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Whither Broadband Policy? In Search of Selective Intervention

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Abstract - The broadband plans deployed by governments have not benefited so far from substantive theoretical or empirical economic insights on the relative effectiveness of alternative combinations of policy interventions (on which more will be said in the next section). This paper make a first attempt at filling this gap by exploring whether some (set of) policy tools has so far proven to be more effective than others. We collected detailed data on the policies adopted by 21 OECD countries and perform a cross-country analysis. Our evidence suggests the relevance of the institutional environment form one side and the importance of demand-side interventions from the other. Interventions on the supply side appear to be less effective on broadband diffusion than those on the demand side.

Keywords: telecommunications policy, broadband, infrastructure investment
JEL Classification: K200, L960, 0310, 0570

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1. Introduction

Broadband infrastructures are increasingly perceived as a key factor influencing the competitiveness and the growth potential of nations. While a precise definition is difficult to find due to the rapid evolution of technology and the existence of a range of alternative interpretations by different institutions, an acceptable way to define broadband is by reference to what broadband connectivity is not, namely a dial-up service for access to the Internet, and to what broadband is for sure, namely a way for consumers to enjoy high speed, two-way and always-on connectivity to the Internet. In other words, the availability of a broadband infrastructure implies the possibility to connect to the internet at a faster speed than conventional dial-up services. About how much faster such connection should be to qualify as broadband there is, however, no agreement. The International Telecommunications Union, for instance, defines as broadband Internet connectivity faster than that affordable with primary rate ISDN, i.e. 1,5 or 2 Mbps. The Organization for Economic Cooperation and Development, by contrast, in various official documents has made reference to the lower threshold of a download speed of 256 Kbps.

Irrespective of the precise definition, broadband services may be delivered through various different technologies. The most widespread technology is, so far, the *Digital Subscriber Line* (DSL) technology, which relies on the existing telecommunication copper network to provide connection speeds ranging from 256 Kbps to 52 Mbps, depending on the specific type of DSL (Asymmetric DSL (ADSL), High Rate DSL (HDSL), Symmetric DSL (SDSL) and Very High Data Rate DSL (VDSL)). The second most widespread technology is the *Cable Modem*, which provides faster connection speeds than the DSL (in the range of 1 to 10 Mbps), allowing for the simultaneous passage on the TV cable of triple-play services: voice, data and television. Other relevant technologies for the provision of broadband services include *Satellite*, *Fixed Wireless Access* (FWA), *Power Line Communications* (PLC, based on the electricity transmission network), *Mobile Wireless* and, most importantly in terms of quality and potential, *Optic Fibre*. Deployment of the latter allows the building of an Internet Protocol-based network that is normally referred to as *Next Generation Network*.

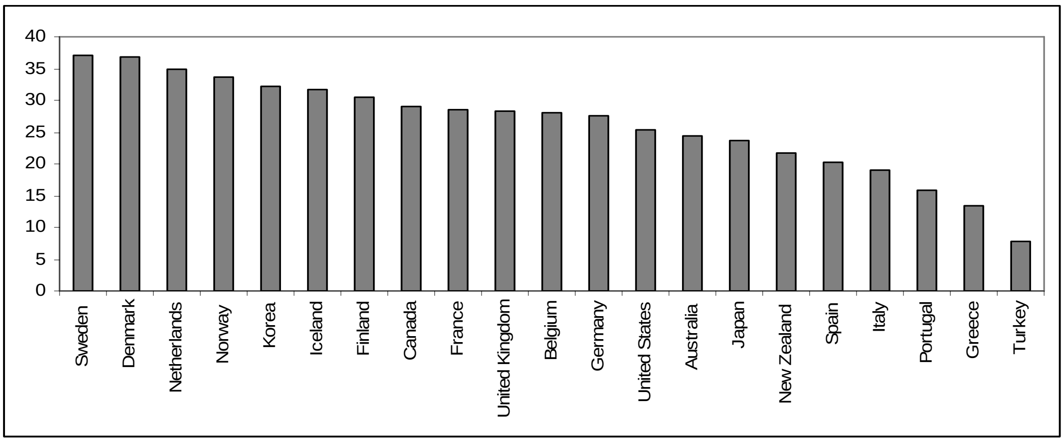
The relevance of broadband for economic activity relates to the range of new and/or better applications that it enables as a platform. These include not only enhanced communication services and video streaming, but also new services in the domain of e-commerce, e-health, e-government and e-education, just to mention the most prominent examples. In addition to this, broadband is widely believed to be a factor stimulating productivity growth, with positive consequences in terms of economic development, and to have positive effects in terms of social cohesion.

In view of the perceived salience, also within public opinion, of the issue of broadband deployment, most governments around the world have adopted policy interventions aimed at promoting investment. Almost all OECD countries have enacted more or less intense policy measures, often in the form of integrated plans requiring the coordination of action at various government levels, with some countries such as South Korea, Japan, the Netherlands, UK and, more recently, Australia, showing particularly high degrees of activism. This has occurred in spite of a lack of consensus on the very rationale for public involvement in broadband. Indeed, the debate on the appropriate role of governments with respect to broadband investment has been and still is intense. In spite of the relatively uncontroversial recognition of the benefits of the existence of an efficient broadband infrastructure, it is not clear whether they outweigh costs nor whether efficient investment would be forthcoming even in absence of public policy intervention.

The answer to these questions is likely to depend on the choice of the relevant public policy objective. The three main objectives of broadband policy may be synthesized as follows: (1) extending the geographic coverage of broadband to areas currently not covered because of high costs of doing so (i.e. reducing or eliminating the so-called digital divide); (2) promoting broadband adoption by the largest possible number of citizens; and (3) improving the technological performance of existing networks by introducing ultra-broadband networks.

In the past few years, different countries have not only chosen different combinations of the above objectives, but they have also adopted a particularly wide range of forms of intervention to stimulate investment in broadband deployment. At present, there is a significant variance in broadband uptake, as can be readily seen from inspection of figure 1, below, illustrating the number of broadband subscribers per 100 inhabitants in the year 2008 for the selection of 21 countries studied in this paper.

Figure 1. Broadband subscribers per 100 inhabitants (year 2008).



Source: Telecommunications Indicators Database (ITU, 2009)

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The broadband plans deployed by governments have not benefited so far from substantive theoretical or empirical economic insights on the relative effectiveness of alternative combinations of policy interventions (on which more will be said in the next section). The aim of this paper is to make a first attempt at filling this gap by exploring whether some (set of) policy tools has so far proven to be more effective than others. In order to do so, we collect detailed data on the policies adopted by 21 OECD countries and perform a cross-country analysis.

In a nutshell, two main conclusions can be drawn from the analysis. The first is that, in addition to policies purposefully devised to stimulate broadband investment, a particularly relevant role should be attributed to the wider institutional environment of the countries considered. The second is that, in choosing among the available policy tools, governments should accord preference to demand-side interventions. This is because government interventions on the supply side appear to be less effective on broadband diffusion than those on the demand side.

The present exercise constitutes a first step in the direction of the definition of a strategy of selective policy intervention. Indeed, the choice of policy mix does not appear to have been particularly focused. Initiatives have been undertaken by multiple government levels sometimes in an uncoordinated fashion and often guided more by budget constraints than by conscious analysis.

The paper is structured as follows. In section 2 an overview of the main public policy tools for the promotion of broadband investment is provided. Section 3 briefly reviews the existing empirical literature that, although focusing more generally on the determinants of broadband penetration, is broadly related to the present paper. Section 4 illustrates the data used in this study and describes the variables. Section 5 contains the econometric analysis. Section 6 concludes.

2. The set of broadband policy tools

The range of policy instruments available to governments to stimulate broadband penetration includes at least three sets of tools. The first concerns directly the domain of telecommunications regulation and is made up of the various regulatory interventions that may contribute to create an investment-friendly regulatory environment. The second includes a varied ensemble of policy measures that may lower the cost of private investment, integrate it or substitute for it in scarcely attractive areas or help in the coordination of multiple investors. The third includes policy measures aimed at increasing the overall level of broadband demand either by stimulating business and/or consumer demand or by expressing additional demand of a public nature. The first and the second set of policy tools can be categorized as "supply-side" policies, while the third set of policy tools as "demand-side" policies.

Among the regulatory instruments that may have a bearing on telecommunications firms' incentives to invest in broadband deployment, at least three sorts of measures have attracted considerable attention: (a) regulatory measures aimed at directly modifying the degree of vertical integration of the existing telecommunications network by introducing operational, functional or structural separation of the incumbent's network; (b) the definition of access obligations to legacy networks and to the new networks through the adoption of so-called active and/or passive remedies; (c) the definition of access prices.

The debate on these three forms of regulatory intervention, particularly intense in the past few years, has not led to agreed-upon solutions. The key issue in the regulation of broadband networks (and particularly of *Next Generation Networks*) concerns the balancing of two, possibly contrasting, objectives: the stimulus to efficient private investment and the need to discipline monopolistic abuse by incumbents.

With regard to the issue of vertical separation, even letting aside the obvious practical obstacles to a modification of the existing vertical structure of the legacy network, it has not been established with certainty whether vertical separation of the access network of incumbent firms from their retail activities has a positive impact in terms of incentives to invest in broadband. On one side, vertical separation is seen as an important tool to ensure effective competition and, through the latter, investment, in light of the fact that a vertically integrated incumbent is better able to adopt anticompetitive practices likely to harm competition (quality discrimination, price squeeze, cross-subsidies etc.). On the other side, vertical separation may undermine incumbents' incentives to invest and/or may entail more or less relevant efficiency losses in terms of scale economies and increased costs of coordination.

The imposition of access obligations both to existing and prospective networks also involves difficult trade-offs. By imposing the same access obligations of legacy networks to new networks, competition at the retail level is spurred, but at the cost of a possible reduction of incumbents' incentives to invest. This trade-off figures prominently in the choice of the specific type of remedy suited to the broadband networks, and particularly in the choice between passive remedies (access to ducts, access to copper sub-loops, access to unbundled fibre) and active remedies (access to a range of bitstream products at regulated conditions). Equally relevant with respect to the mentioned trade-off is the issue of the definition of access prices that has recently been focused on the question of the design of forms of "risk sharing" and of a "risk premium", endorsed by the European Commission.

Other, less prominent, regulatory policy tools relevant for the purpose under consideration include the inclusion of broadband services within the domain of Universal Service

Obligations, a modification of the system through which prices are harmonized throughout various regions of the same country (in countries where it exists) that could help direct resources where needed and the possibility to define access obligations for non-telecommunications firms possessing physical networks whose use may help reduce the costs of new networks rollout.

As for the supply-side interventions different from regulatory measures mentioned above, they could be defined as more akin to the category of "industrial policies". They include a varied range of policy tools that express different levels of public involvement and have been adopted in various different combinations by OECD countries. Most countries have recently adopted some form of public financing of broadband infrastructures. Public funds may be provided through various means, and particularly through *fiscal incentives programs*, *long-term loans programs for broadband suppliers* and *subsidies*. Korea and Japan have historically played a particularly active role in the provision of public financial support to private broadband players. They have more recently been joined by a large number of countries.

Public funds may also be involved in the creation of *Public-Private Partnerships* (hereinafter, PPPs), although they do not constitute an essential element of these agreements. Recourse to PPPs is, indeed, often motivated by the public sector's objective to attract private capital towards infrastructure financing, so as to complement or substitute for limited public resources. PPPs may take many different forms, associated to different degrees of involvement of public players. In some cases, often denominated *Private Finance Initiatives* or DBFO (*Design-Build-Finance-Operate*), financial resources are predominantly of a private nature. In other cases, the presence of public capitals is more substantial. This is the case for PPPs in the form of DBO (*Design-Build-Operate*), BOT (*Build-Operate and Transfer*), BT (*Build and Transfer*), BRT (*Build-Rent and Transfer*). In the latter cases the infrastructure is typically owned by the public sector and maintained and operated by the private sector on an open access basis.

Relevant examples of the adoption of PPPs include the experience of *CityNet* in Amsterdam, a range of cases in France, where a specific legal framework has been set in place and, more recently, the cases of New Zealand and Australia, where the government has adopted plans to institute PPPs for the deployment of fibre networks of an FTTH type (Fibre-to-the-Home), with a substantial input of public funds. In particular, the Australian *National Broadband Network* envisages an investment of 23.6 billion euros in order to cover 90% of the population through an NGN that operates only at the wholesale level. In New Zealand, the government has proposed in the past few months to finance up to 50% of the costs of a new broadband access network that would cover 75% of the population.

Another relevant form of supply-side intervention consists in the *coordination of the sharing of networks and investments*, which may be enacted through various specific policy measures. One way in which coordination may be obtained is through initiatives aimed at coordinating the civil works necessary to the rollout of broadband connections, which make up a substantial portion of the total costs of broadband deployment (of course, this refers to the adoption of broadband technologies, such as optic fibre, which require the rollout of entirely new networks). Another form of coordination is implicit in the adoption of rules imposing the obligation to leave in the newly built ducts enough space to lay down multiple fibre optic cables. Finally, some programs promoting the cooperation among public administration and private parties different from PPPs can also be interpreted as policies aimed at coordinating the sharing of networks and investments.

Further supply-side policies that have been enacted by a relevant number of countries are: (a) *territorial mapping programs*, i.e. public initiatives aimed at supporting investment decisions by private operators by providing detailed information on the existing broadband coverage and eventually on the potential demand expressed in different geographic locations of the country; (b) *promotion of specific technological standards*, which refers to the more controversial decision adopted by some governments to support the adoption of specific technological solutions, especially for new buildings and for infrastructure initiatives adopted at the local level (e.g., by municipalities financing the deployment of local networks); (c) *administrative simplification*, namely initiatives aimed at reducing the bureaucratic costs involved by broadband investments; and (d) *spectrum policy and rationalization of the use of frequencies*, which may be enacted to pursue a number of different goals, including raising fresh funds to finance broadband investment and reducing barriers to entry to wireless firms wishing to provide broadband services, especially in rural or geographically disadvantaged areas where wired connection are more difficult to lay down.

Demand-side policies may be more or less strictly targeted to stimulating broadband penetration, with some policies being more generally targeted at promoting ICT use by consumers and small businesses. Among the demand-side policy measures more clearly aimed at increasing incentives to invest in broadband can be included: (a) *public demand of specific services*, such as the provision of new or improved e-government, e-health or e-education applications, which increases the returns to investment in broadband particularly in circumstances in which private demand is still latent; (b) *incentives for business demand* such as, for instance, those envisaged by programs of enhancement of ICT penetration in SMEs; (c) *incentives for private demand*, among which IT alphabetization initiatives and vouchers may play a relevant role; (d) *demand subsidies*; and (e) *demand aggregation policies*, namely schemes aimed at coordinating the potential demand of consumers in order to ensure efficient resource allocation either through the registration of households' willingness to subscribe to broadband services (as done in the UK) or through more elaborate forms of coordination (as adopted in Sweden).

3. Previous literature

Broadband penetration has been the focus of a growing body of empirical research, as Internet accessibility has become one of the primary aspects of many business activities and services as well as an objective of social cohesion. The need for understanding both broadband demand and supply has so encouraged several empirical investigations aimed at explaining the variability of broadband deployment across areas within one country (Rappaport *et al.*, 2003; Grubesic, 2003; Prieger, 2001) or region (Aizu, 2002) and across nations (Bauer *et al.*, 2003; Cava-Ferreruela and Alabau-Munoz, 2006).

While some studies explicitly attempt to investigate the determinants of broadband demand (e.g., Madden and Simpson, 1997; Madden *et al.*, 1999; Eisner and Waldon, 2001; Rappaport *et al.*, 2003), others examine both supply and demand factors (e.g., Garcia-Murillo and Gabel, 2003; Bauer *et al.*, 2003; Cava-Ferreruela and Alabau-Munoz, 2006).

The former generally use micro-data, where the statistical unit is the household and the dependent variable is a binary choice (i.e. the use of a broadband/dial-up Internet connection). Trying to address the determinants of demand, this first body of research focuses on household characteristics (such as household size, income, age and education) while, on the supply side, only the price of broadband and dial-up service is included. For example, in the study by Rappaport *et al.* (2003), multinomial logistic models are implemented on a sample of about 20000 US households and it is found that education and income level positively affect broadband use in individual households. Probabilistic models are also used to examine individual households' decisions and broadband adoption by Madden and Simpson (1997) and Madden *et al.* (1999) for Australia, Takanori and Toshifumi (2006) for Japan, Cerno and Pérez-Amaral (2007) for Spain, and Cardona *et al.* (2009) for Austria.

Those studies that include both supply and demand side factors present more comprehensive analyses, as they consider also supply factors and argue that the provision of broadband services is shaped by the demand characteristics to the extent to which demand stimulates telecommunication firms' investments in specific areas. Thus, from this point of view, the research focus is the geographical digital divide and the reasons of spatial disparities rather than the choice of individual households; as Grubesic and Murray point out (2002), the geographical provision of broadband service is likely to be a function of profit seeking firms, so that only those locations with a potential for immediate return on investment will be selected for hardware upgrades. The link between population characteristics, infrastructure investments and broadband access is shown by several studies. Grubesic (2003) explores broadband access options in the state of Ohio (in the USA) and find that income, education, age, location and competition from alternative broadband platforms influence digital subscribers line infrastructure investment leading to a urban/rural divide. Similarly, Bauer *et al.* (2003), implementing a supply-demand model on a sample of 30 OECD countries, show that the potential demand (along with cost conditions of deploying advanced networks) is one of the most influential factors explaining broadband uptake, although the relative income position appears not significant in their estimation.

In a more recent paper, Cava-Ferreruela and Alabau-Munoz (2006) implement a supply-demand model similar to that of Bauer *et al.* (2003) and provide more robust results. The two authors examine a sample of 30 OECD countries from 2000 to 2002 and explore the factors influencing broadband demand, supply and adoption. By performing multivariate regression analysis, Cava-Ferreruela and Alabau-Munoz (2006) find that technological competition and the low cost of deploying telecommunication infrastructures are likely to be the key drivers for broadband supply, while the predisposition to use new technologies is the crucial determinant of broadband demand. In particular, they show a positive correlation between broadband penetration, on the one hand, and income, household density, population density, urban population, education and competition between technologies, on the other; differently, market competition (measured by the percentage of telephone lines of new entrants) does not seem to have a significant influence on the availability of broadband infrastructures for DSL or for cable technology. Nevertheless, notice that other studies (see, e.g., Garcia-Murillo and Gabel, 2003) report a positive and statistically significant effect of market competition on the percentage of broadband users in a given country. Finally, that the private and business demand drives broadband investments and diffusion is also found by Prieger (2001) on US data, which extends his analysis to some proxies for the composition of the business market (considering the percentage of manufacturing and services firms and firms' dimension) that, however, do not show statistically significant effects.

Impact of regulatory choices in the telecommunications sector on broadband penetration (Manenti ecc.)

Despite the rich array of results provided by the empirical studies above mentioned, which may help defining policy strategies, a systematic analysis of the role played by policy interventions is still missing. This may be due to two facts. On the one hand, the limited availability of data, that strongly constraints empirical models on this issue (especially when one tries to introduce policy variables) and forces researchers to caution in interpreting estimation results. On the other hand, the few available results are not encouraging. Bauer *et al.* (2003), for example, add to their econometric model some dummies reflecting policy regimes (that include unbundling, the separation of cable and telephone company ownership, and the availability of government funding to support broadband deployment), which, however, do not produce statistically significant parameter estimates. Similarly, a comparative study of broadband diffusion in Asia by Aizu (2002) reports that government policies do not have much influence in promoting broadband use. Nevertheless, tax incentives to encourage firms to serve underserved markets are suggested by some authors (see Gabel and Kwan, 2002) along with medium-intervention strategies involving both supply-side actions to assist in the establishment of broadband networks and demand-side actions to promote broadband service adoption (Cava-Ferreruela and Alabau-Munoz, 2006).

4. Data and methodology

We collect data from various sources in order to develop a well-suited dataset for econometric analysis purposes. The final dataset covers 21 OECD countries and collects a rich array of country-specific information about telecommunications, socio-economic conditions, demographic characteristics and institutional features. Data refer to 2006 and 2007 for the most part, while we were forced to use also data for the 2002-2005 period for some variables.

Broadband penetration. We measure broadband penetration by using the number of broadband subscribers per 100 inhabitants ($BBSUB_i$). Such a measure is provided by the World Telecommunications Indicators Database (ITU, 2009).

Industrial policies and demand policies. As our main focus, we are interested in investigating the effect, if any, of telecommunications-specific industrial and demand policies on broadband penetration in OECD countries. Thus, we need to develop appropriate indicators for these two groups of policies at the country level. In order to pursue this goal, we consider various policies or government initiatives. On the supply side, we include:

- the presence of PPPs;
- the coordination of the sharing of networks and investments;
- territorial mapping programs;
- fiscal incentives programs;
- long-term loans programs for broadband suppliers;
- the promotion of specific technological standards;
- spectrum policy and rationalization of the use of frequencies;
- administrative simplification;

On the demand side, we consider:

- public demand of services;
- demand aggregation policies;
- incentives to business demand;

• incentives to private demand;

• demand subsidies.

Unfortunately, we cannot consider all of these components separately in the empirical analysis, since the small number of observations does not allows us to use a large number of variables in the operative model (what would cause the well known problem of the loss of degrees of freedom and prevent us from implementing statistical inference on the data). Thus, we construct two synthetic indicators according to the following strategy. As a first step, we aggregate the policies' components for both supply and demand side for each country, by adding 1 when each component (i.e. policy or government initiative) is in place in the individual country. Doing so, we obtain two raw indexes that range from 1 to 8 (in the case of industrial policies) and from 1 to 5 (in the case of demand policies). Notice that this is a standard procedure for coding qualitative institutional variables and that it is routinely used in empirical analysis (see, for example, La Porta *et al.*, 1998). In this way, however, we are not sure to validly compare countries, given that countries with the same value in one of the two (or both) indexes may adopt substantially different policies. Therefore, as a second step, we group countries on the base of the number of different policies which they adopt and cluster them in three classes for both industrial and demand policies in order to reduce the risk of wrong coding. In accordance with their qualitative nature, the two final variables for both supply and demand side policies (respectively, $INDPOL_i$ and $DEMPOL_i$) take a value of 3 in the case of widespread policies, of 2 in the case of limited policies, and 1 when policies are absent or very limited. In this way, we also minimize heteroskedasticity and problems with influential outliers.

Several further variables are included in our analysis as controls.

Venture capital availability. Venture capital may be an important determinant of broadband penetration, by affecting capital availability of new ICT firms and potential competitors. We consider two indicators as a measure of venture capital: venture capital investments in communication as a percentage of all venture capital investment in a given country (source: OECD Information Technology Outlook, OECD, 2008) and the venture capital investments in communication in a given country, as a percentage of all venture capital investment, weighted by the ease for finding venture capital in the same country (source of the first component: OECD Information Technology Outlook (OECD, 2008); source of the second component: Global Competitiveness Report, World Economic Forum, 2009). The two variables are called, respectively, VCC_i and VCE_i.

Effectiveness of antimonopoly policy. Also the effectiveness of the antimonopoly policy of a given country may be an important influence on the broadband penetration in the same country, by shaping firms' behavior and, in turn, investment decisions. We measure such a dimension using the index provided by the Global Competitiveness Report (World Economic Forum, 2009) and coding it as a dummy variable that equals 0 if the antimonopoly policy is lax and not effecting at promoting competition and 1 if the antimonopoly policy is effective and promotes competition (the final variable is called $ANTIMON_i$).

Quality of laws about ICT use. How the law regulates the use of information technology instruments and protect consumers is of major importance on the demand of Internet hosts and broadband. Thus, we include an index for the degree of sophistication of laws relating the use of information technology (such as electronic commerce, digital signatures and consumer protection). The index ($LAWICT_i$) ranges from 1, when these laws are non existent, to 7, when they are well developed and enforced (source: World Economic Forum, 2009).

Number of websites. The demand of fast Internet connections may be also affected by the contents available (as suggested by Cava-Ferreruela and Alabau-Munoz, 2006). In this case, we use data from the OECD Communication Outlook (OECD, 2003) and include a variable that measures the number of websites per 1000 inhabitants ($WEBSITES_i$).

Technological competition. The potential influence of technological competition on broadband penetration has been suggested by some contributions (e.g., Cava-Ferreruela and Alabau-Munoz, 2006). In our empirical analysis, technological competition is represented by the following three variables: mobile cellular subscriptions per 100 inhabitants ($MOBSUB_i$), mobile cellular subscriptions (per 100 inhabitants) as a percentage of total telephone subscribers ($MOBTELSUB_i$), number of dial-up Internet subscribers per 100 inhabitants ($DIALUP_i$). The source of the variable is the World Telecommunications Indicators Database (ITU, 2009) for $MOBSUB_i$ and $MOBTELSUB_i$, and OECD Statistical Database (OECD, 2009) for $DIALUP_i$.

Availability of Internet hosts. The number of Internet hosts per 100 inhabitants ($HOSTS_i$) measures the potential demand of broadband connections (source: OECD Statistical Database (OECD, 2009)).

Population characteristics. In the empirical analysis we use several demographic indicators that capture some population characteristics potentially relevant in shaping broadband demand: urban population as a percentage of total population ($URBAN_i$; source: Demographic Yearbook (UN, 2007)), population density per Km2 ($POPDENS_i$; source: World Development Indicators (World Bank, 2009)), female as a percentage of total population ($FEMALE_i$; source: Demographic Yearbook (UN, 2007)), percentage of population under 15 years ($UNDER15_i$; source: Demographic Yearbook (UN, 2007)), percentage of population over 60 years ($OVER60_i$; source: Demographic Yearbook (UN, 2007)), graduates as a percentage of total population ($GRADUATES_i$; source: OECD Statistical Database (OECD, 2009)). The potentially relevant role played by the population age structure is pointed out by Gabel and Kwan (2000), Rappaport *et al.*

(2000) and Prieger (2001), that of the education level by Gabel and Kwan (2000), Rappaport *et al.* (2000), Prieger (2001), Grubesic (2003) and Cava-Ferreruela and Alabau-Munoz (2006), that of sex by Rappaport and Taylor (2000) and Prieger (2001), that of the percentage of urban population by Prieger (2001) and Cava-Ferreruela and Alabau-Munoz (2006), that of population density, finally, by Prieger (2001), Garcia-Murillo and Gabel (2003), Bauer, Kim and Wildman (2003) and Cava-Ferreruela and Alabau-Munoz (2006).

Other demand characteristics. We also include the logarithm of the GNI per capita (GNI_i) (as suggested by Gabel and Kwan, 2000, Rappaport *et al.*, 2000, Prieger, 2001, Garcia-Murillo and Gabel, 2003, Grubesic, 2003, Bauer, Kim and Wildman, 2003, Cava-Ferreruela and Alabau-Munoz, 2006), and the value added of services as a percentage of GDP ($SERVICES_i$) (as suggested by Prieger, 2001). For both variables the source is World Development Indicators (World Bank, 2009). Doing so, we try to measure individuals' capability to afford the price of Internet connections and the type of business demand (services presumably do require Internet connections more than industrial or agricultural activities).

Quality of electricity supply. Finally we use an indicator in order to measure the quality of the infrastructures needed for broadband Internet connections, specifically we use an index ($ELECTRICITY_i$) that range from 1, when the quality of the electricity supply (i.e. lack of interruptions and lack of voltage fluctuations) is worse than in other countries, to 7, when it meets the highest standard in the world (source: World Economic Forum, 2009).

Table 1 reports a descriptive analysis of the dataset.

Table 1. Descriptive statistics (cross-country data).

VARIABLE DEFINITION	NAME OF THE VARIABLE	OBS	MEAN	STD.DEV.	MIN	MAX
Broadband subscribers (per 100 inh.)	$BBSUB_i$	21	20.34	7.91	3.85	31.95
Demand policies	$DEMPOL_i$	21	2.19	0.60	1.00	3.00
Industrial policies	$INDPOL_i$	21	2.33	0.79	1.00	3.00
Venture capital availability	VCC_i	21	10.22	9.06	0.00	29.30
Venture capital availability (weighted)	VCE_i	21	2.45	2.01	0.00	6.23
Anti-monopolicy policy	$ANTIMON_i$	21	0.76	0.44	0.00	1.00
Urban population	$URBAN_i$	21	77.52	10.44	54.90	98.6
GNI (logarithm)	GNI_i	21	10.33	0.29	9.38	10.85
Graduates (per 100 inh.)	$GRADUATES_i$	21	1.16	0.26	0.62	1.65
Mobile subscriptions (per 100 inh.)	$MOBSUB_i$	21	97.48	17.21	57.46	136.34
Mobile subscriptions (per 100 inh., % total telephone sub.)	$MOBTELSUB_i$	21	66.30	6.01	50.70	79.40
Dial-up Internet subscribers (per 100 inh.)	$DIALUP_i$	21	8.47	5.94	0.09	20.40
Internet hosts (per 100 inh.)	$HOSTS_i$	21	17.10	14.19	0.44	48.88
Websites (per 100 inh.)	$WEBSITES_i$	15	36.14	27.47	2.90	84.70
Population density (per Km2)	$POPDENS_i$	21	141.03	146.28	2.67	486.57
Services (% of GDP)	$SERVICES_i$	21	69.14	6.02	53.47	77.28
Female (% of population)	$FEMALE_i$	21	50.55	0.72	49.11	51.59
Quality of electricity supplì	$ELECTRICITY_i$	21	6.21	0.75	4.20	6.90
Population under 15 years (%)	$UNDER15_i$	21	17.45	3.07	13.32	26.81
Population over 60 years (%)	$OVER15_i$	21	21.30	4.49	8.82	29.67
Laws relating ICT	$LAWICT_i$	21	5.22	0.64	3.60	6.10

5. Econometric analysis

5.1 Correlation analysis

We consider broadband penetration as a function of industrial and demand policies and of the control variables above described; formally, we consider the following relation (variables' description is provided in the previous section):

$$BBSUB_i = f\left(DEMPOL_i, INDPOL_i\right) + g\begin{pmatrix} ANTIMON_i, URBAN_i, GRADUATES_i, MOBSUB_i, MOBTELSUB_i, \\ DIALUP_i, HOSTS_i, WEBSITES_i, POPDENS_i, VCC_i, VCE_i, LAWICT_i, \\ SERVICES_i, FAMALE_i, ELECTRICITY_i, UNDER15_i, OVER15_i, GNI_i \end{pmatrix} \quad (1)$$

Given the small number of observations, we cannot consider all the covariates in the same regression model (what would cause, as mentioned above, the impossibility of performing statistical inference on the data). Therefore, we divide our statistical analysis in two steps. First, we undertake a correlation analysis in order to identify those control variables that are correlated with broadband penetration in a statistical significant way. Second, once the subset of potentially relevant variables is selected, we perform an econometric analysis on various model specifications. In this section, we present the results of the correlation analysis.

In the correlation analysis, we calculate the correlation coefficients of $BBSUB_i$ and each covariate included in the second part of equation (1); then, we calculate the p-value for each correlation coefficient and identify those relations that are statistically relevant on the base of a conventional level of significance.

Table 2 reports the statistical results of this analysis; while the first and the second columns report variables' definition and name, the third and the fourth columns report, respectively, the value of the pairwise correlation coefficients and the p-values, the fifth column identifies those relations that can be considered statistically significant. Interesting relations are so unveiled.

Table 2. Pairwise correlation coefficients between broadband penetration ($BBSUB_i$) and selected variables.

VARIABLE DEFINITION	NAME OF THE VARIABLE	CORRELATION COEFFICIENT	P-VALUE	STATISTICAL SIGNIFICANCE
Anti-monopolicy policy	$ANTIMON_i$	0.72	0.002	***
Laws relating ICT	$LAWICT_i$	0.78	0.000	***
Venture capital availability	VCC_i	0.57	0.006	***
Venture capital availability (weighted)	VCE_i	0.43	0.050	**
Quality of electricity supplì	$ELECTRICITY_i$	0.85	0.000	***
Internet hosts (per 100 inh.)	$HOSTS_i$	0.63	0.002	***
GNI (logarithm)	GNI_i	0.63	0.002	***
Graduates (per 100 inh.)	$GRADUATES_i$	0.38	0.083	*
Urban population	$URBAN_i$	0.33	0.142	
Mobile subscriptions (per 100 inh.)	$MOBSUB_i$	0.04	0.851	
Mobile subscriptions (per 100 inh., % total telephone sub.)	$MOBTELSUB_i$	-0.23	0.307	
Dial-up subscribers (per 100 inh.)	$DIALUP_i$	-0.04	0.835	
Websites (per 100 inh.)	$WEBSITES_i$	0.34	0.204	
Population density (per Km2)	$POPDENS_i$	0.25	0.264	
Services (% of GDP)	$SERVICES_i$	-0.07	0.756	
Female (% population)	$FEMALE_i$	-0.15	0.497	
Population under 15 years (%)	$UNDER15_i$	-0.09	0.671	
Population over 60 years (%)	$OVER15_i$	0.11	0.615	

Note: level of confidence of statistical significance ("*" = 90%, "**" = 95%, "***" = 99%).

First, the effectiveness of anti-monopoly policies ($ANTIMON_i$) is shown to be statistically related with the broadband penetration as well as the quality of laws relating the use of information technology ($LAWICT_i$). Such a finding shows that the national institutional environment may be of major importance for the diffusion of broadband Internet connections, by affecting both firms' behavior (by means of antimonopoly policies) and broadband demand (by means of the consumer protection and the regulation of electronic commerce).

Second, the availability of venture capital is correlated with the broadband penetration in a statistically significant way, when it is measured by means of both the amount of venture capital investments in communication, expressed as a percentage of all venture capital investment (VCC_i), and the amount of the venture capital investments in communication (as a percentage of all venture capital investment) weighted by the ease for finding venture capital in the given country (VCE_i).

Third, the quality of the electricity supply ($ELECTRICITY_i$) has a statistically significant correlation with the broadband penetration. Thus, also the quality of the infrastructures (such as the electricity supply) results as a potentially relevant variable in our analysis.

Fourth, broadband penetration may be also affected by the volume of the potential demand, that we measure by using the number of Internet hosts ($HOSTS_i$) and a proxy for the per capita income (GNI_i).

Finally, the demographic characteristics of the population (with the exception of $GRADUATES_i$) and technological competition seem to be statistically non relevant, what apparently contrasts empirical findings of other studies (see, for example, Cava-Ferreruela and Alabau-Munoz, 2006).

5.2 Regression analysis

5.2.1 Ordinary least-square regressions.

The correlation analysis allows us to define a subset of control variables potentially relevant in explaining the cross-country variability of broadband penetration. In this section, we develop a multivariate regression analysis in order to further explore the statistical relations above mentioned.

We consider the following regression model:

$$BBSUB_i = \beta_0 + \beta_1 DEMPOL_i + \beta_2 INDPOL_i + \beta_3 VCC_i + \beta_4 VCE_i + \beta_5 ANTIMON_i \qquad (2)$$

$$+\beta_6 HOSTS_i + \beta_7 LAWICT_i + \beta_8 ELECTRICITY_i + \beta_9 GNI_i + \beta_{10} GRADUATES_i + \varepsilon_i$$

where symbols' meaning and variables' descriptions are given in the previous section. The vector $\beta = [\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9, \beta_{10}]$ defines the parametric structure (in particular β_0 is the model constant), while ε_i is the error term. Given the small number of observations, we start considering an abridged version of the model and progressively add the controls, so testing the estimation robustness.

Table 3 and Table 4 report the estimation results of, respectively, abridged and extended model specifications. In both tables, while the first column reports the variables, the remaining columns report the estimated parameters of the various model specifications.

Table 3. Cross-country estimation results: abridged model versions.

VARIABLE	MODEL (a)	MODEL (b)	MODEL (c)	MODEL (d)	MODEL (e)
Dep.Var.: *$BBSUB_i$*	Coef. (Std.Err.)	Coef. (Std.Err.)	Coef. (Std.Err.)	Coef. (Std.Err.)	Coef. (Std.Err.)
$DEMPOL_i$	4.681 (2.376) *	4.196 (2.201) *	4.089 (1.619) **	4.142 (1.607) **	1.284 (2.034)
$INDPOL_i$	4.101 (2.191) *	2.732 (2.122)	-1.058 (1.822)	-1.564 (1.862)	-0.298 (2.034)
VCC_i	--	0.408 (0.195) *	0.332 (0.144) **	--	0.489 (0.164) ***
VCE_i	--	--	--	1.481 (0.629) **	--
$ANTIMON_i$	--	--	13.067 (3.240) ***	14.259 (3.193) ***	--
$GRADUATES_i$	--	--	--	--	11.413 (3.805) ***
Statistical details					
No. Obs.	21	21	21	21	21
Prob. > F	0.000	0.000	0.000	0.000	0.000
R-square	0.881	0.905	0.951	0.952	0.937

Note: level of confidence of statistical significance ("*" = 90%, "**" = 95%, "***" = 99%).

Table 4. Cross-country estimation results: extended model versions.

VARIABLE	MODEL (f)	MODEL (g)	MODEL (h)	MODEL (i)
Dep.Var.: *$BBSUB_i$*	Coef. (Std.Err.)	Coef. (Std.Err.)	Coef. (Std.Err.)	Coef. (Std.Err.)
$DEMPOL_i$	2.772 (1.491) *	0.406 (1.806) *	-0.264 (1.489)	-0.768 (1.654)
$INDPOL_i$	0.093 (1.638)	-1.062 (1.609)	-1.412 (1.365)	0.062 (1.493)
VCC_i	0.316 (0.125) **	0.346 (0.116) ***	0.344 (0.098) ***	0.350 (0.117) ***
$ANTIMON_i$	8.715 (3.268) **	8.495 (2.999) **	6.374 (2.664) **	--
$LAWICT_i$	--	--	--	2.708 (0.850) ***
$HOSTS_i$	0.220 (0.085) **	0.192 (0.079) **	0.164 (0.068) **	0.255 (0.073) ***
GNI_i	--	0.837 (0.417) *	--	--
$ELECTRICITY_i$	--	--	2.120 (0.642) ***	--
Statistical details				
No. Obs.	21	21	21	21
Prob. > F	0.000	0.000	0.000	0.000
R-square	0.965	0.972	0.980	0.969

Note: level of confidence of statistical significance ("*" = 90%, "**" = 95%, "***" = 99%).

The parameter estimates show that demand policies may be an important influence on broadband penetration. Indeed, model specifications (a), (b), (c), (d), (f) and (g), reported respectively from the second to the fifth column of Table 3 and in the second and third column of Table 4, show that the demand policies (as measured by our synthetic index) have a positive and statistically significant effect on broadband penetration in OECD countries. On the contrary, industrial policies turn out as statistically significant only in model specification (a), so that government interventions on the supply side appear to be less effective on broadband diffusion than those on the demand side.

The parameter estimates referring to the control variables are broadly stable across the various model specifications and confirm all the relations unveiled by the correlation analysis. In particular, the effectiveness of anti-monopoly policies ($ANTIMON_i$), the sophistication of laws relating the use of information technology ($LAWICT_i$), the availability of venture capital (as measured by both the variables VCC_i and VCE_i), the quality of the electricity supply ($ELECTRICITY_i$), the number of Internet hosts ($HOSTS_i$), the per capita income (GNI_i) and the percentage of graduates ($GRADUATES_i$) all have a positive and statistically significant effect on broadband penetration. Notice that the variables' couples $LAWICT_i$-$ANTIMON_i$, GNI_i-$ELECTRICITY_i$, VCC_i-VCE_i, $GRADUATES_i$-$HOSTS_i$ and $GRADUATES_i$-$ANTIMON_i$ show a statistically significant pairwise correlation coefficient; thus, individual variables (within couples) are included one by one in the operative model in order to avoid multi-collinearity problems.

The diagnostic analysis (performed by using the F-statistics), notwithstanding the small number of observations, leads us to reject the null hypothesis of joint non statistical significance of all the parameters. Statistical details of the abridged model specifications are reported in Table 3, while those of the extended model specifications are collected in Table 4.

5.2.2 Three-stage least-square regressions.

Endogeneity.

The ordinary least-square estimation, presented in the previous section, has showed that the demand policies may play an important role in explaining the cross-country variability of broadband penetration. Nevertheless, countries do not have all the same capabilities to undertake stimulating policies on the demand side, which are presumably costly for the government. So, in this section, we consider the indicator of demand policies as an endogenous variable in order to make our econometric model more complete and to increase, in turn, the overall statistical robustness of the estimation results.

For this purpose, we consider the demand policies that a given country adopt as a function of the central government gross surplus/deficit spending (as a percentage of GDP) and the government gross debt (as a percentage of GDP). Both these measures are provided by the World

Economic Outlook Database (IMF, 2008) and refer to 2007. In our operative model, they are called, respectively, $SURPLUS_i$ and $DEBT_i$.

Econometric specification.

Formally, we consider the following cross-country two-equation model:

$$BBSUB_i = \delta_0 + \delta_1 DEMPOL_i + \delta_2 INDPOL_i + \delta_3 VCC_i + \delta_4 VCE_i + \delta_5 ANTIMON_i + \delta_6 HOSTS_i + \delta_7 GNI_i + \upsilon_i \quad (3)$$

$$DEMPOL_i = \lambda_0 + \lambda_1 SURPLUS_i + \lambda_2 DEBT_i + \tau_i \quad (4)$$

where the vectors $\delta = [\delta_0, \delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6, \delta_7]$ and $\lambda = [\lambda_0, \lambda_1, \lambda_2]$ define the parametric structure (in particular δ_0 and λ_0 are the two model constants), while υ_i and τ_i are the error terms. Notice that, in our operative model, it is possible to deduce the structural parameters from the known reduced form parameters. There is no more than one structure that can lead to the same reduced form, therefore we can estimate the structure.

As equations (3) and (4) show, we allow broadband penetration to react to demand policies and, simultaneously, demand policies to react to $SURPLUS_i$ and $DEBT_i$. Consequently, υ_i is likely to be correlated with $DEMPOL_i$. Thus, we jointly estimate the two equations using a three-stage least square procedure (3SLS hereafter). Let us call $X = [X_1, X_2]$ the matrix of regressors, where X_1 is a matrix composed of variables assumed exogenous with respect to the broadband penetration, while X_2 is made of m variables that are suspected to be endogenous in the model (the demand policies index in this case). Select a number $k \geq m$ of instrumental variables Z that satisfy the two fundamental requirements that $\mathrm{Cov}(Z, X_2) \neq 0$ (relevance) and $\mathrm{Cov}(Z, \zeta) = 0$ (exogeneity). Then a system 2SLS is implemented, where, in the first stage, X_2 is regressed over Z and a constant. The parameter estimates so generated are then saved and used to form a consistent estimate of the covariance matrix of the disturbances ζ that allows for correlation of the residuals across the equations of the system. The covariance matrix is finally adopted as a weighting matrix to re-estimate the system and get the new values of the parameters in the last step. The last two steps are iterated over the estimated disturbance covariance and parameter estimates until the parameter estimates converge.

When the instruments do not have a statistically significant role in explaining the cross-country variation of demand policies, they are called "weak". In the presence of weak instruments, the estimated coefficients from the identification test turn out non-standard and tests are misleading (Staiger and Stock, 1997). As we have mentioned above, an instrumental variable must satisfy two requirements: it must be correlated with the included endogenous variable (relevance) and orthogonal to the error process (exogeneity). On the one hand, the former condition may be

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readily tested by examining the fit of the first stage regression. The first stage regression is a reduced form regression of the endogenous variable $DEMPOL_i$ on the full set of instruments Z; the relevant test statistics here relate to the explanatory power of the excluded instruments Z_1 in this regression.[1] On the other hand, to verify the exogeneity of the instruments, it is commonly implemented the Sargan test of the overidentifying restrictions; in particular, the hypothesis being tested with the Sargan test is that the instrumental variables are uncorrelated to some set of residuals, and therefore they are acceptable instruments. The results of the diagnostic analysis of our estimation are commented at the end of the following sub-section.

Results and diagnostics.

Table 5 reports the estimation results. While the first column reports the variables, the remaining columns report the estimated parameters of the various model specifications. The two-equation parameters, simultaneously estimated, are reported in succession.

Table 5. Cross-country estimation results: three-stage least-square estimation.

VARIABLE	MODEL (m)	MODEL (n)	MODEL (o)
Eq. 1. Dep.Var.: *BBSUB$_i$*	Coef. (Std.Err.)	Coef. (Std.Err.)	Coef. (Std.Err.)
DEMPOL$_i$	6.125 (2.127) ***	4.325 (2.558) *	6.344 (2.804) ***
INDPOL$_i$	-2.258 (1.991)	-1.827 (1.531)	-2.422 (1.761)
VCC$_i$	0.359 (0.111) ***	0.359 (0.104) ***	--
VCE$_i$	--	--	1.453 (0.506) ***
ANTIMON$_i$	9.565 (2.962) ***	9.228 (2.723) **	10.954 (3.052) ***
HOSTS$_i$	0.151 (0.083) *	0.166 (0.072) **	0.155 (0.081) *
GNI$_i$	--	0.243 (0.480)	-0.128 (0.528)
Eq. 2. Dep.Var.: *DEMPOL$_i$*	Coef. (Std.Err.)	Coef. (Std.Err.)	Coef. (Std.Err.)
SURPLUS$_i$	0.115 (0.053) **	0.114 (0.055) **	0.113 (0.054) **
DEBT$_i$	0.022 (0.003) ***	0.023 (0.003) ***	0.023 (0.003) ***
Statistical details			
No. Obs.	21	21	21
Wald test (eq. 1): *p*-value	0.000	0.000	0.000
R-square (eq. 1)	0.949	0.962	0.950
Wald test (eq. 2): *p*-value	0.000	0.000	0.000
R-square (eq. 2)	0.688	0.691	0.690
Sargan test [*p*-value]	3.208 [>10%]	2.025 [>10%]	1.741 [>10%]

Note: level of confidence of statistical significance ("*" = 90%, "**" = 95%, "***" = 99%).

[1] More precisely, the first stage *R*-square is the "squared partial correlation" between the excluded instruments Z_1 and the endogenous regressor in question. It is defined as $(RSS_{Z1} - RSS_Z)/TSS$, where RSS_{Z2} is the residual sum of squares in the regression of the endogenous regressor on Z_2 – the included instruments –, and RSS_Z is the RSS when the full set of instruments is used.

Addressing endogeneity problems, the robustness of the estimation results is increased, as the *R*-square of the equation (3) shows very high values and the index of demand policies turns out as statistically significant in all the model specifications (m), (n) and (o) considered, reported from the second to the fourth column of Table 5.

Further interesting results are obtained. Specifically, demand policies are shown to be endogenous with respect to the central government gross surplus/deficit spending, so that the higher the surplus/deficit ratio, the wider the extension of the public policies on the demand side. Moreover, countries with a high level of government gross debt seem to be more likely to undertake demand policies, what suggests, in this case, that the causal relation may also goes from public policies to public debt.

We have performed a diagnostic analysis of both the estimation strategy and results. First, we have checked relevance and exogeneity of the instruments used in the estimation. In order to test the relevance condition, as recommended by Bound *et al.* (1995), we have examined the first stage *R*-square, which, in our model specifications, turns out greater than 0.3, that is the commonly used acceptance threshold (Shea, 1997). In order to test the exogeneity condition, we have implemented the Sargan test of the overidentifying restrictions. The test results lead us to not reject the null hypothesis (at the conventional level of significance, 10%), thus the instruments pass the test and they are statistically validated. Second, as an overall diagnostic procedure, we have performed the Wald test on all the model specifications; the test results, notwithstanding the small number of observations, lead us to reject the null hypothesis of joint non statistical significance of all the parameters. Statistical details of the 3SLS estimation are reported in Table 5.

6. Conclusions

The objective of this paper has been to fill a small but relevant gap in the empirical literature on broadband deployment by providing an analysis of the relative effectiveness of a range of supply-side and demand-side policy interventions aimed at stimulating broadband investment. The lack of empirical analyses specifically focused on the policy side of the broadband debate may be motivated by a number of reasons that include the difficulty of gathering adequate information for a number of countries sufficient to make the analysis meaningful in a policy context that is permanently in flux. One of the strengths of this paper is that it relies on a dataset assembled in part on the basis of such time-consuming process of information-gathering. Indeed, the data on the policies adopted in the 21 OECD countries considered in the study have been carefully retrieved on the basis of an extensive analysis of the existing academic literature, of consulting firms' reports, official documents and governments' and newspapers' websites. This strength turns out to some extent to be a weakness of the paper, however, to the extent that it has limited the number of countries that could be taken into account in the analysis so far.

The relevance of the analysis performed in the paper is not only academic. The ubiquitous broadband investment plans adopted by governments worldwide have not been able to rely on much substantive guidance from the economic profession in their choice of policy tools. At a time in which the financial crisis makes governments' budget constraints ever more binding (even if it also provides in some countries renewed impetus for the adoption of infrastructure-centred Keynesian policies), this lack of information on which to ground selective interventions is particularly unfortunate.

The present paper makes a first, albeit small, step in the direction of providing some information that may constitute the basis for selective broadband policy interventions. From a practical point of view, the conclusion that may be most useful to policy-makers in the short term is that demand-side policies show, on the aggregate, greater effectiveness than supply-side interventions. Indeed, the results of our analysis show that demand policies (as measured by our synthetic index) have a positive and statistically significant effect on broadband penetration in the 21 OECD countries considered, while industrial policies turn out as statistically significant only in one out of 10 model specifications. This is to some extent surprising, in light of the fact that most of the attention has been historically placed on supply-side interventions, with demand-side interventions being considered a useful, though not essential, component of a broadband policy plans.

Other relevant results concern our control variables. On the positive side, we are able to single out a number of "institutional" variables, i.e. a number of variables capturing the characteristics of different countries institutional environment, that appear to play a role in broadband penetration. This is the case for the effectiveness of anti-monopoly policies, the quality of laws relating the use of information technology and the availability of venture capital, all shown to be statistically related with broadband penetration. The quality of other sorts of infrastructures, and particularly electricity supply, has also a statistically significant correlation with the broadband penetration.

On the negative side, we obtain some results that question the results of previous studies. More specifically, we find that the demographic characteristics of the population (with the exception of the variable capturing the proportion of graduates in the population) and technological competition seem to be statistically non relevant, in apparent contrast with other studies (see, for example, Cava-Ferreruela and Alabau-Munoz, 2006).

Further work is surely needed to improve the strength of the present analysis. In particular, the dependent variable should be more carefully characterized by taking into account not only DSL penetration, as it has been done in this study, but also the data on alternative broadband technologies. The number of countries considered should also be extended. In spite of these limitations, however, we believe that our research work may be of some use to both researchers and policy-makers.

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