impact seemed to increase when they controlled for endogeneity. Polder et al. (2010) showed that ICT investment and usage constituted important drivers of innovation activity in the Dutch manufacturing and services sectors. Broadband was particularly relevant in the services sector, where it was found to be positively related to product, process, and organizational innovation, while in the manufacturing sector it was found to be significant only for product and organizational innovation. As for the LAC region, Santoleri (2013) provided evidence of the role of ICTs in enabling product and process innovation for a sample of Chilean firms. He also provided evidence that advanced ICT usage was needed to enhance the innovation-enabling role of the new technologies.

Regarding the impact of ICTs on productivity, several authors have found clear empirical evidence of a positive effect. In a seminal study, Brynjolfsson and Hitt (2003) explored the effect of computerization on productivity and output growth in a sample of US firms over the 1987–1994 period and found a positive relationship. This relationship has been confirmed over the years by several empirical studies in various contexts. For example, Hempell (2005) found significant evidence of the productivity effects of ICT using a generalized method of moments (GMM) estimator on panel data of German firms for 1994–1999. Arvanitis and Loukis (2009) and Kaiser and Bertschek (2004) confirmed this finding using data from Greece and Switzerland, and Germany, respectively. For the LAC region, Gutiérrez (2011) found a positive and significant effect of ICT investments on labor productivity in Colombian manufacturing enterprises.

However, the impact of ICT may be conditioned by certain characteristics of the internal context of a firm. In particular, some authors have highlighted the importance of complementary investments, pointing out that the productivity impact of ICT adoption may increase if combined with investment in human capital or internal restructuring (Brynjolfsson and Hitt 2000). Knowledge stock and skills are determinants of absorptive capacity, which may influence firm capabilities to make the most of new technologies (Benhabib and Spiegel 1994; Cohen and Levinthal 1990).

Organizational complements and intangible assets are considered crucial for ICT influence on productivity (Cardona et al. 2013). The economic impact of ICT may also depend on the sector of activity. In that sense, services-related firms may benefit more from ICT than companies in other sectors.[11]

External factors may also be important in determining impact. In fact, ICT effects can be larger if a firm has strong linkages with external organizations. Network externalities may also be present, whereby the benefits of having adopted a technology depend on the adoption decisions of other users. As for internet connection, the economic returns of connectivity should rise once the society achieves a certain threshold of connectivity penetration.

Clearly, the concept of ICTs includes a variety of different technologies, with different potential effects on firm performance. Recently, broadband internet connection has been indicated as one of the most effective ICTs because of its potential to enable a wide set of productivity-enhancing services. Some authors have argued that broadband has become a necessary part of the infrastructure for economic and social development, comparing it to historic advances such as railroads, roads, and electricity (Mack and Faggian 2013; Jordan and De León 2011).

In this section we contribute to the existing literature by empirically studying the impact of broadband adoption on firm performance in LAC, a region that has been understudied in relevant academic research. First we analyze the relationship of ICTs with innovation activities, and then we focus on their impact on firm productivity.

Broadband and Innovation

Empirical Model

To explore the link between broadband and innovation, we estimate the following equation, modeling the probability a firm will carry out an innovation activity:

$$\Pr\left[INNOVATION = 1\right] = f\left(\delta + \gamma\, Broadband + \beta_X X\right) \qquad (4.2)$$

To measure innovation activity, we consider two binary variables: process innovation, which takes the value 1 if a firm has introduced a new or significantly improved process to produce or supply products over the previous three years; and product innovation, which takes the value 1 if the firm has introduced a new or significantly improved product (goods or services) over the previous three years. Broadband is a dummy variable that takes the value 1 if the firm has a high-speed internet connection on its premises.

We include control variable X to account for other factors that may influence innovation activity at the firm level. As in the case of technology diffusion, we use the percentage of workers with at least a bachelor's degree as a proxy for human capital (skilled human capital) and, as in Bertschek et al. (2013), we include investment to explain innovation. In this case, we approximate investment with a dummy variable that takes the value 1 if the firm has bought a fixed asset in the previous year, such as machinery, vehicles, equipment, land, or buildings.

We include four firm size variables (micro, small, medium, and large) since innovative activity may depend on the size of the enterprise (see also Chap. 2). Past research has found that big companies can amortize sunk costs related to innovation activity, exhibit more capacity for risk diversification, and have lower financial constraints (e.g. Acs and Audretsch 1988; Cohen and Klepper 1996). Moreover, we include exporter and FDI as control variables. It is possible that companies exposed to international markets face more pressure to innovate in order to remain competitive. FDI may also provide a channel for international knowledge spillovers, if the organizational structure and governance of the multinational companies allow it. In all estimations, we include country and three-digit sector dummy variables to control for unobserved industry- and country-specific effects.

In order to estimate the proposed equation, we first use a simple probit model. Nevertheless, this approach can provide biased results due to endogeneity (either deriving from reverse causality or unobservables). Given this, we complement the model with a bivariate recursive probit, instrumenting broadband access with two additional variables. The first instrument is the percentage of other firms that have adopted broadband in the same country and sector. This seems to be a suitable instrument, as individual firm performance is not expected to be related to industry averages (excluding the firm's own response), while these averages are expected to be positively related to a firm's decision to adopt broadband (see the "Data and Main Patterns of Internet Diffusion in LAC" section of this chapter). The second instrument is a variable that represents a firm's use of email. Email usage is supposed to be closely linked to broadband adoption, but not related to firm performance, because of its massive diffusion across all types of firms. Data analysis confirms these hypotheses.

Additionally, we extend the analysis by considering not only broadband adoption, but also the degree of exploitation of its potential. To do so, we run additional regressions including a dummy variable for the use of each of the following three internet activities: making purchases, delivering services to clients, and researching or developing ideas for new products and services. This information is collected through the survey only for the firms that have a broadband connection on their premises. Finally, we include an indicator of intensity of use, represented by a dummy variable taking the value 1 if a firm performs all three activities.

Estimation Results

Table 4.6 summarizes our estimation results for the determinants of innovation activities. As there is no direct interpretation of the coefficients of probit and biprobit models, we present average marginal effects, which represent the average percentage change in the probability of introducing a product or process innovation. Columns 1 through 4 display the results for product innovation, while columns 5 through 8 correspond to process innovation. For the biprobit estimations, the *Rho* term, which measures the correlation among the residuals of the innovation and broadband adoption equations, is negative and significant for all the specifications. This means that the biprobit model is probably more accurate and controls for the endogeneity caused by unobservables and for possible reverse causality.

The variable broadband shows a significant and positive impact on the probability of a firm introducing a product and a process innovation[12] in the specifications that do not consider different internet uses (columns 1, 3, 5, and 7).[13] In all these cases the significance level is at 1 %. However, when we introduce the variables for different internet uses (columns 2, 4, 6, and 8), the coefficient and significance level of the broadband regressor decreases and some interesting results arise. First, as expected, internet use for research is clearly related to both product and process innovation. In all cases, the significance level is 1 % and the average marginal effect is in the order of 11 %.[14] Second, internet use to deliver services is not significant for product innovation but is positively correlated to process innovation. This result seems to confirm that the internet may promote innovation by enabling new distribution schemes. Third, internet use for purchases is not positively related to any innovation activity.

Table 4.6 Determinants of innovation

Variables	*Product innovation*				*Process innovation*			
	Probit		Biprobit		Probit		Biprobit	
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Broadband adoption	0.135***	–0.01	0.231***	0.086*	0.128***	–0.026	0.268***	0.109**
	(0.020)	(0.030)	(0.039)	(0.046)	(0.021)	(0.031)	(0.042)	(0.050)
Internet use for purchases	n.a.	0.018	n.a.	0.014	n.a.	0.021	n.a.	0.021
		(0.020)		(0.019)		(0.020)		(0.020)
Internet use to deliver services	n.a.	0.016	n.a.	0.012	n.a.	0.041**	n.a.	0.037*
		(0.020)		(0.020)		(0.021)		(0.020)
Internet use for research	n.a.	0.119***	n.a.	0.110***	n.a.	0.110***	n.a.	0.106***
		(0.020)		(0.020)		(0.021)		(0.021)
Internet for purchases, to deliver services, and for research	n.a.	0.057**	n.a.	0.060***	n.a.	0.047*	n.a.	0.045*
		(0.025)		(0.024)		(0.025)		(0.025)
Micro firm	–0.097***	–0.087***	–0.069***	–0.063**	–0.071***	–0.061**	–0.038	–0.032
	(0.026)	(0.026)	(0.028)	(0.028)	(0.027)	(0.027)	(0.028)	(0.028)
Small firm	–0.041*	–0.037*	–0.034	–0.031	–0.072***	–0.069***	–0.068***	–0.066***
	(0.023)	(0.023)	(0.023)	(0.022)	(0.023)	(0.023)	(0.023)	(0.023)
Medium firm	–0.041**	–0.041*	–0.040*	–0.041*	–0.069***	–0.069***	–0.074***	–0.075***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
Skilled human capital	0.001***	0.001**	0.001**	0.001**	0.001***	0.001***	0.001***	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	–0.002	0.008	–0.004	0.006	–0.036*	–0.026	–0.037*	–0.028
	(0.021)	(0.020)	(0.020)	(0.020)	(0.021)	(0.021)	(0.020)	(0.020)

(continued)

Table 4.6 (continued)

Variables	*Product innovation*				*Process innovation*			
	Probit		Biprobit		Probit		Biprobit	
	(*1*)	(*2*)	(*3*)	(*4*)	(*5*)	(*6*)	(*7*)	(*8*)
Exporter	0.038**	0.031*	0.038**	0.031**	0.034**	0.027*	0.027*	0.021
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Investment	0.132***	0.122***	0.129***	0.120***	0.194***	0.185***	0.187***	0.179***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log likelihood	−3636.74	−3574.01	−4973.88	−4915.17	−3720.49	−3661.42	−5054.89	−4999.6
Rho	n.a.	n.a.	−0.202**	−0.182**	n.a.	n.a.	−0.287***	−0.264***
			(0.069)	(0.069)			(0.073)	(0.075)
/Athrho	n.a.	n.a.	−0.205**	−0.184**	n.a.	n.a.	−0.295***	−0.270***
			(0.072)	(0.072)			(0.080)	(0.074)
Observations	5939	5939	5886	5886	5935	5935	5882	5882

Source: Authors' elaboration based on WBES data

Notes: Estimated marginal effects from the probit and biprobit regressions. Delta-method standard errors in parentheses. * Coefficient is statistically significant at the 10% level, ** at the 5% level, *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. n.a. = not applicable

As for the intensity indicator, in all cases it is positively related with innovation activity, which suggests that using broadband for a variety of activities is relevant beyond individual uses. In fact, firms that use the internet for all three activities increase their probability of innovating by approximately a further 5 %.[15] Overall, these results seem to confirm the hypothesis that simple access to technology is not sufficient to improve performance, but that using technology adequately is necessary to exploit its potential fully.

Among control variables, being a large firm is positively associated with the probability of innovation. In fact, the micro, small, and medium firm coefficients are, in most cases, significant and negative. This shows that the baseline scenario (large firms) is the most propitious for both product and process innovation, confirming that size is an important determinant of innovation, as shown in Chap. 2. As for the coefficient associated with skilled human capital, it is always positive and significant, reflecting the importance of having internal skills to promote innovation. The coefficient of the exporter variable is also positive and significant in most cases, showing that companies competing in international markets have a higher propensity for innovation activity. Nevertheless, being foreign-owned does not seem to increase the probability of innovation in a firm, as the coefficients for FDI are either not significant or negative. A possible explanation for this is related to the fact that multinational enterprises usually concentrate R&D and innovation activities at headquarters and not in their subsidiaries abroad. Finally, the coefficient associated with investment is positive and significant at the 1 % level.

Broadband and Productivity

Empirical Model

To analyze the impact of broadband on labor productivity, we use a model in which firms are supposed to produce according to a Cobb–Douglas production technology, with constant returns to scale on physical capital and labor:

$$Y = AK^{\alpha} L^{1-\alpha} \tag{4.3}$$

where Y represents output, K is physical capital stock, and L is labor. The term A represents total factor productivity (TFP), which may be affected by the availability of a broadband internet connection and by a vector of control variables X:

$$A = f\left(Broadband, X\right) \tag{4.4}$$

Combining both expressions and applying logarithms to linearize the empirical specification:

$$\ln\left[\frac{Y}{L}\right] = \delta + \alpha \ln\left[\frac{K}{L}\right] + \gamma\, Broadband + \beta_X X \tag{4.5}$$

Labor productivity is measured as sales per employee. Physical capital is approximated by the replacement value of machinery, vehicles, and equipment. Among controls X, we include some of the previously defined variables: firm size, skilled human capital, exporter, and FDI. We also include the previously defined product and process innovation dummy variables, considering that higher innovation activity is expected to increase productivity. In all estimations, we add country and three-digit sector dummy variables to control for unobserved effects. The unexplained part of the TFP is captured by the dummy variables and the constant term δ. As in the case of innovation activities, we run additional estimations considering the use of internet for specific activities and the intensity of use. We control for potential endogeneity by using an instrumental variable approach to complement the standard analysis. For that purpose, also in this case, the industry average of broadband adoption and email utilization at the firm level is used to instrument broadband.

Estimation Results

Table 4.7 summarizes the results of our estimations of the determinants of firm productivity. We present OLS results in columns 1 and 2, and the results for the instrumental variables in columns 3 and 4. To check the suitability of the instruments in the 2SLS estimation, we perform some hypothesis and robustness testing, which we also summarize in the table. Results of the Hansen test do not reject the exogeneity hypothesis, while the first-stage weak instrument test provides evidence of sufficient correlation between the instruments and the instrumented variable.

As for innovation activities, broadband has a positive and significant impact on the labor productivity of LAC firms, and its coefficient increases when we control for endogeneity. When we introduce internet

Table 4.7 Determinants of productivity

Variables	*OLS estimations*		*2SLS estimations*	
	(1)	*(2)*	*(3)*	*(4)*
Broadband adoption	0.306***	0.329***	0.551***	1.003***
	(0.047)	(0.072)	(0.112)	(0.294)
Internet use for purchases	n.a.	0.043	n.a.	–0.161*
		(0.044)		(0.096)
Internet use to deliver services	n.a.	–0.051	n.a.	–0.273***
		(0.045)		(0.104)
Internet use for research	n.a.	–0.059	n.a.	–0.329***
		(0.047)		(0.124)
Internet for purchases, to deliver services, and for research	n.a.	0.068	n.a.	0.352***
		(0.055)		(0.131)
Log (capital per worker)	0.193***	0.193***	0.192***	0.192***
	(0.011)	(0.011)	(0.011)	(0.011)
Investment	0.134***	0.131***	0.123***	0.126***
	(0.030)	(0.030)	(0.029)	(0.029)
Product innovation	0.056*	0.055*	0.049*	0.058*
	(0.030)	(0.030)	(0.030)	(0.030)
Process innovation	–0.044	–0.046	–0.051*	–0.042
	(0.028)	(0.028)	(0.028)	(0.028)
Micro firm	–0.525***	–0.514***	–0.468***	–0.449***
	(0.057)	(0.057)	(0.061)	(0.063)
Small firm	–0.356***	–0.352***	–0.340***	–0.329***
	(0.048)	(0.048)	(0.048)	(0.049)
Medium firm	–0.095**	–0.097**	–0.096**	–0.089*
	(0.046)	(0.046)	(0.045)	(0.046)
Skilled human capital	0.007***	0.007***	0.007***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)
FDI	0.295***	0.297***	0.303***	0.300***
	(0.050)	(0.050)	(0.049)	(0.048)
Exporter	0.208***	0.207***	0.201***	0.197***
	(0.034)	(0.034)	(0.034)	(0.034)
Constant	9.162***	9.150***	8.945***	8.825***
	(0.164)	(0.163)	(0.185)	(0.210)
Country dummies	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes
R^2	0.462	0.463	0.457	0.45
Observations	4215	4215	4189	4189
Hansen J			2.646	2.434
F-test weak instrument			204.728***	49.156***

Source: Authors' elaboration based on WBES data

Notes: Estimated coefficients from the regressions. Controls for sector and country fixed effects. Robust standard errors in parentheses. * Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. n.a. = not applicable use variables to the OLS estimation, broadband adoption remains positive and significant, while single activities and intensity do not appear to be relevant. For the instrumental variables estimation, we find a positive and significant coefficient for intensity of use, but a negative sign for individual uses. A possible explanation for these results may be related to the types of internet uses considered in the survey. On the one hand, such activities could have an impact on productivity only with a time lag. Since we are not working with time-series data, we cannot consider this. Also, the negative signs for some individual activities may be linked to the fact that these uses can generate short-term costs in terms of complementary investments, without immediate benefits. On the other hand—as the adoption indicator remains positive and highly significant in all estimations—the impact of broadband on productivity may be related to alternative uses, such as, for example, reducing internal communication costs, improving decision-making, developing new internal process or work practices, and firm restructuring. Finally, the positive and significant coefficient of the intensity indicator in the instrumental variable estimation confirms the importance of simultaneously using ICTs in various aspects of business activity in order to obtain productivity gains.

As expected, the coefficients for physical capital per worker and investment are positive and highly significant, as well as those for skilled human capital. The positive impact of exporter and FDI on productivity verifies the results in Chap. 9 ("International Linkages, Value-Added Trade, and Firm Productivity in Latin America and the Caribbean").[16] Results for innovation activity are also similar to those found in Chap. 2 ("Innovation Dynamics and Productivity").[17] Product innovation shows a positive and significant effect on productivity, while process innovation does not seem to be relevant. A possible explanation for the insignificance of process innovation may be a time lag necessary to translate these improvements into productivity gains. Another possibility is that part of the innovation effect is already captured by the broadband variable.

Final Remarks

This chapter contributes to the empirical literature on technology diffusion and impact, identifying determinants of ICT adoption and exploring the link between broadband use, and innovation and productivity in LAC firms. We have analyzed both inter- and intra-firm diffusion patterns, finding that the ICT adoption behavior of LAC firms was characterized by a basic set of determinants that were quite robust across model estimations and different variable specifications. We found evidence of the presence of both epidemic and rank effects, where larger, older, skill-intensive, exporter, and urban firms were more likely to adopt ICTs. However, once ICTs were adopted, size and location lost importance in relation to intensity of use.

Additionally, we found robust empirical evidence for the positive relationship between broadband and firm performance. In particular, adopting broadband increased a firm's probability of innovating. This effect seemed mainly to be related to internet use in research and development and to the intensity of use, proxied by internet use for various activities. Further estimations provided evidence that broadband adoption and use were a source of productivity growth for LAC firms. These results are aligned with previous ICT literature in the developed world, which suggests that broadband plays an important role in enabling innovation and enhancing productivity.

The availability of novel empirical evidence specific to LAC may offer useful insights for policymakers in designing and implementing initiatives to foster productivity by increasing broadband connectivity. In fact, several countries in the region are investing considerable resources in initiatives such as the Plano Nacional de Banda Larga (National Broadband Plan) in Brazil or the Vive Digital (Live Digital) plan in Colombia.

However, our analysis was limited by data availability and should be complemented with future research. For example, the role of complementarities (e.g. human capital or organizational innovations) and network externalities in increasing the gains derived from ICT adoption remain largely understudied in the empirical literature on LAC. Further research could also look at the role of the national ICT industry. For example, the ability of a country to produce software adapted to the needs of local firms may play a role not only in decisions to adopt ICTs, but also on the impact of ICTs on firm performance once adopted. These extensions may provide a deeper understanding of the linkages between ICTs and firm performance, and on the characteristics that effective public policies should have.

Notes

1. Cathles et al. (2011) performed a time-distance analysis to explore the pace at which the Latin American region is filling the digital gap ascertained by the OECD, finding that it would take about 80 years to reach OECD levels of internet subscriptions.

2. For example, the 2009 Brazil survey included questions on broadband and ICT use in the services sector, but not in the manufacturing sector.
3. The higher percentage of firms using email compared to those having a broadband connection is explained by the fact that only a simple internet connection (not necessarily within the firm or broadband) is required for email.
4. Argentina, Bolivia, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, and Venezuela.
5. Of the observations, 11 % are large firms (over 250 employees), 28 % medium firms (51–250 employees), 39 % small firms (11–50 employees), and 22 % micro-firms (10 or less employees).
6. We could not test the stock and order models because of the lack of panel data.
7. See, for example, Chap. 8 of this book, where Presbitero and Rabellotti find that larger firms are more likely to request bank credit and less likely to be financially constrained.
8. Some studies have found a weak or insignificant correlation between size and ICT adoption, such as Lefebvre et al. (2005) and Love et al. (2005).
9. See for example, Arvanitis (2005); Bresnahan et al. (2002); Fabiani et al. (2005).
10. With the exception of the biprobit estimation in the services sector with broadband as independent variable.
11. Companies in the services sector tend to use ICTs more intensively. Additionally, Crandall et al. (2007) argued that the fact that individuals use broadband at home to connect to their offices or to telecommute makes ICTs more likely to be important in the services industries, such as finance, real estate, or miscellaneous business centers.
12. In Chap. 2, broadband access is found to be a significant determinant of product innovation and innovative sales, but not for process innovation. This inconsistency seems to be related to differences in the econometric approach and in the treatment of R&D as a control. However, overall, the results in Chap. 2 substantially confirm the important role .of broadband in explaining a firm's innovation performance.
13. It is interesting to notice that, once possible endogeneity between innovation and broadband is taken into account, the impact of broadband on innovation activity seems to be higher. This result is similar to what was found by Bertschek et al. (2013), and it may be explained by the fact that adopting broadband could induce a process of internal reorganization that may reduce the contribution of some existing practices to innovation activity.
14. To check the robustness of this result, we perform different estimations, adding alternative measures of R&D spending as controls. In all cases, internet use for research remains positive and significant.

15. The marginal effect for product innovation is slightly higher than for process innovation.
16. Although the magnitude of the coefficients is slightly different because of dissimilarities in the sample and control variables.
17. The difference in significance levels for product innovation compared with the results in Chap. 2 seems to be related to variances in the econometric approach and in the chosen control variables.

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