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Exploring geographic variation in corporate broadband adoption; evidence from Irish small- and medium- sized enterprises (SMEs)

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Abstract

We explore the context-specific determinants of broadband takeup among small- and medium- sized enterprises (SMEs), attempting to shed some light on the sources of the considerable geographic variation in particular. We begin by discussing the determinants of broadband adoption as identified in relevant literature, relate these to the Irish situation and put forward a number of hypotheses. Using cross-section data from a ComReg survey of Irish-based SMEs, we then estimate a logit model of broadband adoption. Findings indicate that, among other factors, a company's industrial sector and other demand proxies are good predictors of broadband adoption. Controlling for other factors, regional market concentration appears to be negatively associated with the probability of broadband adoption. We propose that, in the absence of more detailed information, statistics on regional-level market structure could be a promising indicator of the supply-side.

Keywords: broadband, Ireland, competition, spatial disaggregation, diffusion

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1 Introduction

A growing number of business operations are becoming dependent on network access seeking cost and efficiency improvements. The set of end-point connection technologies that have collectively become known as “broadband” represents a response to an ever-increasing need for affordable, high-bandwidth, always-on connections. Broadband (in conjunction with the broader upgrading of Internet infrastructure in the form of IPv6) promise to extend the scope of Internet applications to, among other things, high definition media delivery and telephony. The opportunities afforded to businesses by the move to broadband have been highlighted in numerous policy-oriented documents (DCMNR, 2003; CEC, 2004; OECD, 2005; Forfás, 2005).

For all its wonders though the spread of broadband has been spatially uneven. Takeup rates vary considerably across countries (CEC, 2004b; OECD, 2006) and at the national level, across regions (Strover, 2001; Grubesic, 2002; Prieger, 2003; CEC, 2006). Some argue that, given the benefits of adoption, uneven takeup contributes to a new kind of inequality often referred to as a “digital divide” (Davison and Cotten, 2003; Prieger, 2003; McCaffery, 2003). Identifying the causes of takeup variation is central to bridging this divide.

A review of international empirical literature points to numerous determinants. Different levels of demand (and their proxies) explain a part of this trend (Grubesic, 2002; Madden and Coble-Neal, 2003; Prieger, 2003). Companies of different sizes and with distinct operational needs are likely to exhibit varying levels of demand for bandwidth (Forman et al., 2005). In addition, adoption experiences may differ due to supply-side factors. High deployment costs, uncertainty, technological limitations and obstacles in securing access to infrastructure as well as local market conditions have meant that the broadband Internet service provider (ISP) market is often spatially fragmented (Greenstein, 2000; van Gorp et al., 2006). In effect, prospective adopters face different broadband access costs and choice of products depending on their location. Moreover, different levels of competition imply varying levels of marketing intensity, a key factor in the diffusion of information (Rogers, 2003) regarding the benefits and costs of broadband.

In this paper we attempt to account for the currently observable differences in corporate broadband penetration across Ireland. Our analysis is informed by a number of a secondary sources, while the analytical part is based on a survey of small- and medium- sized enterprises. The survey indicates that both the number of providers active in each region[1] and their regional market shares vary considerably. We hypothesise that regionally differentiated competition may be an important explanatory factor in the Irish case. Econometric analysis indicates that demand-side factors explain a large part of the trend. Moreover, geographically differentiated competition appears to be an important determinant of broadband adoption. However, it is unclear whether this is a *cause* or a *consequence* of regional takeup variation. In any case, we argue that, in addition to existing measures[2] of service supply, a more accurate picture of the supply-side may be attained by the inclusion of market structure statistics, ideally ones that are disaggregated geographically.

2 Background

2.1 Broadband Connection Platforms: Opportunities and Limitations

Broadband, defined as high-speed[3], always on Internet connectivity, can be delivered to the end customer by a variety of means. Digital Subscriber Line

[1]Following the spatial units employed in the ComReg survey, "regions" are defined here as sub-national territorial units (provinces / cities).

[2]Forfás' (2005) benchmarking exercise included entry level cost, numbers of DSL-enabled exchanges as well as estimates on the roll-out of fiber optic cable and local loop unbundling. A similar set of measures are included in DCMNR (2003). Of those, only the latter two are geographically differentiated and even these are difficult to obtain on a regular basis.

[3]There are no explicitly set criteria as to what speed threshold qualifies as broadband. Conceptually any Internet connection that is faster than 128kbps ISDN may be termed 'broadband', as it signifies a clear break with the first (PSTN) and second (ISDN) generations of end user connectivity. In practice though the most often quoted threshold is that offered by entry-level DSL at 512kbps.

(DSL) and Cable broadband feature among the most popular connection platforms (Bar, et al. 2000; OECD, 2005; Distaso et al., 2006). The former uses microwave technology to carry Internet data across conventional telephony lines, while the latter utilises a similar technology to take advantage of cable television networks. Importantly, neither platform has an impact on the traditional uses of such infrastructure as both technologies transfer data without interfering with voice or television traffic.

DSL has been the primary vehicle for the proliferation of broadband in the EU (including Ireland). Its popularity is owed in no small part in its ability to utilise existing infrastructure. From a provider's perspective, availing DSL to consumers involves a one-off upgrade of the local phone exchange. DSL also allows for multiple ISPs to operate on a single physical network (intra-platform competition), through a process known as Local Loop Unbundling (LLU). The result of competition-minded legal and regulatory provisions, LLU requires incumbent operators to provide alternative ISPs with access to their phone exchanges (i.e.the 'local loop') on a non-discriminatory basis.

On the negative side, inherent limitations in DSL technology mean that it is not always available in rural areas. The problem is that DSL connections can only function reliably when the end-point connection (i.e. the consumer) is situated within a limited distance[4] from the local phone exchange. This has frequently meant that areas outside (and in some cases in the outskirts) of large conurbations do not enjoy DSL coverage at the outset (Strover, 2001; Madden and Coble-Neal, 2003; CEC, 2004a: 11). Overcoming this limitation requires considerable investment, which incumbents may not prioritise given the uncertainty of amortisation.

Other less widespread broadband connection platforms include leased lines, Fixed Wireless Access (FWA), Satellite, Broadband over Power Lines (BPL), Worldwide Interoperability for Microwave Access (WiMAX) as well as fast data services offered by third generation (3G) mobile telephony providers (e.g.

[4]Typically around two kilometers, though this distance varies depending on the quality of the existing copper wire infrastructure.

EDGE, UMTS/GPRS)[5]. As one might expect, the quality of broadband service afforded by the above platforms is highly heterogeneous[6]. Nevertheless, at present, no single platform exhibits clear technological superiority; rather their capabilities tend to be complementary, as the viability of a particular platform is often defined by the technological limitations of another, and/or the need to circumvent access restrictions to infrastructure controlled by the incumbent.

2.2 The Determinants of Broadband Diffusion

A number of empirical studies have attempted to explain the reasons behind the uneven diffusion of broadband. The diffusion of the technology is a complex function of demand- and supply-side factors. In this section we perform a short review of the insights offered by these studies. Where useful analogies can be made, we inform our understanding of demand factors by drawing from literature looking at the broader determinants of Internet diffusion[7]

The uneven geographic distribution of broadband supply is closely related with the characteristics of the specific locale. A critical mass of human presence, economic activity and infrastructure appear to be good predictors of where broadband will be offered first. Examining evidence from the United States, Prieger (2003) found that market size, education, Spanish language use, commuting distance and Bell presence increase broadband availability, while rural location decreases availability.

Given the right market conditions however, geographic determinism may not be inevitable. Using a large-scale survey of ISPs in the United States, Greenstein (2000) found that the propensity of ISPs to offer services other than basic Internet access (including broadband) was influenced largely by firm-specific

[5]Broadband in Gas (BiP) is a recent addition to this list, currently awaiting regulatory approval in the United States.

[6]The different technological solutions employed mean that a great deal of variation exists with regards to uplink/downstream speed, latency (immediacy of responsiveness) and connection reliability.

[7]To an extent, the factors driving the spread of broadband overlap with those behind the spread of earlier (i.e. non-broadband) Internet connection platforms. In both cases demand has been driven by digital content; despite the important qualitative differences in terms of their respective offerings, we believe that the experience obtained during the first stages of Internet diffusion can be a useful guide.

factors[8] and, to a lesser extent, by location-specific factors. Therefore, the *types of companies* that operate in a given market could have a significant effect on the provision of broadband.

The availability of alternative connection platforms could also have a positive effect on broadband supply. The contribution of alternative platforms could be both direct (by providing broadband access where it was previously not available) and indirect (when alternative platforms are introduced by new entrants thus causing incumbents to rethink their position on regional infrastructure investment). Indeed, recent work by Distaso et al. (2006) shows a clear and positive association between increased inter-platform competition and broadband take-up in the EU. However inter-platform competition emerges within a specific set of circumstances. Bar et al. (2000) argue that the emergence of viable inter-platform competition (specifically between DSL and Cable) in the United States rested to a large extent on the presence of a pre-existing, wide ranging cable network. Therefore, the supply of broadband (cost of access, choice and quality of products) is, to an extent, also determined by a country's pre-existing infrastructure (telephony, cable, fiber-optic and, as of recent, the electricity grid).

Even if broadband availability was universal, however, takeup rates would still differ because of varying demand levels. Arguably, nowhere else is the influence of the demand-side as apparent as in the case of South Korea. There, a narrow set of factors including demand for media-rich content and on-line gaming propelled broadband takeup to world-leading levels (Lau et al., 2005). And while any conclusions drawn from the Korean case might be difficult to generalise, the (uncharacteristic) potency of demand-pull factors there is a telling example of what could be achieved when the utility of broadband is high and is perceived to be so. Indeed, Odlyzko (2003) highlights an interesting paradox: U.S. survey data reveal an overwhelming unanimity that broadband is highly desirable but at the same time a lack of knowledge regarding its potential uses.

[8] These included the degree to which an ISP offered diversified services, marketing intensity, catering for business niches and the geographic scope of their business.

This raises the possibility that demand may shift as high visibility applications requiring broadband become increasingly popular.

In the early years, Internet diffusion was fuelled by industries and professions that relied heavily upon information (Cairncross, 1997). In line with early studies on the factors fuelling Internet takeup, Madden and Coble-Neal (2003) find that broadband demand is derivative of education and work requirements.

Furthermore, there is evidence that demand may be geographically differentiated. In a comprehensive review of Internet activity patterns in the U.S. state of Ohio, Grubesic (2002) offers insights into the kind of factors that might stimulate demand for network connectivity. He found that Internet activity was higher in locales with higher household density, income levels, suburban communities and research active educational institutions.

Empirical studies looking at corporate (or indeed SME) broadband adoption patterns have so far attracted little academic interest. The work of Forman et al. (2005) is a notable exception. They find that demand for frontier technologies, is associated with urban locations; they propose that this is due to the geographic concentration of information-intensive firms in these areas.

Finally, a common finding among empirical studies of corporate technology diffusion is that different types of firms exhibit a varying propensity to embrace modern innovations because of their inherent or acquired characteristics. These include the company's size, the industrial sector it operates in and the attributes of the human resources it employs (Karshenas and Stoneman, 1995; Geroski, 1999; Sadowski et al., 2002). The fact is that not all firms have the same internal technological needs or face the same external pressures.

The determinants of corporate broadband adoption are bound to be highly context-specific and in that respect are best established by way of detailed case study.

2.3 The Market for Broadband Services in Ireland

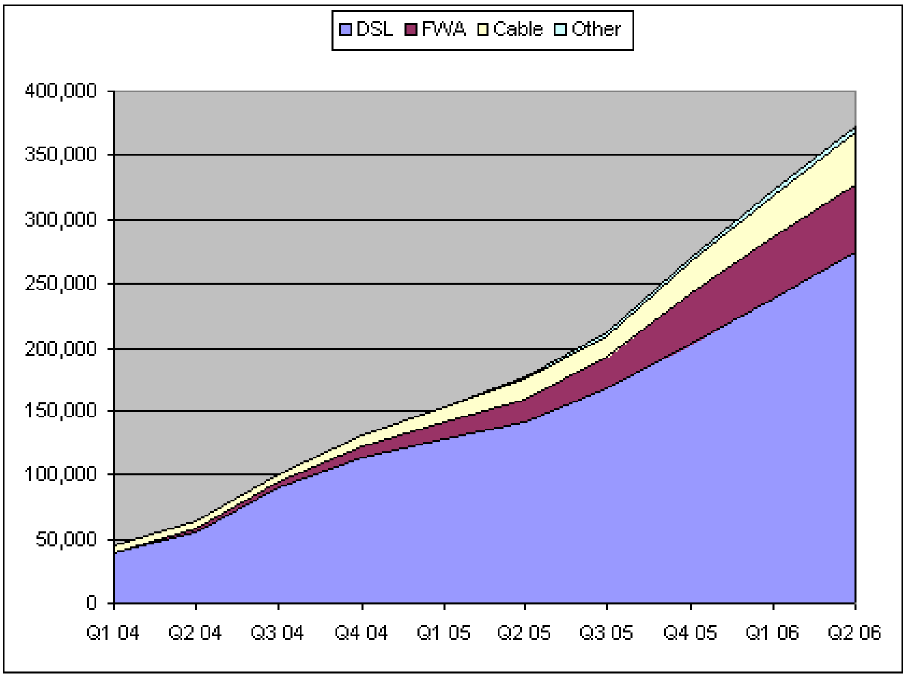
The liberalisation of telecommunications throughout Europe during the 1990s has not been without problems. Deregulation policies have had a varying degree of success in fulfilling the aspiration of a smooth transition from a state-dominated to a fully competitive market. As anticipated early on by Trauth and Pitt (1992), the aim of market efficiency was often contrasted against that of protecting domestic markets from foreign competition. In many cases ex-state operators still control much of the broadband infrastructure, presenting impediments for new entrants.

In Ireland the privatisation of *Bord Telecom Éireann* in July 1999 was seen as an important step in the liberalisation process. The resulting company, now known as *Eircom*, inherited control of the telephony infrastructure, under the supervision of the newly formed *Commission for Communications Regulation*[9] (ComReg). A major concern of the transition to liberalisation was the vulnerability of Eircom to foreign competition, especially given the company's relatively small size (MacMahon, 1995; Begg, 1995). Moreover, Irish regulatory policy was complicated by Eircom's position as a major provider of employment; regulators were warned early on that any interventions would impinge on a particularly sensitive area of public policy (see Begg, 1995: 309-311). Under the provisions of the new regulatory regime, Eircom avails its infrastructure to alternative service providers.

Eircom, through its operation *Eircom.net* has been and remains Ireland's leading ISP in terms of relative market share (Jacobson and Weymes, 2003; ComReg, 2005a; DCMNR, 2006). Other ISPs offer broadband both through Eircom's network and via alternative connection platforms. A counting of available offerings listed on the government-backed website "Broadband Information" (DCMNR, 2006a), indicates that, by the end of June 2006, a total of 58 ISPs were offering broadband. The main broadband technologies deployed in Ireland

[9] ComReg replaced the "Office of the Director of Telecommunications Regulation" and was endowed increased powers to impose penalties for breach of license conditions.

Figure 1: Broadband Connection Platforms in Ireland



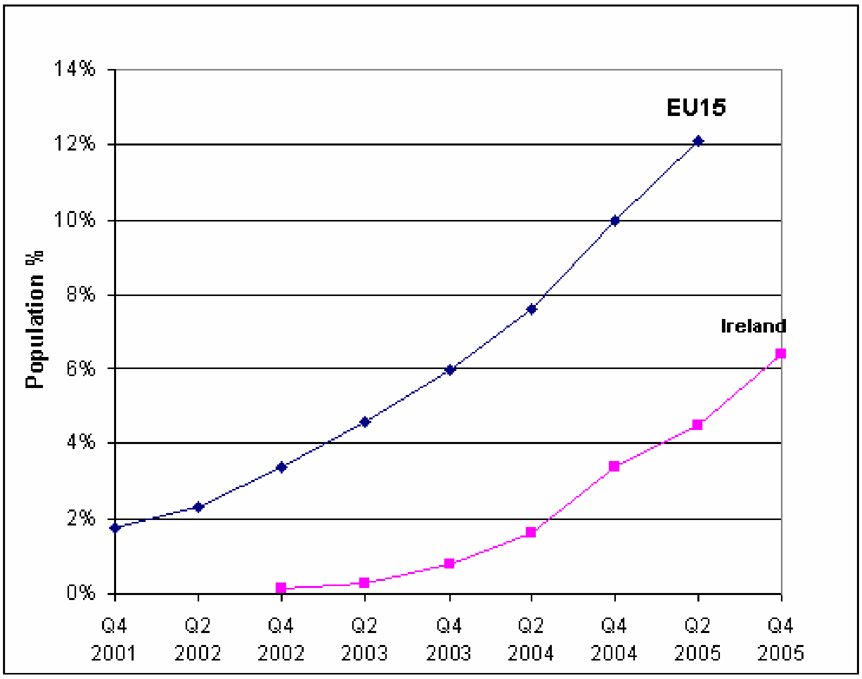
Source: ComReg, Irish Communications Market: Quarterly Key Data

include DSL, Cable, FWA and Satellite. DSL is by far the most common connection platform, though FWA and Cable are becoming increasingly popular (Figure 1).

While a number of ISPs have been offering conventional Internet services since the mid-1990s, broadband services were introduced relatively late. Eircom only begun to roll-out DSL services in 2002. Cable operator NTL, had been initially poised to offer broadband services before Eircom, but due to the technological limitations of its Irish network was unable to do so until 2003 (Jacobson and Weymes, 2003). By comparison, the roll out of DSL services was at an advanced stage in the UK (itself a laggard) by late 2000.

International comparisons hint at an underdeveloped market. Ireland has consistently occupied near-bottom places in comparative league tables of broadband takeup (OECD, 2006; Forfás, 2005). International comparisons with Ireland's EU partners indicate a persistent gap in broadband penetration though

Figure 2: Ireland and EU15: Broadband takeup trends



Source: DCMNR (2006c); based on ComReg and Eurostat data

current figures indicate that the speed of diffusion (given the level of penetration) is comparable (Figure 2) .

It is now clear that the currently low broadband uptake is partly (or perhaps wholly) attributable to the market's late start (DCMNR, 2006c:3-5). This has meant that both necessary technological investment and the marketing of services has lagged. A persistent problem is the coverage of non-urban areas. While 85 per cent of telephone lines are connected to a DSL-enabled phone exchange, in practice an unspecified proportion of these lines fail to support a DSL connection. This is due to either the subscriber's distance from the phone exchange or because of the quality of the intervening copper wires. The combination of the heavy reliance on DSL technology and the fact that 40 per cent of the Irish population resides in rural areas, mean that the limitations imposed by distance have a greater impact in Ireland. As of January 2005 only 38 per cent of Ireland's rural population enjoyed DSL coverage, the second-lowest such figure in the EU (Forfás, 2005). Worse still, in areas where DSL or Cable remains unavailable, choice is constrained to unconventional (and expensive) delivery platforms such as Satellite or FWA.

2.4 Broadband Adoption by Irish SMEs

According to the Chamber of Commerce survey (2005) nearly 93 per cent of SMEs located in Dublin have access to the Internet, over two thirds of which have a broadband connection. For the more peripheral regions of the Border and Midlands the figure was closer to one third. What becomes obvious in the Irish case is that in an era of supposed aspatial, areal uniformity, geography remains stubborn. Companies from all sectors find themselves at a disadvantage in setting up in less urbanised areas. Contrary to popular hype this is as true for Ireland's well re-knowned high tech sector as any other. The cost disadvantage of locating on Ireland's more peripheral west coast is accentuated by telecommunications infrastructure.

> "*Basically if you are looking to lease a 2Mbit line of broadband on the west coast, it will cost you three or maybe four times what it would in Dublin*" (Interview, State Agency Representative, July 2003).

An overview of telecommunications infrastructure in the west of Ireland by the Western Development Commission (an agency concerned with development issues in the Western counties), claimed that Ireland was now part of an Information Society, a key trait of which was, making "*space and distance irrelevant*". In the opening statement, it postulated:

> "*Whether we access the Internet in Tokyo, Dublin or Belmullet, the information will be the same and, in theory, the potential for communication unlimited by location*" (WDC, 2002; p.i).

Much of the rhetoric emanating from state agencies was espousing the spatial uniformity of development in the Information Age. Official policy has been to position Ireland as an ICT/e-commerce hub with the telecommunications infrastructure to compete for foreign direct investment (FDI). Despite this, the latest OECD figures have ranked Ireland in 24th position of 30 countries in terms of broadband access and availability (OECD, 2006).

The reality is that Ireland's technology infrastructure is negatively affecting its competitiveness internationally while also compounding the spatial imbalance nationally. The deficient state of broadband rollout in Ireland, as with many other countries with a high percentage of rural dwellers, is due to the failure of the market. The Western Development Commission pre-empted the failure of the market in their report:

> "*If free market principles determine rollout, then much of the Western region will have extremely limited provision and capacity*" (WDC, 2002, p.114).

A survey completed by the regional authorities in Ireland shows clear evidence of an east-west divide. The less favoured Irish regions of the Border and Midlands see their access to broadband as 'less than satisfactory' and as a result more excluded from the Information Age than their counterparts in the east. A small technology company voices their dismay with the state of broadband in the Midlands region:

> "*It's farcical really, we are meant to be living in the post-liberalisation age, where competition is rife to the stage that it benefits the consumer. Well not here, here your options are nearly as limited as they were under Telecom Eireann* [incumbent]" (Interview, indigenous software company, Athlone, December 2002).

There is recognition on the part of policy makers that lack of provision is adding to regional woes. The most recent document on spatial development in Ireland the national spatial strategy (Department of the Environment, 2005) has placed increasing emphasis on the roll-out of broadband to counteract the spatial imbalance. Yet, the reality shows that new technologies and with their space conquering features have yet to prove the panacea theorised by the Western Development Commission (2002). The idyll that a company can set up in a remote region and have equal access to information is contrasted with the reality that the new space of the information age has become reconstituted within spaces/regions of exclusion. Ireland's less favoured regions remain excluded and denied equal access, both in terms of basic infrastructure and in terms of the cost of employing that infrastructure to access information (see Collins, 2007).

3 Research Methodology

The empirical part of this paper is based on a survey of Irish SMEs and has two primary aims. First, we want to ascertain the level of corporate broadband adoption throughout Ireland at the time of the survey and construct some regionally differentiated measures of competition in the ISP market. Second, we want to identify some of the determinants of broadband takeup and in particular, establish whether regional variation in ISP competition is conditioning the likelihood of adoption.

To begin with, we use the supplied survey data to construct quantitative variables. We then perform simple cross-tabulations of broadband adopters by company size, industry and geographic location. Following this, we present our measures of supply-side competition (and their rationale) and construct quantitative estimates on the basis of the survey data.

On attempting to establish whether our competition measures are associated with the likelihood of adoption we employ econometric modelling. We use a qualitative econometric estimation technique (logit) that is well suited to the analysis of survey-type data. We commence this exercise by performing exploratory bivariate correlations (Pearson's R) between plausible determinants and a broadband adoption dummy. We then estimate a logit model of broadband adoption. As a last step, we perform a cautious interpretation of the estimated model coefficients in an attempt to gauge the relative importance of each of the identified determinants.

4 The Data

4.1 Description

Empirical analysis is based on the *Business Telecommunications Survey*, carried out by Millward Brown IMS on behalf of ComReg. The survey aimed to "*gain an insight into the attitudes and perceptions of the business sector towards fixed, mobile and internet services offered in Ireland*" (ComReg, 2005a:2). Telephone interviews took place in May-June 2005 on a sample of 550 companies throughout Ireland. Those interviewed had responsibility for purchasing decisions in relation to telecommunication and IT services (typically a company manager, IT manager or IT procurement officer). The sample was designed to be nationally representative; quota controls were set for company size and industrial sector (ComReg, 2005b).

The survey was rather broad in its scope, looking at usage patterns for a range of communication technologies (including fixed-line telephony, mobile telephony and internet access). In line with our objectives, we focused our attention on variables concerning Internet usage, as well as those describing the characteristics of participating companies. The variables were coded on the basis of the survey as follows. In terms of Internet usage, the variable *broadb* records information on the company's Internet connection type. It takes a value of 1 for either DSL, Cable, FWA, Leased line or Satellite and a value of 0 for other Internet connections (PSTN, ISDN) or no Internet connection. Additionally, an indicator dummy for "high intensity usage of IT" was constructed (*hint*). It takes a value of 1 if the company uses one or more of the following information technologies: Personal Digital Assistants (PDAs), Wireless Local Area Network (WLAN), Global Positioning System (GPS), General Packet Radio Service (GPRS), Instant Messaging, Voice over Internet Protocol (VOIP Internet telephony); and 0 if they are not used. A Likert-type scaled variable indicating the perceived importance of the Internet to the company's business activities is also included (*intern_r*), taking values in the range from 1 (not important) to 4 (highly important). Moreover, *remote_d*, a dummy indicating usage of remote desktop applications and/or teleworking is an additional proxy of demand. On the supply side, we calculated three proxies of competition in the ISP market (*hfindex*, *eqsize* and *suppno* outlined in section 4.2). Lastly, the survey recorded information on company size (*fsize*), industrial sector (*sector*) and geographic location (*region*). The variables used in the study along with a brief description of their contents are summarised in table 1.

Table 1: Variables used in the study

Variable name	**Brief Description**
broadb	broadband dummy (=1 adopter,=0 non-adopter)
hint	high intensity usage of IT (=1 used, =0 not used)
intern_r	importance of internet to business (=1 low,=4 high)
remote_d	remote desktop / teleworking, (=1 used, =0 not used)
hfindex	Herfindahl Index (HI) value for regional ISP market
eqsize	10 000/hfindex (number of equally sized firms)
suppno	number of suppliers active in the region
fsize	number of employees
sector	industrial sector (as per table 4)
region	geographic location (as per table 3)

Inevitably, adjusting the data to the objectives of our study meant that the initial sample size of 550 was reduced. In order to conform with the widely accepted definition of SMEs (CEC, 1996), we have excluded responses from public sector establishments and companies with more than 250 employees. The result was a narrowed down sample of 511 SMEs. Additionally, as is common with questionnaire-based surveys, the data suffers from a form of censoring; some respondents did not provide an answer for all the variables of interest. In our analysis we have only included those observations for which data on all of the variables of interest was complete. So, this left 390 observations for which full information was available. Tables 2, 3 and 4 present the adoption patterns prevalent in the sample according to company size, their location and their industrial sector.

Table 2: Broadband adoption by size (size group intervals as per CEC, 1996)

Size Group	**Adopters**	**Adopters**	**Sample**
(number of workers)	*(out of size group total)*	*(%)*	*(%)*
1-10	93/203	45	52
11-20	38/61	62	16
21-50	38/57	67	15
51-100	44/58	76	15
101-250	9/11	82	3
Total	222/390	57	100

Table 2 hints at a sample dominated by smaller companies (68 per cent are companies with fewer than 20 workers). It is also clear from table 2 that takeup rates increase with firm size. On the lower end, among micro-companies (1-10 workers) only 45 per cent were using some form of broadband. This contrasts to a 76 and 82 per cent adoption rate in the last two size groups (51-100 workers and 101-250 workers respectively).

Table 3: Broadband adoption by geographic location

Location	**Adopters**	**Adopters**	**Sample**
(city or province)	*(out of region total)*	*(%)*	*(%)*
Dublin	92/130	71	33
Rest of Leinster	45/92	49	24
Cork	17/21	81	5
Waterford	5/13	38	3
Limerick	3/9	33	2
Rest of Munster	26/54	48	14
Galway	9/13	69	3
Rest of Connaught	15/35	43	9
Rest of Ulster	10/23	57	6
Total	222/390	57	100

Table 3 indicates that just over half (57 per cent) of surveyed companies were based either in Dublin or the wider province of Leinster. There are also some indications of an urban/rural divide, with the cities of Dublin, Cork and Galway demonstrating higher takeup rates than their respective wider provinces. However this is not the case for Waterford and Limerick, though this may be due to the small number of observations in these cities.

Table 4: Broadband adoption by sector

Sector	**Adopters**	**Adopters**	**Sample**
	(out of sector total)	*(%)*	*(%)*
Agriculture	2/9	22	2
Mining	21/35	60	9
Manufacturing	26/51	51	13
Transport	11/20	55	5
Utilities	2/3	67	1
Wholesale Trade	26/46	57	12
Retail Trade	23/51	45	13
Hotels and Restaurants	21/47	45	12
Finance	17/22	77	6
Services	73/106	69	27
Total	222/390	57	100

Finally, table 4 shows that companies in Finance and Services exhibited the highest take up rates (77 and 69 per cent respectively), hinting at the strong demand-side considerations prevalent in those sectors. Companies operating in Agriculture and Retail Trade and Hotels and Restaurants were primarily non-adopters.

4.2 Estimates of geographically differentiated competition in the Irish broadband market

The term "competition" is open to multiple interpretations. We choose to think of competition here as *the action of competing for resources under equitable circumstances*, a view of competition that is closer to the (intuitive) lexical sense of the term (Shepherd, 1990), rather than the more abstract definition favoured by some economists for its neutral normative stance (e.g. see Shy, 1995).

We entertain the scenario that the intensity of competition in the broadband supply market is a key determinant of take up. We identify three main mechanisms linking supply-side competition with the likelihood of technological adoption:

(i) *Through competitive price-setting*; the rationale here is that price competition reduces profit margins to a level that approximates efficiency.

(ii) *By way of service differentiation*; the presence of competitive actors may favour the introduction of heterogeneous services (e.g. delivery platforms) to cater for a wider spectrum of preferences.

(iii) *By way of information diffusion*; competitive ISPs labour to increase their relative market shares by way of marketing, thus collectively diffusing information about the qualities of the technology and furthering the overall market's scope.

The intensity of competition cannot of course be observed directly; instead, under certain conditions, the structure of the market ISPs operate in can provide us with indirect evidence of competitive activity. In that respect, descriptive statistics of market structure such as the number of suppliers active within a given market and the relative market shares they command are commonly employed as indicators of the extent to which a market is competitive (Shepherd, 1990; Shy, 1995; Jacobson and Weymes, 2003; Distaso et al. 2006).

We acknowledge that the presence of many suppliers with respectable market shares does not guarantee that "competition" is taking place. It is conceivable that, among other things, collusion among suppliers may suspend competitive behaviour. However, in the given context we have no reason to believe that this may be the case; arguably the combination of a large number of ISPs (many of which are new entrants) and the high growth potential of the broadband market render the possibility of collusive practices remote.

Furthermore, in the case we examine here, suppliers set prices at the national level. So, regionally differentiated competition should not have a direct impact on price setting. At the same time though, due to technological limitations and unequal access to infrastructure, geographic location *does* constrain the range of products ISPs can avail to customers (in terms of delivery platform, speed, contention ratio, latency etc.) and by extension, imply variability in the overall access cost. As such, it is reasonable to expect that the number of regionally active ISPs may be a predictor of the range of available products. Additionally, since not all ISPs operate in every region, the impetus for marketing is also differentiated regionally. Hence, the number of ISPs and their relative market shares may also be thought as proxies of marketing intensity. Therefore, within the confines of our empirical study, supply-side competition is a plausible determinant of the adoption of broadband through mechanisms (ii) and (iii).

With the above considerations in mind, we employ three descriptive measures of market structure as our competition proxies:

(a) The number of ISPs that are active in every region, as evidenced by the survey. An ISP must have at least one customer to qualify as active in that region.

(b) The Herfindahl concentration index, defined as the sum of the squares of each ISP's percentile market share in every regional market. More specifically, a Herfindahl Index (HI) value may be calculated as: HI $= \sum_i^n (s_i^2)$ where s_i is the percentile market share of ISP i in the regional market, and n is the number of ISPs. Thus defined, HI can range from 0 to 10 000 with higher values implying a more concentrated market.

(c) The number of equally sized ISPs that would generate the estimated HI. Calculated as the the inverse of HI, i.e. 10 000/HI .

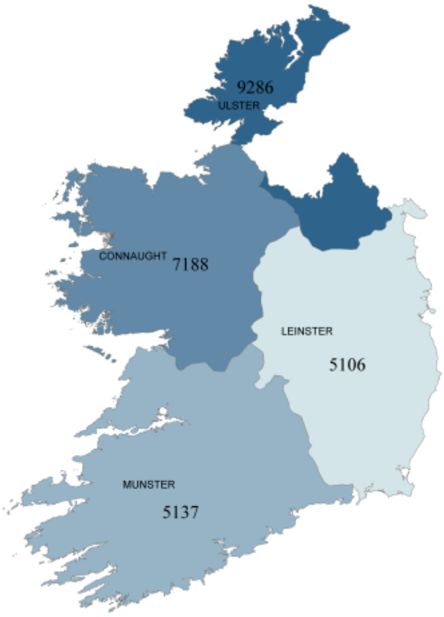
A couple of provisos are in order at this point. The first measure infers the supply of service ex post thus ensuring that no ISP is counted which has not offered its services in a given region . This is at the possible expense of underestimating the true number of suppliers active in that region, as its value is censored to those firms that participated in the survey. It is also worth noting that the second and third measures do not differ in substance. The distinction here is justified in conceptual grounds, as an aid to interpretation. Table 5 presents estimates of the three measures for each of the regional classifications included in the survey, while figures 3 and 4 present the spatial arrangement of regional ISP markets and their respective HI values.

Table 5: ISP competition measures per region

Region	ISPs	Herfindahl Index	Equally Sized ISPs
Dublin	15	3901.294	2.563
Rest of Leinster	13	5106.871	1.958
Cork	5	5833.333	1.714
Waterford	4	5833.333	1.714
Limerick	4	4200	2.381
Rest of Munster	9	5137.314	1.946
Galway	4	4861.111	2.057
Rest of Connaught	4	7188.365	1.391
Rest of Ulster	2	9286.694	1.076

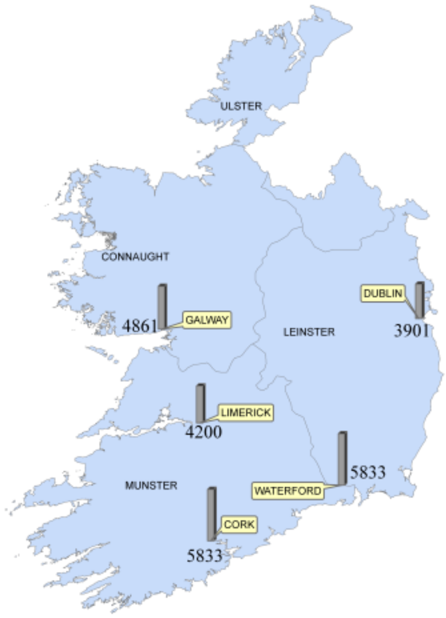
Source: Authors' Calculations, based on ComReg Data

Figure 3: Herfindahl Index values by province (excluding major cities)



Source: Authors' Calculations, based on ComReg Data

Figure 4: Herfindahl Index values by city



Source: Authors' Calculations, based on ComReg Data

Calculations indicate a sharp contrast between the centre (Dublin) and the periphery. Dublin, Limerick and Galway possess less concentrated markets than their respective provinces, while the opposite is true for Cork and Waterford. Interestingly though the city/rural divide does not persist in all of Ireland's regions; more ISPs are operating in the Rest of Munster than in either Cork, Waterford or Limerick. This particular observation could be explained by the presence of intense inter-platform competition in the area. Lastly, reflected in all three measures is a wide competitive divide between the most concentrated region (Rest of Ulster) and the least concentrated one (Dublin).

5 Econometric Modeling

5.1 Hypotheses

Numerous contributions in the area of technology diffusion postulate that the individual choice of adoption versus non-adoption is a function of each company's characteristics (for an overview see Geroski, 1999; also Karshenas and Stoneman, 1995). The idea is that firm characteristics such as *firm size* and *industrial sector* can act as reliable proxies for a number of known determinants of adoption, including the availability of finance, the technological intensity of their operations, the worker's skills content, opportunity costs, attitudes towards risk and exposure to technological marketing. Therefore, we expect firm size (*fsize*) to exert a positive influence on the probability of adoption. Moreover, the specific industrial sector (*sector*) a SME operates in may exert either a positive or negative influence, depending on the requirements it imposes on information (Forman et al., 2005).

An alternate approach, most notably represented by the work of Rogers (1983), involves measuring determinants of adoption directly by way of perceptions. Perceptions of the candidate technology's overall *relative advantage* have often been found to explain variation in adoption trends. While such an approach to measuring demand has obvious disadvantages (non-uniformity of perceptual ranking and hence near-meaningless marginal effects), in the absence of better measures, it is still a useful control variable. The ComReg survey included a question on the importance of the Internet to the company's operations (*intern_r*). We expect a positive relationship between perceptions of the relevance of the Internet and the likelihood of adoption. With regards to proxies of demand, the various Internet applications that broadband facilitates are also viable candidates (*hint, remote_d*). Finally with respect to the various competition measures, we expect indications of concentration in the ISP market (*hfindex*) to be negatively associated with adoption; likewise, the greater the number of ISPs (*suppno*) or the number of equally sized ISPs (*eqsize*), the greater the likelihood of adoption. Table 6 summarises the expected signs suggested by the above hypotheses.

Table 6: Variable signs suggested by hypotheses

Variable name	**Expected sign**
fsize	+
sector	+/-
intern_r	+
hint	+
remote_d	+
hfindex	-
suppno	+
eqsize	+

5.2 Modeling the Decision to Adopt

We assume the adoption (or non-adoption) state the firms are in at the time of the survey to be the result of a rational decision process. Company managers and IT procurement officers weigh the benefits of broadband against its costs and take a rational decision regarding adoption. While in reality decision makers are presented with a multitude of options (regarding platform, provider, specific product etc), here we narrow down the set of options to just two: adoption or non-adoption. Additionally, given the limitations of the data, a further two assumptions are implicit in our modelling exercise. Specifically we assume that:

(i) All participating companies could get access to at least one broadband connection platform (DSL/Cable/FWA/Leased Line/Satellite) had they wished to;

(ii) The offerings of different ISPs (and their respective connection platforms) are perfect substitutes.

While these assumptions should be kept in mind, we believe that they need not be restrictive. Given the multitude of technology platforms on offer, the possibility of universal availability is not remote. And since this study considers broadband in its entirety, it is reasonable, in the interest of tractability, to consider it as one homogeneous product. Granted, in practice, only few viable alternatives may be on offer; arguably though this variation is captured, in part, by our ex post supply-side proxies (*suppno*, *eqsize*, *hfindex*).

If we assume the variables in table 1 to represent supply- and demand-side determinants of adoption, then it should be possible to construct a simple explanatory model of company behaviour. Econometric estimation by means of a logit model is well suited to the study of technology adoption. As a qualitative model it is appropriate for the examination of dichotomous decisions. Importantly, unlike similar models (e.g. probit), its logarithmic structure yields broadly understood odd ratios of the marginal effects of a unit's increase in each independent variable on the probability of adoption. As such the bivariate logit approach has been popular with cross-section (equilibrium) studies of diffusion (e.g. see Sadowski et al., 2002).

We may now consider the decision to adopt (Y_i) as a binary dependent variable whereby the independent variables (determinants of adoption) are subject to ranking (0,1,2,3...). $Y_i$is modeled against a set of independent explanatory variables collectively referred to as X_i. $Y_i$can take the values of either 0 (indicating non-adoption) or 1 (indicating adoption). Hence, the probability distribution function of a company's decision to adopt will be:

$$P_i = \frac{1}{1+e^{-Xi}} = \frac{e^{Xi}}{1+e^{Xi}} \quad (1)$$

(1) indicates the non-linear relationship between X_i and Y_i. One can now consider the following regression model:

$$Y_i = \beta_1 + \beta_2 X_{2i} + ... \beta_k X_{ki} + u_i \quad (2)$$

It is therefore assumed that for each company i the decision to adopt (Y_i) is dependent on the values of k regressors $X_{2i}...X_{ki}$, plus a disturbance term u_i.

5.3 Estimation

Theory and prior experience must inform the composition of X_i. Prior to commencing econometric estimation we calculated bivariate correlation coefficients (Pearson's r) between plausible determinants and our adoption dummy, thus charting the way towards viable candidates (reported in Appendix C). A first full run of the model with sector-fixed effects showed all the substantive variables to be statistically significant. We attempted three such saturated specifications (reported in Appendix A), each time substituting the various (mutually exclusive) competition proxies (*hfindex*, *suppno*, *eqsize*); all three measures were shown to be (individually) statistically significant and with the expected signs. In the end our competition proxy of choice was *eqsize*, as we felt it is conceptually easier to understand than *hfindex* (thus aiding interpretation) while being richer in information content than *suppno*. This initial specification was subsequently narrowed down to a parsimonious model excluding statistically insignificant sector-fixed effects, yielding:

$$broadb = \beta_1 + \beta_2 fsize + \beta_3 eqsize + \beta_4 hint + \beta_5 remote\_d + \beta_6 intern\_r + \beta_7 sector9 + \beta_8 sector10 + u_i \quad (3)$$

The results of estimation are presented in table 7.

Table 7: Logit Model of Broadband Adoption (dependent *broadb*, n=390)

Independent Variable	**Coefficient**	**Standard Error**	**Odds Ratio**
fsize	0.0113073***	0.0042515	1.011371
eqsize	0.6968873***	0.256402	2.007494
hint	0.9375223***	0.2664809	2.553646
remote_d	0.5262245***	0.2904363	1.69253
intern_r	0.3518242***	0.1191639	1.421659
sector9	1.390135**	0.5565675	4.015394
sector10	0.7020409***	0.2677787	2.017867
constant	-3.532553***	0.7492032	

(*, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels respectively)

The parsimonious specification presented here explains a substantial degree of variation in the data, as evidenced by the Count R-squared value of 0.70; the conventional goodness-of-fit measure for logit models also indicates a good fit (McFadden R-squared=0.1488). The likelihood ratio test, a conventional test of the hypothesis that $\beta_1=\beta_2=... \beta_k= 0$, indicates that the independent variables are jointly statistically significant (p=0.000). There is no evidence of strong bivariate correlations among the regressors (see Appendix).

Since our supply-side proxy (*eqsize*) has been constructed using highly heterogeneous geographical units (cities/provinces) our estimates here may potentially suffer from the *"modifiable areal unit problem"* (MAUP) [10]. One usually applied check is to dissaggregate the offending variables to different geographical units and perform sensitivity analysis. However in the present case, such an approach is not feasible, given the the lack of fine geographic detail in the ComReg data. Instead, we perform a rather crude robustness check of our estimates by including proxies of a geographic unit's size (variables *area_km*: surface in square kilometers and *population*: headcount, both from CSO (2002)) in two separate specifications reported in Appendix A (Table 11)). These additional specifications confirm that, after controlling for scale effects[11], all the substantive variables are statistically significant and demonstrate the same qualitative relationships with the dependent. Therefore, the interpretation that follows is based on the parsimonious specification (3).

To begin with, the coefficients have no straightforward interpretation other than with regards to their sign: specification (3) indicates that all included regressors exert a positive influence on the likelihood of adoption. A measure of the relative weight of the variables can be obtained by exponentiating the obtained coefficients (e^{β}). The exponentiated coefficients can then be interpreted as the odds of adoption, for a marginal increase in each of the regressors, ceteris paribus. The odd ratios for a marginal change in each of the regressors are

[10] A problem which may occur when variables that are linked to unequally sized and shaped geographical units are treated as continuous (for a detailed exposition see Openshaw, 1984).

[11] While we control for *scale effects* (i.e. the substantial size difference between city/province) we are unable to test the sensitivity of our results with respect to different geographical delimitations (shape effects).

also presented in table 7. What follows is an interpretation of their individual marginal effects (holding other regressors constant) in the order suggested by the model. A proviso is in order at this point; given the overall small number of observations, one ought to avoid placing too much emphasis on the precise values of estimated odd ratios. Therefore, the *magnitude* of the probabilistic relationships quoted thereafter should be viewed as indicative of relative weights.

Sector fixed effects and demand proxies appear to be significant explanatory factors, as reflected in the magnitude of their marginal effects. Our estimates suggest that a company operating in the financial sector (*sector9*) is about 4 times more likely to have broadband, while a services company (*sector10*) is about 2 times more likely to have broadband. Using one or more bandwidth intensive Internet applications (*hint*) increased the likelihood of adoption by a factor of 2.5. Increased perception of the importance of the Internet (*intern_r*) also had a positive effect on the likelihood adoption, though due to the nature of the variable, its marginal effects have no straightforward interpretation. Usage of remote desktop or teleworking applications made a company about 1.7 times more likely to adopt.

Our findings suggest that there is a strong negative association between regional market concentration and the probability of adoption. Interpeted mechanistically, the addition of another equally sized ISP (*eqsize*) in one of Ireland's regional broadband markets would make a SME situated there twice as likely to takeup broadband. However, given that an ISPs decision to enter a regional market is almost certainly conditioned by manifested levels of demand (i.e. demand and supply are determined *simultaneously*) we are unable to say what the precise direction of causality is.

In making more general inferences, additional caution is warranted given the small number of observations dedicated to each geographic unit; though many of these geographic units are large enough to contain thousands of SMEs the survey only samples a few dozen companies within each one. In addition, our study is limited to the level of geographic aggregation selected at the survey and is oblivious of variation *within* these rather sizeable geographic units. Therefore, results with regards to regional variation should be seen as holding true primarily to our sample, and any population inferences on the basis of these results are tentative. Having said that, we have no reason to believe that our sample is biased either, so it remains likely that the observed relationships do hold more broadly. Further research is needed to clarify this.

Finally, controlling statistically for other factors, the addition of another worker (*fsize*) increases the likelihood of adoption just 1.01 times. This last finding is consistent with other work on the determinants of technology adoption (Geroski, 1995; Stoneman, 2001). As we control for various demand proxies, it is likely that *fsize* here captures other residual effects that correlate well with size, such as the company's ability to finance the implementation of broadband, which is not constrained to connection and line rental costs but also includes a baggage of associated infrastructure and training expenses.

6 Conclusions

In this paper we have tried to shed some light on the determinants of corporate broadband adoption in Ireland, and its considerable geographic variation in particular.

Though our study is based on small-scale survey at one point in time that does not allow firm inferences, there are good indications that the broadband market in Ireland is regionally fragmented. We have hopefully highlighted here that Ireland's "digital divide" is not defined solely by a dichotomous availability dimension, but rather comes in a variety of shades. Our analysis indicates that competition in the Irish ISP market is differentiated regionally and that, controlling statistically for other factors, regionally differentiated competition is associated with the likelihood of broadband adoption.

If the level of regional market concentration is indeed conditioning the likelihood of broadband adoption then reductions in market concentration may encourage the takeup of broadband in Ireland's regions. While our quantitative analysis cannot shed light on the direction of causality, when one takes into account the range of competition-related grievances raised in numerous benchmarking exercises (Forfás, 2005: 13-14), the general picture becomes highly suggestive.

Reducing the amount of concentration can be achieved by forging ahead with the (currently stalled) LLU process and promoting inter-platform competition. Worryingly, Distaso et al. (2006) present evidence which suggests that inter-platform concentration in Ireland actually increased in the 2000-2004 period. A growing number of voices support the view that universal service access hinges to a great extent on continuing regulatory intervention (Rickford, 1998; Bar et al., 2000). Irish policy makers too appear to be converging towards this view as highlighted by the proposed plans to give ComReg concurrent competition law powers (DCMNR, 2006b).

At the same time, regulatory policy should be mindful of the implicit trade-off between equity and efficiency. On the one hand the physical obstacles imposed by geography can only be overcome by way of substantial infrastructure investment which few single providers are in a position to deliver. On the other hand, increased competition may facilitate broadband takeup by increasing the amount of choice and helping diffuse information. If investment cannot be dependent on government funding, incentives should be in place to encourage private initiative, while ensuring that competition is upheld.

In that respect, market structure statistics are important quantitative benchmarks of the supply-side at the *regional level*, a part of the broadband market that is not easy to gauge in a systematic manner. The value of geographically-differentiated market structure statistics for policy is not ephemeral but is bound to increase further as the market matures and approaches saturation. Moreover, although we have based our measures on the regional market shares of ISPs, such stastistics do not have to be based on such. Concentration indices based on the market shares of alternative technological platforms (e.g. DSL, Cable, FWA etc) or other specific broadband products (e.g. specific connection speeds and added-value services) might also do a good job at highlighting regional supply bottlenecks. In the case of Ireland such indicators could be constructed with relative ease using data from ComReg's regular survey or even the Central Statistics Office's (CSO) "e-Commerce Enterprise Survey".

More generally, regional concentration indices (and their variations) could provide valuable supply-side benchmarks for other types of telecommunications technologies, especially those that require considerable regional capital investment.

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Appendices

A Alternative Logit Models

Table 8: Saturated Logit Model 1 (dependent *broadb*, n=390)

Variable	**Coefficient**	**Standard Error**	**Odds Ratio**
fsize	0.0119753***	0.004372	1.012047
eqsize	0.7568823***	0.2608757	2.13162
hint	0.8623832***	0.2728697	2.368799
remote_d	0.5296409*	0.2941731	1.698322
intern_r	0.377968***	0.1207286	1.459316
sector1	(reference)		
sector2	1.755249*	0.9433605	5.784889
sector3	1.099222	0.9195224	3.001829
sector4	1.588219	0.9932119	4.895021
sector5	1.089268	1.617669	2.972099
sector6	1.56865*	0.9245429	4.800164
sector7	1.231066	0.9174513	3.424878
sector8	1.065053	0.9223293	2.900992
sector9	2.684117***	1.0211	14.64526
sector10	1.996679**	0.8977154	7.364555
constant	-5.0507***	1.184885	

(*, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels respectively)

Table 9: Saturated Logit Model 2 (dependent *broadb*, n=390)

Variable	Coefficient	Standard Error	Odds Ratio
fsize	0.0120895***	0.0044366	1.012163
hfindex	-0.0002182***	0.0000823	0.9997818
hint	0.8590385***	0.6439604	2.360889
remote_d	0.5379607**	0.5029939	1.712511
intern_r	0.3863966**	0.1775298	1.471668
sector1	(reference)		
sector2	1.743308**	5.350536	5.716224
sector3	1.082393	2.691478	2.951734
sector4	1.540992	4.593651	4.669221
sector5	1.11703	4.874154	3.055766
sector6	1.581629*	4.4614	4.862872
sector7	1.238226	3.138606	3.449488
sector8	1.050031	2.613255	2.857739
sector9	2.715693***	15.33846	15.11508
sector10	1.987124**	6.49182	7.294525
constant	-2.407144**	1.079155	

(*, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels respectively)

Table 10: Saturated Logit Model 3 (dependent *broadb*, n=390)

Variable	Coefficient	Standard Error	Odds Ratio
fsize	0.0121875***	0.0044189	1.012262
suppno	0.0620051**	0.261559	1.063968
hint	0.8561757***	0.6405573	2.35414
remote_d	0.5564539***	0.5116128	1.744475
intern_r	0.3939239***	0.1793828	1.482788
sector1	(reference)		
sector2	1.731579*	5.280889	5.649566
sector3	1.09791	2.730555	2.997893
sector4	1.608617	4.926829	4.995898
sector5	1.324863	6.221574	3.761668
sector6	1.561801*	4.364422	4.767397
sector7	1.200462	3.015477	3.321651
sector8	1.122655	2.805594	3.073004
sector9	2.698532***	15.04977	14.8579
sector10	2.009259***	6.627327	7.457786
constant	-4.232927***	1.075237	

(*, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels respectively)

Table 11: Controlling for geographic scale (dependent *broadb*, n=390)

Variable	Coefficient	S. E.	Coefficient	S. E.
fsize	0.0111764***	0.0042248	.0110953***	0.004231
eqsize	0.4985254**	0.2904701	0.7005371***	0.2561751
area_km	-.00000184	0.0000129		
population			-1.73e-07	2.10e-07
hint	0.9639351***	0.2674858	0.9475069***	0.2669866
remote_d	0.4933717**	0.2910692	0.5120517**	0.2903944
intern_r	0.3283033**	0.1203854	0.3398287***	0.1200898
sector9	1.379351**	0.5576801	1.365724**	0.5556228
sector10	0.6792947**	0.2686866	0.6978044***	0.2681838
constant	-2.827698***	0.8904248	-3.354872***	0.7777253

(*, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels respectively)

B Descriptive Statistics

Table 12: Descriptive Statistics, ComReg Survey May-June 2005

Variable	n	Mean	Std. Dev.	Min.	Max.
broadb	398	0.5628141	0.496663	0	1
fsize	511	22.42661	34.58763	1	250
eqsize	510	2.028827	0.4322107	1.076809	2.563252
suppno	510	10.26471	4.628277	2	15
hfindex	510	5207.133	1369.349	3901.295	9286.694
hint	511	0.2857143	0.4521966	0	1
remote_d	395	0.2734177	0.4462787	0	1
intern_a	392	4.183673	0.9579063	1	5
sector1	511	0.0234834	0.1515812	0	1
sector2	511	0.0900196	0.2864903	0	1
sector3	511	0.1174168	0.3222318	0	1
sector4	511	0.0450098	0.2075288	0	1
sector5	511	0.0058708	0.076471	0	1
sector6	511	0.1056751	0.3077226	0	1
sector7	511	0.1526419	0.3599944	0	1
sector8	511	0.1174168	0.3222318	0	1
sector9	511	0.0450098	0.2075288	0	1
sector10	511	0.297456	0.4575868	0	1
area_km	510	10900.14	10235.67	20.35	24505.98
population	510	755033.5	549919.1	44594	1609798

C Correlation Matrix

Pearson's Bivariate Correlations

	broadb	*fsize*	*eqsize*	*suppno*	*hfindex*	*hint*	*remote_d*	*intern_a*	*sector1*	*sector2*	*sector3*
broadb	1										
fsize	0.2069	1									
eqsize	0.1753	0.0319	1								
suppno	0.1316	-0.0129	0.828	1							
hfindex	-0.1535	-0.0244	-0.957	-0.8061	1						
hint	0.283	0.1898	0.0978	0.0807	-0.0967	1					
remote_d	0.2288	0.223	0.1153	0.0734	-0.1116	0.3791	1				
intern_a	0.1977	0.0457	0.0259	-0.0363	0.0081	0.1695	0.1245	1			
sector1	-0.1077	-0.0617	0.0073	0.0264	-0.0171	-0.0378	-0.0555	0.0421	1		
sector2	0.0195	-0.0475	-0.0407	-0.0089	0.0318	0.0788	-0.0507	-0.0503	-0.0483	1	
sector3	-0.0465	0.0641	0.0178	0.0254	-0.0321	0.0279	0.0537	0.0057	-0.0596	-0.1218	1
sector4	-0.009	-0.0529	-0.0331	-0.048	0.01	-0.0189	0.0147	0.0044	-0.0357	-0.073	-0.0902
sector5	0.0173	-0.0027	0.0687	0.0172	-0.06	0.0611	0.0781	0.0445	-0.0135	-0.0276	-0.0341
sector6	-0.003	-0.0869	-0.0546	-0.0411	0.08	0.0744	-0.009	0.0135	-0.0562	-0.1148	-0.1418
sector7	-0.0926	-0.0614	-0.0457	0.006	0.0632	-0.1167	-0.0489	-0.0023	-0.0596	-0.1218	-0.1504
sector8	-0.0915	0.0039	0.0391	-0.0095	-0.0566	-0.0983	-0.0845	0.0036	-0.0569	-0.1162	-0.1436
sector9	0.1005	-0.0213	0.0311	0.028	-0.0095	-0.034	-0.0495	0.0115	-0.0376	-0.0768	-0.0948
sector10	0.1474	0.1473	0.0426	0.0156	-0.0431	0.0624	0.1191	-0.0138	-0.0939	-0.1918	-0.237

	sector4	*sector5*	*sector6*	*sector7*	*sector8*	*sector9*	*sector10*
sector4	1						
sector5	-0.0205	1					
sector6	-0.085	-0.0322	1				
sector7	-0.0902	-0.0341	-0.1418	1			
sector8	-0.0861	-0.0326	-0.1354	-0.1436	1		
sector9	-0.0568	-0.0215	-0.0894	-0.0948	-0.0905	1	
sector10	-0.142	-0.0538	-0.2234	-0.237	-0.2261	-0.1494	1