Internet Access Demand in Europe:
An Econometric Study

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Abstract

This project presents an empirical study of Internet access demand in Europe. It considers more than 450000-pooled cross-European data for 1997, 1998 and 2000. The analysis includes attributes of the choice and the decision-maker. The logit model reveals that the dominant drivers of the demand are non-price factors. It appears that it is fuelled by qualitative access and usage externalities; the dynamics of information exchange and search. The marginal utility an individual derives from internet access interdepends both on the number (search) and the profile (exchange) of already-existing subscribers. The project concludes that the participation in the internet economy depends on human capital factors and the scarcity of access devices. Therefore, computing training has increased probabilities to widen access.

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PHASE I: INTRODUCTORY REMARKS

SECTION 1.1. INTRODUCTION

For this econometric study on internet access demand in Europe, the assumption of individual rationality is a widely accepted doctrine in economic theory. It asserts that individuals will demand internet access services if the marginal utility they derived from consumption is positive. The internet is an international network of computers that transmits and exchanges multi-data[1] (Cave and Mason, 2001). Its infrastructure, that is, backbone and intrastate networks[2] have been built by the National Science Foundation (NSF) since 1970, whereas after its privatisation in 1995 its maintenance was passed to a group of communication companies, referred to as internet service providers (ISP). The providers designed the service in such as way that internet can only be accessed through the world wide web[3] (WWW), where streams of data can be retrieved easily. In addition, this design makes it impossible for a user to consume the service in isolation. Economists will say that the utility of a new user interdepends on the number of already existing subscribers.

For the purpose of this project, we will look closely at internet access. However, it is also necessary to highlight on the difference between access and usage. Internet access refers to the subscription to the network, while usage refers to the consumption of online services; this means that access is a precondition for usage. Also, both services exist in various forms and intensities. For example, modem access and WAP access[4]; games and downloading of educational material. However, during 1997-2000, which is covered in this project, penetration rates for broadband connection types in Europe, like ADSL were negligible (Eurobarometer 53, 2000). Therefore, it is assumed that only the dial-up access exists.

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[1] The Transmission Control Protocol/Internet Protocol (TCP/IP) ensures interoperation between networks.
[2] Intrastate networks are within countries; Backbone networks are over-Atlantic networks.
[3] The Web is based on the Hypertext Transfer Transmission Protocol (HTTP).
[4] The Wireless Access Protocol (WAP) allows for satellite and mobile digital communications.

I will show a strong correlation between usage and access because of the rationale behind the utility interdependencies, resulting in relating factors called externalities. Externality, a broad concept in economic theory, refers to the benefits and costs gained by incumbent users of a network, when an additional individual joins it. Conceivably, if the benefit is higher than the cost, then the more users to communicate, the higher becomes the individual’s marginal willingness to pay for Internet access and vice versa. Therefore, to assure that Internet exhibits positive externalities, greater understanding of the mechanics of the Internet is necessary; not only from a technical, but also from an empirical socio-economic perspective. It is for this reason that I would employ econometric techniques in modelling the demand for internet access.

The theoretical framework used is the one of the telephone demand analysis adapted to the conventional behavioural theory of consumer choice and examined within a binary response probabilistic setting. This framework parallels the one that have been used in previous empirical studies. However, this study will move a stage further to link internet access demand to a wide range of socio-economic factors observed in pooled cross-European data. Taylor, Rappoport and Kridel (1999) analysed US data for 1996 and 1997[5]. Moreover, Norris (2001) examined from a political perspective EU data for 1996 and 1999, while Cracknell, Majumdar and Patel (2002) studied Internet demand in the UK. Some other studies analysed Internet growth in terms of hosts (Hargittai, 1999). Bauer, Berne and Maitland (2002) regressed internet hosts on pooled OECD datasets.

SECTION 1.2. EMPIRICAL EVIDENCE

There is evidence in favour of increased popularity of the Internet and consequently the demand for access. Network economics suggest that the reason for this lies

[5] According to the authors, it was the first analysis on the topic.

primarily on the positive network effect (Capello, 1994). It is thus interesting, to examine whether the demand for access is driven by price factors, as conventional economics argues, or by network externalities as economics of networks imply.

For the introductory stage it is important to observe the facts of internet growth (Commission, 1997-2000; OECD 1997-2000). It is estimated that 3 million worldwide internet users at 1995, outreached half billion by late 2002. Specifically, half the worldwide users in 1995 and a third in 2002 were situated in the US. Nevertheless, for 1995 the proportion of worldwide internet users in Europe was a quarter, while the gap between the Europe and the US is closing (Norris, 2002). By the end of 2002 the EU15 percentage of Internet users was more than 50% of the whole population. Note that in 1999 it was just 20%. Figure 1.1 depicts the diffusion of Internet at the EU15, the US and a composite Internet trend for more than 200 countries.

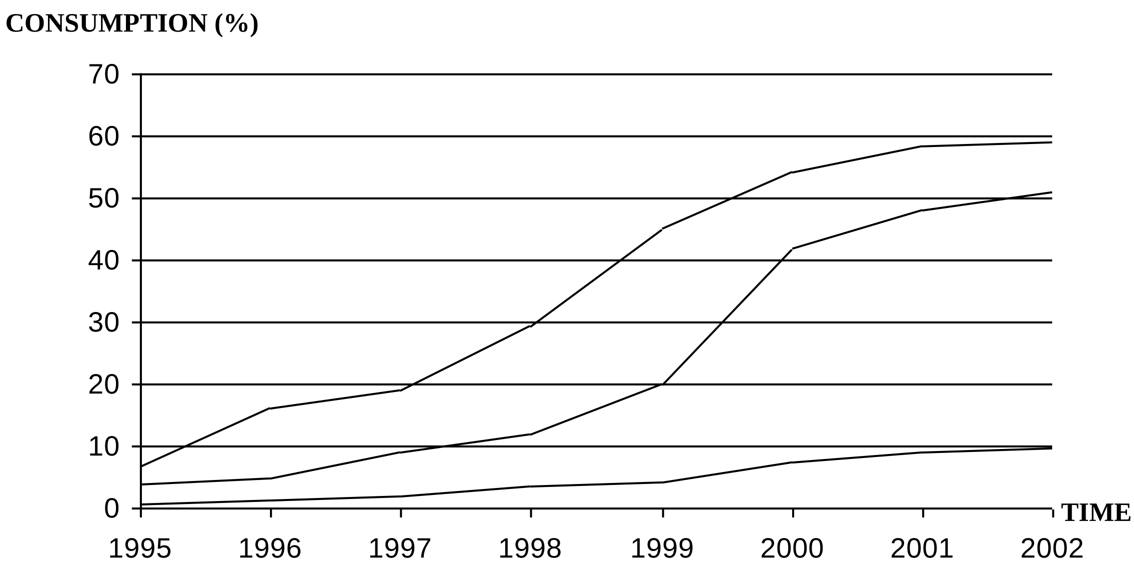

Figure 1.1. Consumption trends of internet access services
Sources: US: OECD; EU15: Eurobarometer; World: NUA.com

Table 1.1 reveals price trends and the size of the Internet across the EU15 countries[6]. During 1997 and 1998 price reductions are marginal, though some countries are experiencing increase in access prices. However, Finland is the only country where the price of access increased slightly from 1998 to 2000. Despite that host activities in Finland almost doubled. Portugal and Greece have increased slightly in host activities, though they remained as the two countries with the least activity in 2000. In addition, table I.1 and figure I.1 suggests that there is a strong positive correlation between consumption trends and hosts activities. The larger the size, the more people subscribe. This facilitates endogenous internet growth (McKnight and Bailey, 1997).

Table 1.1. Size of internet network and access prices

	1997		**1998**		**2000**		**Overall Change**	
	Hosts	**Price**	**Hosts**	**Price**	**Hosts**	**Price**	**Δ(Host)**	**Δ(Price)**
Austria	13.4	89.81	16.2	82.07	64.8	38.59	+51.4	-51.2
Belgium	8.6	52.02	15.1	72.15	59.2	43.80	+50.6	-8.2
Denmark	30.4	61.56	36.3	42.89	108.9	30.51	+78.5	-31.0
Finland	87.5	32.05	99.9	24.08	171	28.83	+83.5	-3.2
France	5.7	46.11	7.4	60.16	38.9	33.65	+33.2	-12.5
Germany	12.1	65.49	14.0	68.44	41.1	34.12	+29.0	-31.4
Greece	2.6	58.28	3.8	60.15	13	39.34	+10.4	-18.9
Ireland	10.8	67.71	12.6	65.37	50.5	42.53	+39.7	-25.2
Italy	4.2	46.56	5.6	38.96	37.3	29.30	+33.1	-17.3
Luxembourg	10.2	54.27	14.7	63.02	55.4	48.22	+45.2	-6.1
Netherlands	24.3	56.59	32.9	51.51	112.5	42.79	+88.2	-13.8
Portugal	4.0	76.66	4.6	53.66	16.7	46.57	+12.7	-30.1
Spain	4.3	51.01	6.1	42.09	30.1	36.93	+25.8	-14.1
Sweden	36.1	43.96	43.0	42.31	134.4	29.74	+98.3	-14.2
UK	17.0	54.47	20.5	58.09	72.9	33.68	+55.9	-20.8
EU	11.6	57.10	14.4	55.00	51.6	37.01	+40.0	-20.1

[6] Price is measured in USD PPP. It is the simple average of the peak and off-peak internet access baskets for 20 monthly hours. The network size is measured in hosts per 1000 people. A host denotes every computer that has internet connection. It is observed by recording the number of IP addresses which are unique for each host. This is the most accurate measure of Internet size. The OECD Communications Outlook estimates these statistics.

SECTION 1.1.3. PROJECT PLAN

The project is organised into five phases. The first Phase dealt with the introductory remarks above. Phase II reviews the perspective economic. Phase III and IV trace the empirical analysis. Phase IV is the conclusion.

The first section of Phase II reviews the microeconomic theoretical elements in modelling internet access demand. The second section considers the relevant econometric issues. Particularly, in the first part, the project discusses the cost and benefits of the internet. Then, it performs a behavioural analysis of internet adoption where the index model is derived. In the second part, a logit model of internet access demand is specified. After that, the project considers techniques of estimation and inference to justify the logit selection. The subsequent Phase III presents the methodology of the project and thus exposes the structure of the empirical analysis presented in phase IV.

The first section of Phase IV comments on the data and variables. The second section contains the estimation and discussion of the empirical models. Principally, the first part performs an evaluation of the data sources and discusses the selection of variables. The other part reports the coefficient estimates and remarks the policy implications arising from the analysis. Phase V is a conclusion analysed in two sections. The first summarises the conclusions of the project. The last suggests future research.

PHASE II: LITERATURE REVIEW

SECTION 2.1. MICROECONOMICS OF INTERNET ADOPTION

The advent of the Internet as a viable business and leisure tool is likely to have the same impact on firms and individuals as the spread of personal computers during the early 1980s (Wiseman, 2000). This literature will now discuss the cost benefit analysis of Internet access and its externalities. These are costs efficiencies, short-term costs and benefits of access and usage, effects and benefits of ISP strategies and the deterrence effect.

2.1.1. COST-BENEFIT ANALYSIS

For this project and like in any economic research, the main purpose of the cost benefit analysis is primarily to determine whether resources have been utilised in the most effective and cost efficient way. Thus, I will examine the costs and economic values of infringement. The purpose of measuring costs and economic values will be to demonstrate that resources are allocated efficiently and that activities undertaken by the various networks demonstrate best value for money. This means:

Costs efficiencies. From the microeconomics perspective, Internet minimises substantially the costs of communication and operation. Currently, electronic communications, like e-mail and e-commerce, have become common for firms and individuals. For instance, in 2000 70% of internet users are make use of email (Eurobarometer, 2000). Moreover, Internet reduces trading costs, increases price transparency and as a result online prices for commodities are less (Madden and Coble-Neal, 2000). The diversification of online services might also affect individual norms in labour supply, habit formation and even consumption choice. For example, in 2000 one internet user in four carries out bank operations and searching job opportunities.

Short-term costs and benefits of access and usage. From the macroeconomics perspective, Internet shrinks the physical distance between economic actors and stimulates perfect competition. What is more, Internet creates larger international markets for tradable goods and services, which might also reinforce the law of one price (Welfens, 2000). Indeed, the EU strategies, designed to reform the telecommunications sector in early 1990s, are currently progressing to foster the creation of an inclusive and dynamic online economy (e-Europe 2002, 2000).

Effects and benefits of ISP strategies. Associated with the apparent low cost of advertising and marketing a product on the web and the existence of lots of buyers and sellers, it can be argued that the internet economy can be developed in the future into a thick market. However, a big burden of the trade cost is passed on to the consumer; it is he/she who buys the computer, modem and internet connection.

The deterrence effect. Primarily, an individual is refrained from using the internet due to congestion. Congestion is a negative externality that causes service degradation and infrastructure downturns, such as increases in waiting time or failures of implementing an online service. Equally important are the security problems with online payments. For instance, in spite of the many benefits associated with e-commerce, only 1% of overall sales in the US and 0.5% in the EU accounts for e-commerce (Litan and Rivlin, 2001).

2.1.2. THE RANDOM UTILITY APPROACH

In that part I develop and analyse models of binary stochastic choice, generated by optimisation of random expected utility functions.

Lemma 2.1.2. Assume there exists a randomly selected sample of individuals $\{i = 1, ..., N\} \subseteq \Omega$. Additionally some common characteristics s of the individuals (decision-makers) are observed and some γ are not[7]. Assume further that individuals

[7] For instance, computing aptitude, experience and intelligence.

are rational and face the exogenously specified set of binary choice $B=\{y_j\}$ indexed by $J=\{j: j=0,1,\ 1=\text{"Internet Access"},\ 0=\text{"No Internet Access"}\}$. The choice in B has measured attributes ψ. Let $U^j(\psi, s_i, \gamma_i)$ denote the level of utility derived from the two choice. also Then, the adoption of internet service by individual i is determined by random utility maximisation (RUM). That is,

$$j = \arg\max_{j=\{0,1\}} \left\{ U^1(\psi, s_i, \gamma_i), U^0(\psi, s_i, \gamma_i) \right\}$$

Since the vector γ is random, the values of the utility function will be stochastic. Let treat γ as an explicit argument. In that instance,

$$U^j(\psi, s_i),\ j=\{0,1\}\ \text{ and }\ i=1,...,N \quad (0.1)$$

is now defined as an intra-individual stochastic utility function whose value at any argument is a random variable depending on exactly which individual i is drawn from the cross-section (Domencich and McFadden, 1975; Train, 1986). Then, by lemma 2.1.2 access is feasible, if this is the choice that maximises the utility of individual i constrained by B. Hence,

$$U^1(\psi, s_i) > U^0(\psi, s_i) \qquad (0.2)$$

An illustration of equation (0.2) combined with an intuitively explanation of the internet size (n) and access price (p), when service quality (φ) is kept constant is performed. The difference in monetary utility of individual i for having access or not is given by

$$\upsilon_i^* = U^1\left(n, P, \bar{\phi}, \bar{s}_i\right) - U^0\left(n, P, \bar{\phi}, \bar{s}_i\right)$$

which is negatively related to price and concave over network activity. The concavity implies that the marginal utility to existing Internet users increases only for the first group of subscribers, ceteris paribus (including access price)[8]. The utility contours are depicted in the Internet price-size space of figure 2.1.

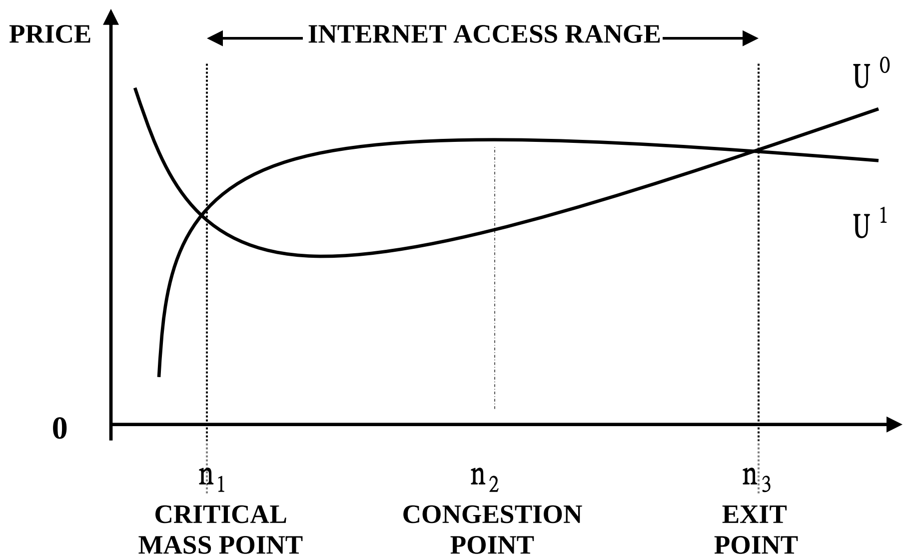

Figure 2.1. Utility contours in the internet size-price space

Figure 2.1 connotes that individual i will find it attractive to join a well-sized network. This requires a critical minimum number (mass) of users, denoted by n_1; at that point a user is well off as a non-user. In the range below n_1 the individual is better off if he does not enter the network, because both the number of people communicating and the size of network to search for information are small. Conversely, when the network size reaches n_1 and lies in the interval (n_1, n_2) internet access adds positively to utility. Hence, the individual will decide to enter the network. In that range access is feasible even when price increases, as the positive network effect counteracts the negative effect of price on the individual's utility.

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[8] In mathematical terms this is equivalent to $\partial U^1 / \partial n \leq 0$ and $\partial^2 U^1 / \partial n^2 \geq 0$. In addition, U concave implies $-U$ convex.

However, falling access prices caused by falling costs of computing in the supply side induces prices to fall; demand for access will rise. In turn, by constant service quality, the rise in demand causes the emergence of congestion in the system and therefore internet access service deteriorates. Internet size adds to utility at a declining rate. The more subscribers entering a congested network the less the efficiency of usage. This is happening in the range $[n_2, n_3)$. At the exit point n_3 the congestion is so heavy that the individual derives positive utility only by dropping out. Note that technological advances can improve the quality of the internet service and it is therefore possible for congestion or any other deterrence effect to eliminate or occur at a higher level of network size than n_2.

2.1.3. DERIVATION OF THE INDEX MODEL

Returning to the specification in equation (0.1). It has stochastic components γ and therefore to derive the index model it is necessary to introduce the following additive functional structure (Blackorby, Primont and Russel, 1985)

$$U^j(\psi, s_i) = V^j(\psi, s_i) + \eta^j(\psi, s_i)$$

where V is deterministic and reflects the representative tastes of the population Ω; η is stochastic and reflects the effect of individual idiosyncrasies in preferences or unobserved attributes for the choice in B. After some simple manipulations and setting $\varepsilon_i = \eta_i^1(\psi, s_i) - \eta_i^0(\psi, s_i)$ the latent model can be written as

$$u_i^* = V^1(\psi, s_i) - V^0(\psi, s_i) + \varepsilon_i \qquad (0.3)$$

where u_i^* is the latent variable and it is continuous. It is termed latent because it is unobserved. The econometrician only observes a limited amount of information that filters from u_i^* to u_i, which is known as the binary-dependent variable of the model. Thus, the only possible utilisation of the latent representation model in econometric analysis, is to say that an individual i will choose to access the Internet if u_i^* exceeds the threshold level of zero. This implies that

$$u_i = \begin{cases} 1, \text{ if } u_i^* > 0 \\ 0, \text{ if } u_i^* \leq 0 \end{cases} \qquad (0.4)$$

Since the model is unobserved, the binary event in (0.4) will occur with some probability. It is called the response probability of choosing internet access from B and is described by the index model in (0.5)

$$P_i = P\left(j=1 \mid B, \psi, s\right) = \Pr ob\left[\eta^1\left(\psi, s_i\right) - \eta^0\left(\psi, s_i\right) < V^1\left(\psi, s_i\right) - V^0\left(\psi, s_i\right)\right] \qquad (0.5)$$

At this instance, the index model does not have a known functional form. It is only known that P is a cumulative probability function (CDF) and hence is non-decreasing and bounded between 0 and 1. Then, to specify a functional form for P a mapping G is used. Let G be a monotonically increasing function that represents the joint CDF of the difference of the random components $\eta^1(\psi, s_i)$ and $\eta^0(\psi, s_i)$. Simultaneously, it also translates the range of V into $[0,1]$, so that it lies within the probability scale. Hence, P can be written in a hidden integral form as

$$P_i = G\left(V^1\left(\psi, s_i\right) - V^0\left(\psi, s_i\right)\right) \qquad (0.6)$$

A necessary condition for (0.6) to hold is statistically independence across individuals. For the purposes of the empirical analysis the linear form in (0.7) approximates the difference between the functions V in (0.6). It is also general enough to accommodate any possible combination of and interactions between variables. Thus,

$$V^1(\psi, s_i) - V^0(\psi, s_i) = \sum_{k=1}^{\kappa} \beta_k \left[X_k^1(\psi, s_i) - X_k^0(\psi, s_i) \right] = \beta' x_i \qquad (0.7)$$

where $X_k^j(\psi, s_i)$ are empirical functions with no unknown parameters. They include both the attributes of the choice and the attributes of the individuals $i = 1, ..., N$; $x' = \left(X_1^1 - X_1^0, ..., X_k^1 - X_k^0\right)'$ is the vector of these functions; $\beta = (\beta_1, ..., \beta_\kappa)'$ is the vector of the unknown parameters to be estimated.

SECTION 2.2. ECONOMETRIC MODELLING OF INTERNET ACCESS DEMAND

2.2.1. SPECIFICATION OF THE INDEX MODEL

In fitting a functional form on the index model, the uniform, standard normal and logit CDF are considered. Parameter estimates are sensitive to distributional assumptions imposed on G. From (0.6) and (0.7) the index model can be written as

$$P_i = G\left(\beta' x_i\right) \quad (1.1)$$

The linear probability model is obtained if it is assumed that G is linear over the range of V, which truncates it within the $[0,1]$ range. $F(\beta' x_i)$ denotes the uniform CDF.

$$P_i = F\left(\beta' x_i\right) = \begin{cases} 0, \text{ if } \beta' x_i < 0 \\ x_i' \beta, \text{ if } 0 < \beta' x_i < 1 \\ 1, \text{ if } \beta' x_i > 0 \end{cases} \quad (1.2)$$

On the other hand, if G is assumed to be a smooth non-linear ogive then a possible selection is the normal or the logistic distribution[9]. That is,

$$P_i = \Phi\left(\beta' x_i\right) \quad (1.3)$$

$$P_i = \Lambda\left(\beta' x_i\right) = \frac{\exp\left(\beta' x_i\right)}{1+\exp\left(\beta' x_i\right)} \quad (1.4)$$

where $\Phi(\beta' x_i) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{V} \exp\left(\frac{-t^2}{2}\right) dt$ denotes the standard normal CDF in (1.3) and $\Lambda\left(\beta' x_i\right)$ the logistic CDF in (1.4).

The specification selection would be based on both the econometric and microeconomic theory. From the econometrics point of view, the logit model has the computational advantage of a closed (explicit) functional form with convenient curvature properties for numerical optimisation. This is not the case for the probit model, though in an empirical work are virtually equivalent (Amemiya, 1981). However, the linear model is inappropriate. Therefore, the selection discussion would be focused between the linear and logit model.

From the microeconomic perspective, the functional specification must be in accordance with the RUM hypothesis and the procedure of obtaining the index model in (1.1). McFadden and Domenich (1975) demonstrates that each one specification in (1.2)-(1.4) are valid, under specific distributional assumptions for the stochastic components of utility η^1 and η^0. Then, uniformly, normally and logistically distributed $\varepsilon_i = \eta_i^1 - \eta_i^0$ yields the linear, probit and logit models respectively.

[9] Cauchy distribution is another alternative and gives the arctan probability model.

Specifically, to obtain the logit model lemma 2.2.1 is necessary and sufficient. In overall, it states that if the stochastic components of the utility function are independent Weibull distributed (also called type I extreme error) a logistic specification is guaranteed for (1.1).

Lemma 2.2.1. If $\eta_i^j \sim \text{iid.Weibull}\left(\alpha^j\right)$ for $i=1,2$ then:

1. $\eta_i^j + v_i^j \sim \text{Weibull}\left(\alpha^j - v_i^j\right)$, for $\forall\ v_i^j$ deterministic

2. $\underset{i=1,2}{\text{Max}}\ \eta_i^j \sim \text{Weibull}\left(-\log \sum_{k=1}^{V} \exp\left(-\alpha^j\right)\right)$

3. $$\text{Prob}\left[v_i^1 + \eta_i^1 \geq v_i^0 + \eta_i^0\right] = \frac{\exp\left(v_i^1 - \alpha^1\right)}{\exp\left(v_i^1 - \alpha^1\right) + \exp\left(v_i^1 - \alpha^0\right)}$$

   α^j can be absorbed in V_i^j and interpreted as an effect specific to the choice in B.

4. Then $\underset{(1),\,(2),\,(3)}{\Rightarrow}$ $\varepsilon_i = \left(\eta_i^1 - \eta_i^0\right) \sim \text{iid.logistic}$

2.2.2. MODEL ESTIMATION

The next econometric question is how the unknown vector of the parameters β can be estimated in a consistent and efficient way. The asymptotic properties of the estimators would clarify this.

Consider the linear probability model. It is not a sensible way to approximate probabilities by a linear function. First of all, empirically, is not possible to truncate it within the probability scale. Second, suppose that we could, then the estimates are inconsistent and heteroskedastic. To illustrate, apply ordinary least squares (OLS) to the regression equation

$$y_i = \beta' x_i + \varepsilon_i \quad (1.5)$$

Then, the OLS estimator in (1.6) does not satisfy the Gauss-Markov conditions (Wooldridge, 2002).

$$\hat{\beta}_{OLS} = \left[\sum_{i=1}^{N} x_i x_i'\right]^{-1} \left[\sum_{i=1}^{N} x_i y_i\right] (1.6)$$

Lemma 2.2.2. Violation of Gauss-Markov conditions

1. Inconsistency: Regressors are stochastic and correlated with the errors

$$E(x_i \varepsilon_i) \neq 0$$

   This is shown asymptotically by the theorems of Khintchine and Sluztky.

2. Inefficiency: The error is a Bernoulli variable and hence heteroskedastic

$$\mathrm{Var}(\varepsilon_i) = \sigma_i^2 \neq \sigma^2 \text{ since } \mathrm{Cov}(\varepsilon_i \mid x_i) = \beta' x_i \left(1 - \beta' x_i\right) \text{ varies with x}$$

A remedy for the inconsistency is to find instruments that are correlated with x_i and uncorrelated with ε_i. Because of heteroskedasticity, this should be done within the framework of the generalised methods of moments (GMM), so that to transform the heteroskedastic model in (1.5) to a homoskedastic one and obtain a weighted least squares estimator.

Instead, the logit model is used. This is an intrinsically non-linear model; it is not possible to transform the variables and turn it into a linear one. It is estimated by the maximum likelihood estimation method (MLE), since the probability distribution function (PDF) that generates the estimates is known. This provides more efficient estimates than the non-linear estimation technique, which use only the first two moments of the observations. However, due to the lack of identification what it is estimated is β/σ_ε; thus set $\sigma_\varepsilon = 1$. The MLE technique is standard. An individual with an outcome $y_i = 1$ and $y_i = 0$ contributes to the likelihood the terms

$$\lambda_{i1} = P\left(y_i = 1 | x_i, B\right) = 1 - F\left(-\beta' x_i\right)$$
$$\lambda_{i0} = P\left(y_i = 0 | x_i, B\right) = F\left(-\beta' x_i\right)$$

Then, by independence, the joint PDF of $y_i, ..., y_N$ can be written as:

$$P\left(y_1, ..., y_N, x_1, ..., x_N\right) = \prod_{y_i = 0} F\left(-\beta' x_i\right)^{y_i} \prod_{y_i = 1} \left(1 - F\left(-\beta' x_i\right)\right)^{1 - y_i}$$

Hence, the Likelihood function for the whole sample, when assuming ε_i is logistically distributed is given by

$$L(\beta; x_i) = \prod_{i=1}^{N} \left[F\left(\beta' x_i\right)\right]^{y_i} \left[1 - F\left(\beta' x_i\right)\right]^{1 - y_i} = \frac{\exp\left(\beta'\right) \sum_{i=1}^{N} x_i y_i}{\prod_{i=1}^{N} \left[\left(1 + \exp(\beta' x_i)\right)\right]} \tag{1.7}$$

By taking logs in (1.7), the log-likelihood is obtained as

$$\ell\left(\beta; x_i\right) = \beta_j \sum_{i=1}^{N} x_i y_i - \sum_{i=1}^{N} \log\left[1 + \exp\left(\beta' x_i\right)\right]$$

Epigrammatically, the first order condition for maximisation of the Log-likelihood function requires the score vector evaluated at β_{MLE} to be zero, that is,

$$S(\beta)\Big|_{\beta=\hat{\beta}_{MLE}} = \frac{\partial \ell(\beta)}{\partial \beta}\Bigg|_{\beta=\hat{\beta}_{MLE}} = 0$$

and also the Hessian matrix be is required to be negative definite matrix, that is[10],

$$H(\beta) = \frac{\partial^2 \ell(\beta)}{\partial \beta \partial \beta^{'}} \geq 0$$

FOC equations are non-linear in β and estimation involves numerical optimization. Such a procedure is the method of scoring. It uses the Taylor expansion up to its second term as an approximation to the Score function (Hidalgo, 2000; Greene 1995). That is,

$$S(\beta) = S(\beta_0) + \left(\frac{\partial}{\partial \beta^{'}} S(\beta_0)\right)(\beta - \beta_0) + \frac{1}{2}(\beta - \beta_0)^{'}\left(\frac{\partial}{\partial \beta \partial \beta^{'}} S(\bar{\beta})\right)(\beta - \beta_0) = 0$$

where $\bar{\beta} = \alpha\beta + (1-\alpha)\beta_0$ and $\alpha \in [0,1]$ $\forall$ β and $\beta_0 \in \mathbb{R}^n$

After some manipulations it is obtained that

$$\beta_{MLE} = \beta_0 - \left(\frac{\partial}{\partial \beta \partial \beta^{'}} S(\bar{\beta})\right)^{-1} \frac{\partial S(\beta_0)}{\partial \beta_0}, \text{ where } \bar{\beta} = \alpha\beta_{MLE} + (1-\alpha)\beta_0 \qquad (1.8)$$

However, equation (1.8) cannot be uniquely solved for β_{MLE}, since it is in both sides. Thus, the Newton-Raphson algorithm evaluates the derivative of β_0 at each step until the estimate converges. That is,

$$\beta^{i+1} = \beta^{i} - \left(\frac{\partial}{\partial \beta} S(\beta^{i}) \frac{\partial}{\partial \beta^{'}} \lambda(\beta^{i})\right)^{-1} \left(\frac{\partial}{\partial \beta} S(\beta^{i})\right) \qquad (1.9)$$

[10] The log-likelihood is globally concave as the Hessian is always negative definite.

The iterative procedure in (1.9) converges to the global maximum of the likelihood function; for the logit model it usually takes at most 10 iterations. Hence,

$$\beta_{MLE} = \lim_{i \to \infty} \beta^{i} \quad (1.10)$$

It can also be proved that β_{MLE} is a convenient estimator with some nice asymptotic properties listed in lemma 3.2.1.

Lemma 2.2.3. Properties of β_{MLE}

1. Unbiasedness: $E\left(\beta_{MLE}\right) = \beta$
2. Consistency: $p\lim \beta_{MLE} = \beta$
3. Asymptotic normality: $\sqrt{T}\left(\beta_{MLE} - \beta\right) \rightarrow_{d} N\left(0, I^{-1}(\beta)\right)$
4. Efficiency: $Cov\left(\beta_{MLE}\right) = I^{-1}(\beta)$

<u>2.2.3. MODEL INFERENCE</u>

To successfully apply the logit model, it is essential to illustrate how to perform statistical tests and interpret the estimates (Dougherty, 2002). To start with, consider a continuous explanatory variable such as age $(x_{i\kappa})$. Then (1.11)

$$\frac{\partial P(y_i = 1 | x_i)}{\partial x_{i\kappa}} = \Pi\left(\beta_{MLE}^{'} x_i\right) \beta_{MLE,\kappa} = \frac{\exp\left(\beta_{MLE}^{'} x_i\right)}{\left(1 + \exp\left(\beta_{MLE}^{'} x_i\right)\right)^2} \beta_{MLE,\kappa} \quad (1.11)$$

gives the estimated change in the probability of accessing the internet for individual i when age varies, evaluated at the mean values of the explanatory variables.

Though, when x_{ik} is a dummy variable, say employment status, it is no sensible to interpret “small” changes in this variable. Suppose that x_{ik} is a binary variable, say student, then the partial effect on the probability of access when the individual is a student, holding all other variables fixed, is

$$
\begin{aligned}
&P\left(Access=1|Student=1\right)-P\left(Access=1|Student=0\right)= \\
&\Lambda\left(\beta_1\bar{x}_1+\beta_2\bar{x}_2+\ldots+\beta_{\kappa\text{-}1}\bar{x}_{\kappa-1}+\beta_k\right)-\Lambda\left(\beta_1\bar{x}+\beta_2\bar{x}+\ldots+\beta_{\kappa\text{-}1}\bar{x}_{\kappa-1}\right)
\end{aligned}
$$

Similarly, if x_{ik} denotes the limited-dependent variable household size then the change in the probability of access when, say household size changes from 2 to 3 persons, is simply

$$
\begin{aligned}
&P\left(Access=1|hhsize=3\right)-P\left(Access=1|hhsize=2\right)= \\
&\Lambda\left(\beta_1\bar{x}_1+\beta_2\bar{x}_2+\ldots+\beta_{\kappa\text{-}1}\bar{x}_{\kappa-1}+\beta_{k,3}\right)-\Lambda\left(\beta_1\bar{x}+\beta_2\bar{x}+\ldots+\beta_{\kappa\text{-}1}\bar{x}_{\kappa-1}+\beta_{k,2}\right)
\end{aligned}
$$

For testing about the coefficients, the tests from the general MLE analysis- Wald, Lagrange Ratio and Lagrange Multiplier tests can be used. They can be used to test if a variable is individually significant, or if the variables in the logit model are jointly significant. Stata computes the Wald statistic for exclusion restrictions following the data output of the general logit model. Stata reports the significance level of the statistic using standard normal Z approximations. For instance, to test the set of q linear hypothesis $H_0: R\beta = r$ jointly, then the Wald test statistic, under H_0 is

$$
W=\left(R\hat{\beta}_{MLE}-r\right)'\left(RCov\left(\beta_{MLE}\right)R'\right)^{-1}\left(R\hat{\beta}_{MLE}-r\right)\to_d \chi^2_q
$$

Finally, goodness of fit statistics are reported after the estimation procedures. These are measures indicating the ability of the logit model to forecast observed responses. For example, consider the Receiver Operating Characteristic (ROC) curve plots sensitivity versus one minus specificity as the cut-off point c varies. From this analysis the percentage of correct classification is also obtained.

Sensitivity (specificity) is the fraction of observed positive (zero) outcomes cases that are correctly classified by the model. For sensitivity, a prediction is classified as positive if $P(y_i = 1) \geq c$, where c is equal to 0.5; otherwise is classified as negative. The classification is correct if it is positive and $y_i = 1$ or if it is negative and $y_i = 0$. The greater the predictive power of the model the more bowed is the ROC curve. Hence, the area underneath is measuring the predictive power of the model. A model with no predictive power has area 0.5; a perfect model has area 1.

PHASE III: METHODOLOGY

This phase describes the methodological framework of carrying the empirical analysis. In sequel, it consists of four interrelated steps; the data collection, database preparation, model estimation and results interpretation.

Data Collection. For data collection, the following principles have been considered. First, it is important to use large pan-European samples that provide information on the attributes of choice and on the attributes of the decision-makers. Secondly, the data must be random, representative of the whole EU population and the statistical methodology that has been drawn consistent. Indeed, the Eurobarometer surveys provided by the European Commission meet the above requirements. The only exception is the attributes of the choice. Data on these parameters has been gathered from specialised reports produced by the OECD Communications Outlook. An overall evaluation of the data sources, from the point of view of this project, is performed in subsection 4.1.1.

Data Preparation. Database preparation is undeniably an essential step in the analysis and requires systematic and laborious efforts to be completed successfully. Any mistakes in the procedure of variables construction might be transmitted in the parameter estimates and therefore extract wrong results from the model. Primarily, special attention is given to choosing the right variables, based on economic theory. So, descriptive statistics in the form of relative frequencies of the dependent variable relating to an independent variable are considered. This is also helpful in determining the type of functional relationships. The selection of variables is the initial step. The next one is its construction. It mainly involves the recoding of data and missing values treatment. Data were considered for the years 1997, 1998 and 2000. Each dataset contains more than 200 variables (selected about 50) with sample sizes 16078, 16224 and 16362 respectively. Finally, the data has been pooled into a single dataset using Stata. The discussion of the database preparation is performed in subsections 4.1.2 and 4.1.3.

Model Estimation. Under model estimation, there will be an attempt to improve the understanding of the underlying multivariate relationships, by controlling for the specific effects. In essence, the MLE technique has been applied to obtain the estimated probabilities, standard errors and then the marginal effects. Moreover, several test statistics are reported. In particular, the Wald test is used to examine the individual and overall significance of the independent variables in the analysis. Besides, the Pearson goodness of fit test, the percentage of correct classifications together with the sensitivity and specificity measures checking the model fitness are also reported. Through systematic testing of various specifications the best performing models of residential and workplace internet access demand are presented in section 4.2.1.

Results Interpretation. This is the fourth and last step. In this part, estimates are evaluated in the light of economic intuition. Here the relevant hypotheses of network economics theory have been considered in order to answer a number of questions on logit regressions. One of the purposes is to examine the drivers of the increase in Internet access demand. Specifically, is it driven by falling prices (supply side) reflected in falling access prices or by access externalities (demand side)? To answer this I will examine closely the predicted marginal effects of the attributes of the choice. The discussion of the model will finally lead to some issues related to policy. Subsection 4.2.2 includes the interpretation of the model. Subsection, 4.2.3, carries on with the policy implications.

PHASE IV: EMPIRICAL ANALYSIS

SECTION 4.1. DATA AND VARIABLES

4.1.1. DATA SOURCES EVALUATION

Each Eurobarometer survey consists of 1000 face-to-face interviews on an identical set of questions per Member State[11]. They have been established since 1973 and conducted 2-5 times per year. The samples are representative of the whole population aged fifteen years and over. They have been drawn using stratified sampling procedures. Interviews are performed in the mother tongue language of the interviewee. The EC's Public Opinion Surveys and Research Unit publish the results, whereas the datasets are stored at the Inter-university Consortium for Political and Social Research (ICPSR) in Germany[12]. The surveys are easily accessible and made available for research purposes free of charge.

[11] Exceptions are the cases of Germany (West Germany: 1000, East Germany: 1000), Luxembourg: 600, United Kingdom: 1300 (300 in Northern Ireland). Therefore, in the estimation are treated separately.

[12] Further information on the Eurobarometer surveys is provided at http://www.gesis.org/en/index.htm, http://europa.eu.int/comm/public_opinion/index.htm and http://www.data-archive.ac.uk.

A great advantage of these datasets has been the cornerstone of this project; due to the richness of the data it is possible to link Internet access demand to a wide range of economic and socio-demographic variables. On the other hand, the serious limitation of the Eurobaromer is the household income data. Particularly, in the special Eurobarometer "Measuring Information Society" no data are provided on household income. However, it is known that income is a strong explanator of Internet access demand. Therefore, the Standard Eurobarometer Surveys has been used instead. In the Standard Eurobarometer surveys the dichotomy of access is observable, though no data are provided on computing training and aptitude. Note that these, together with household's estimated cost of access, are observable in the MIS surveys.

Likewise, the Communications Outlook Series consists of seven biennial editions. They are conducted on behalf of the OECD's Committee on Information, Computer and Communications Policy (ICCP). In overall, it is a specialised series of reports that provides harmonised indicators on the performance of public communication infrastructures and the diffusion of telecommunications services for all the 29 OECD countries. Definitely, the Communications Outlook enriches the analysis of Internet access demand. Particularly, Internet indicators can be used to construct attributes of the choice variables. Nevertheless, a limitation of these reports is that internet access price includes only ISP hook-up costs and the line rental. However, the cost of initial monetary investments such as access devices (PC) is not recorded. In this report, price of access is the simple average of peak and off-peak price. In addition, there is no actual network service quality data. For instance, there is no data on modem dial tone delay and the traffic transmission speed between intra networks. Instead, indicators of the telephone system have been considered.

4.1.2. ATTRIBUTES OF THE CHOICE

Dependent Variable. Before proceeding, the dependent variable is presented. Internet access is a binary variable coded to equal 1 if the respondent's answer to the question: “Do you have access to, or do you use the internet/www at home?” was positive and 0 if negative. The distinction between home and office access was explicit; another question was asking the respondent to indicate if he/she accesses the Internet at the workplace and/or university. Missing values are very few (66 in 1997, 36 in 1998 and none in 2000) and therefore recoded as 0’s. This is attributed possibly to people’s ignorance of the internet, that eliminates over the time.

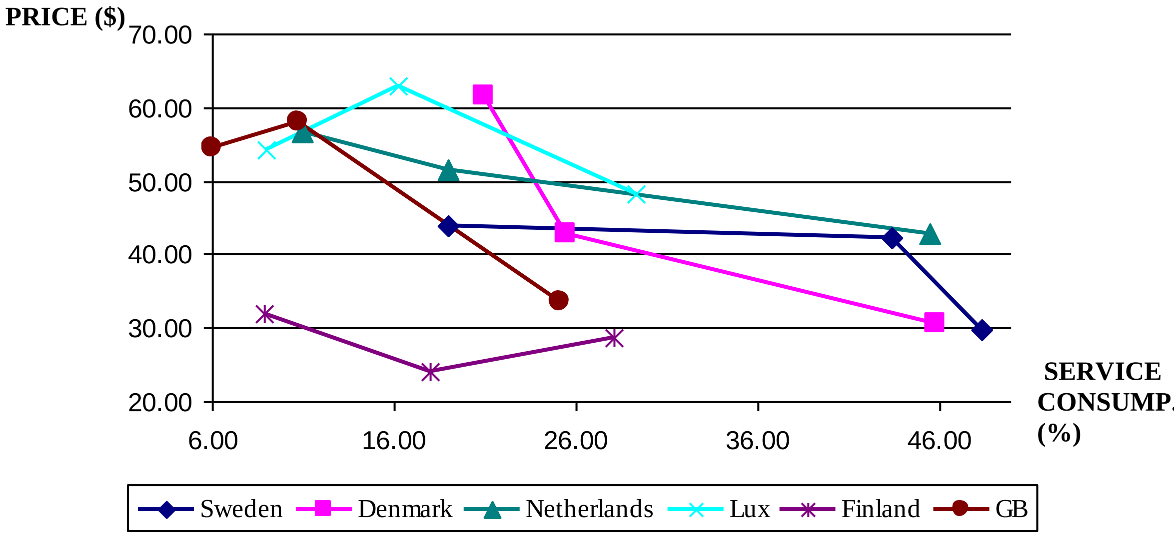
In addition, to perform a straightforward comparison between internet access at home and at workplace a second logit model has been developed. Workplace access takes the value 1 if the respondent accesses the internet at office and/or university and library and 0 otherwise. However, the following analysis of attributes refers only to model 1.

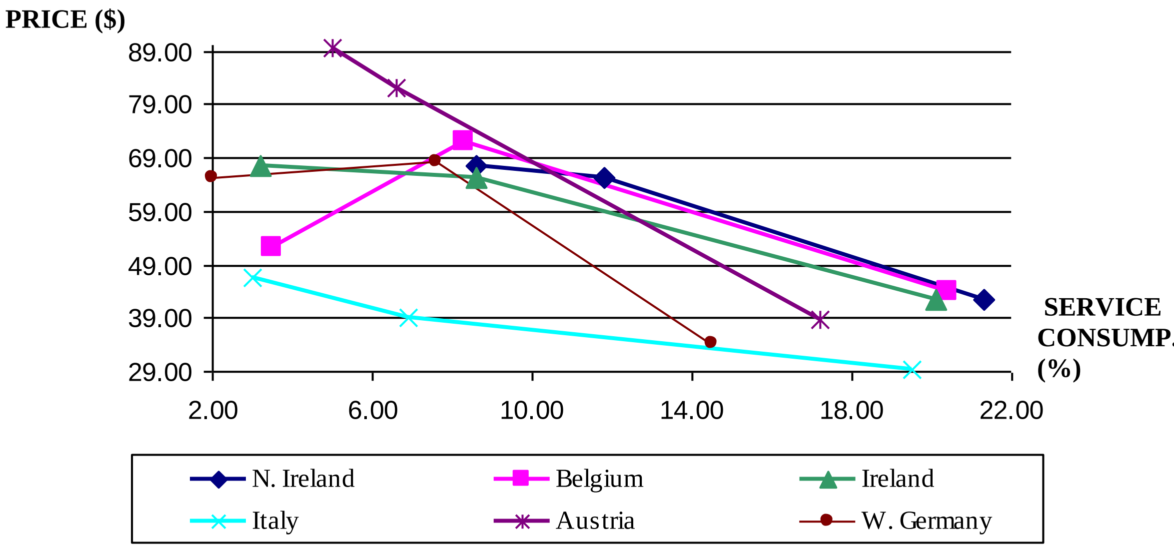
The attributes of the choice of internet access are reported in table 4.1.

Table 4.1. Attributes of the choice
Price of Internet access
Network size
Network fault rate

As it is expected, the price of access is negatively correlated with the dependent variable. Indeed, while the internet is diffusing, Europe was experiencing falling access prices throughout the period 1997-2000. However, the EU price is doubled than that in the US **(OECD, 2001)**. Obviously, price is also correlated with network size (-0.62). Nonetheless, to test the economic theory it is imperative to include both variables in the model and threat their interpretation with care. Figure 4.1 has three plots, so that the demand patterns and the corresponding access prices in the EU15 states are tabulated as countries with (a) light, (b) average and (c) heavy users.

Positions on the plotted graph denote the years 1997, 1998 and 2000. Remarks have been given in the introduction.





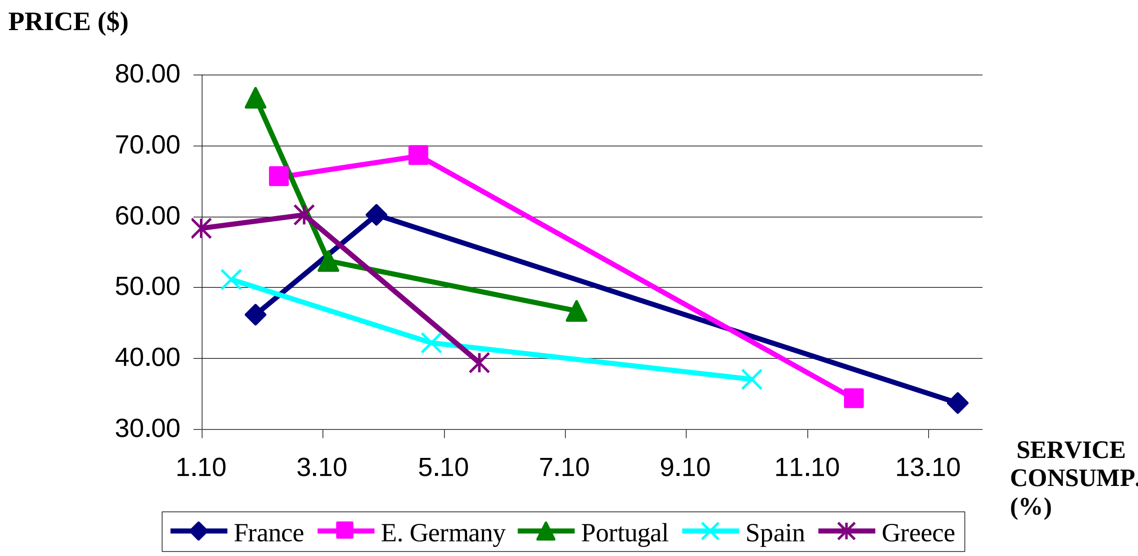


Figure 4.1. Internet access consumption by access price

The next variable under consideration is the network fault rate. It represents faults in telephone system per 100 lines. The fault rate declines in the period under examination, though not dramatically. Therefore, it is not expected to have a significant explanatory power in the pooled model, though it should have a negative sign. Table 4.2 reveals that countries like Greece and Spain with low Internet access demand rate are subject to high fault rates. All other countries have similar fault rates.

Table 4.2. Access demand and network fault rate

	1997		**1998**		**2000**		**Overall Change**	
(%)	**Demand**	**Faults**	**Demand**	**Faults**	**Demand**	**Faults**	**Δ(Demand)**	**Δ(Faults)**
Austria	5.00	7.2	6.60	6.2	17.20	6	12.2	-1.2
Belgium	3.49	5.0	8.30	4.7	20.40	4	16.9	-1.0
Denmark	21.00	7.2	25.50	6.8	45.80	5.4	24.8	-1.8
Finland	8.90	6.8	18.00	9.0	28.10	8.4	19.2	+1.6
France	2.00	5.9	4.00	6.2	13.60	6	11.6	+0.1
W. Germany	2.00	5.0	7.60	4.3	14.50	3.6	12.5	-1.4
E. Germany	2.40	5.0	4.70	4.3	11.90	3.6	9.5	-1.4
Greece	1.10	31.0	2.80	24.0	5.70	17	4.6	-14.0
Ireland	3.20	14.0	8.60	15.0	20.10	14	16.9	0
N. Ireland	8.60	14.0	11.80	15.0	21.30	14	12.7	0
Italy	3.00	4.2	6.90	16.2	19.50	17.2	16.5	+13.0
Luxembourg	9.00	10.2	16.20	8.3	29.30	10.1	20.3	-0.1
Netherlands	11.00	24.3	19.00	2.4	45.50	2.7	34.5	-21.6

Portugal	2.00	4.0	3.20	14.7	7.30	35.8	5.3	31.8
Spain	0.02	4.3	0.05	14.0	0.10	15	0.1	10.7
Sweden	19.00	36.1	43.40	4.3	48.30	4.4	29.3	-31.7
GB	6.00	17.0	10.70	13.6	25.10	14.3	19.1	-2.7
EU	6.3	11.6	11.6	10.5	22.0	11.4	15.6	-0.2

4.1.3. ATTRIBUTES OF THE INDIVIDUALS

The socio-economic variables that were determined to be relevant in this study are presented in table 4.3. Note that only age and years of schooling are continuous, whereas all the other variables are qualitative dummies.

Table 4.3. Attributes of the Individuals

Household income
New high-tech index
Old high-tech index
Country of residence
Employment status
Age
Years of schooling
Political affiliation
Gender
Marital status
Household size
Household children below fifteen years old

Previous studies (Taylor et al, 2002) shows that individuals from affluent households have a higher propensity to access the Internet, than those from poor ones. Indeed, using the Internet involves a complex chain of personal abilities and access to technical resources, many of which related to income. For instance, income constrains the ability of individuals to invest in PCs, to purchase ISP services and acquire the relevant computer training (Hargittai, 1999). Household income is measured in Euro and is given in four harmonised quartiles as at the date of the interview[13]. If the respondent has not specified the household income, it is recoded as missing. In the pooled sample there are 14233 missing values due to the income variable. Figure 4.2 shows Internet access demand per income quartiles and confirms the above discussion. For this figure and the rest bar charts, the first column denotes the corresponding percentage observed in the 1998 sample, the second in 1999 and the third in 2000. The percentage of the pooled sample is simply the mean of the percentages in each cross-section.

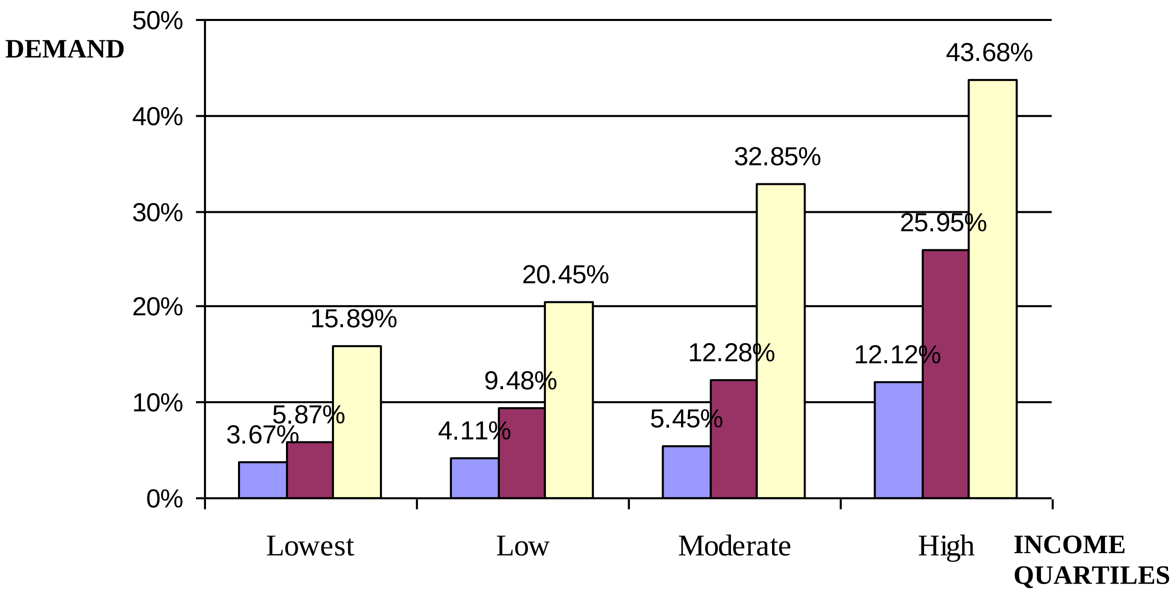


Figure 4.2. Internet access demand by household income quartiles

Moreover, penetration rates for complementary telecommunications services to access service devices are also expected to be important predictors of the demand. For that reason a new high-tech index and an old high-tech index are constructed for each

[13] The categories remain the same in all the periods and are not adjusted for inflation. In each country income is specified in the local currency. For example, the UK categories (£) are: 1. <240, 240-319, 320-399, 400-479, 480-599, 600-729, 730-829, 830-999, 1000-1149, 1150-1664, 1665-2000, >2000, refusal and do not know. However, no more information is provided on the construction of the four harmonised income quartiles. The exact question is “Please count the total wages and salaries per month of all members of this households; all pensions and all social insurance benefits; child allowances and any other income like rents, etc…and give me the letter of the income group your household falls into before tax and other deductions”.

individual in the sample. The first index is coded as 1 if the respondent accesses at home the Cable TV, independent FAX machine, Video recorder and Teletext and 0 he does not. Likewise, the second one is coded as 1 for access to a desktop computer/PC with modem and CD-ROM system and 0 otherwise[14]. As figure 4.3 shows, the demand rate corresponding to indexes increases from 1997 to 1998.

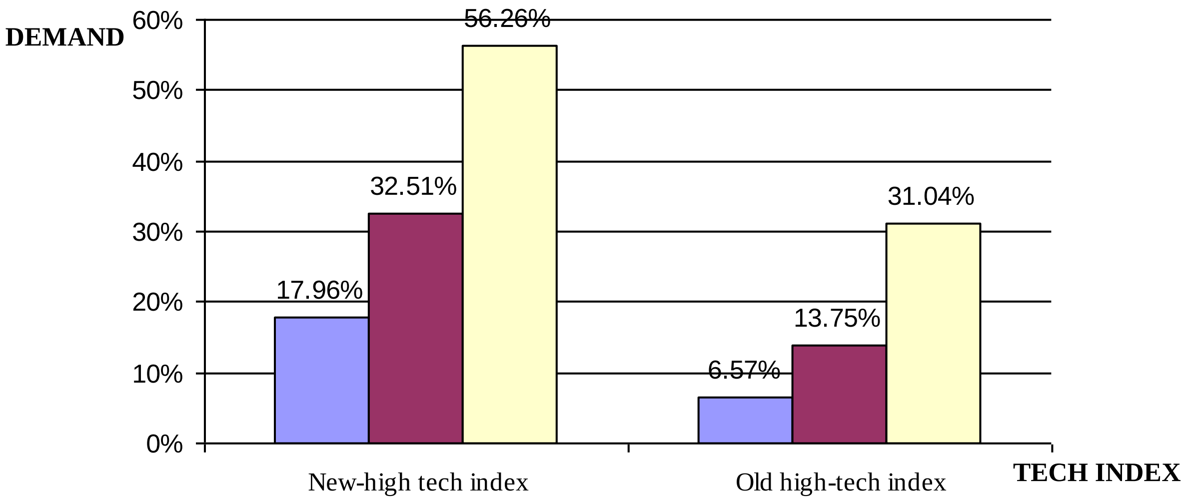
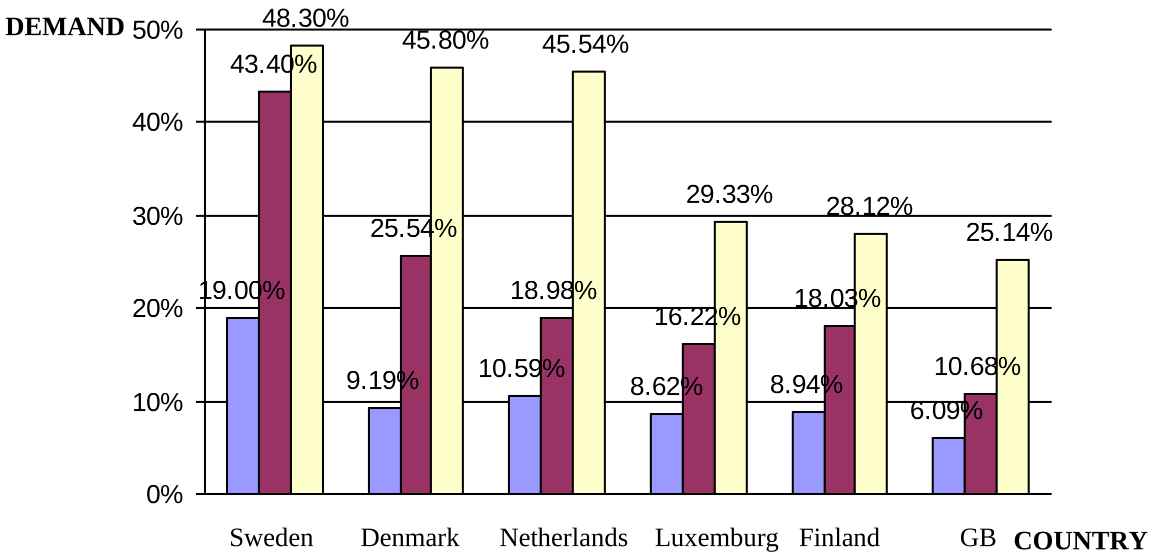


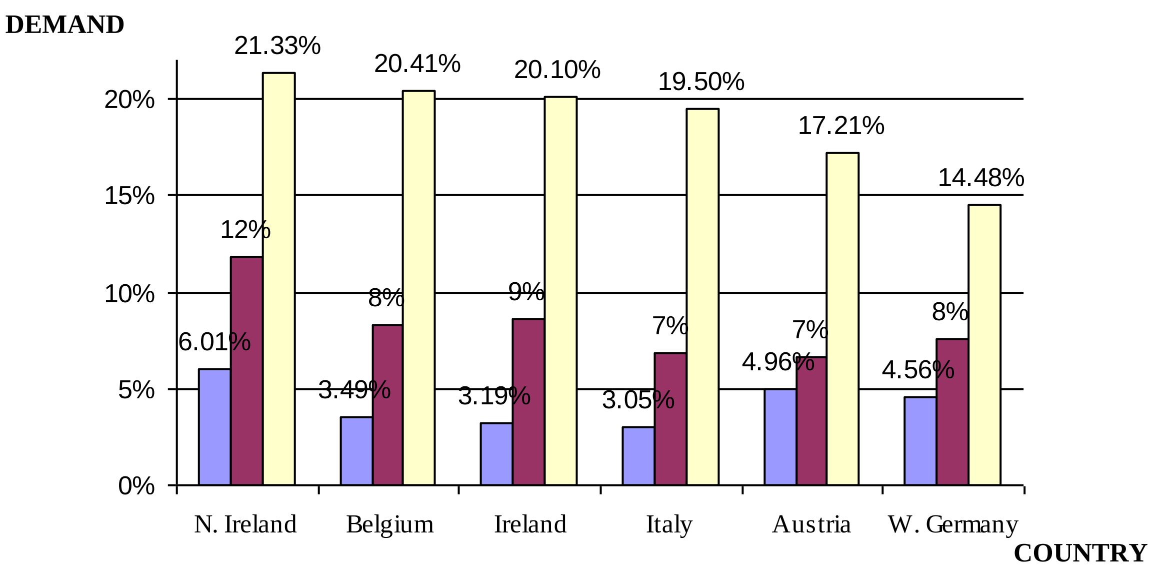
Figure 4.3. Internet access demand by new and old high-tech indexes

Each country enters the model as a dummy. For example 1 if household is in Germany. The reference country is Great Britain, as Internet access demand is roughly closed to the EU average. Indeed, the EU15 belong to the group of industrialised nations. In addition, they have established relatively stable democratic political systems and generally achieved high levels of literacy **(Hargittai, 1999)**. Yet, as it was stated in the introduction, and figure 4.4 shows diagrammatically, important differences are noted.

---

[14] Roughly, there were 50 missing values per device per sample. They recoded as 0. Note that access to the telephone system has not an explanatory power on Internet access demand. This is not the case when more that one telephone line exists **(Taylor et al, 2000)**. However, no data exists. The wording of the question on each device is identical to the one used to derive the dependent variable


DEMAND
50%
40%
30%
20%
10%
0%
48.30%
43.40%
19.00%
45.80%
25.54%
9.19%
45.54%
18.98%
10.59%
29.33%
16.22%
8.62%
28.12%
18.03%
8.94%
25.14%
10.68%
6.09%
Sweden
Denmark
Netherlands
Luxemburg
Finland
GB
COUNTRY


DEMAND
20%
15%
10%
5%
0%
21.33%
12%
6.01%
20.41%
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3.49%
20.10%
9%
3.19%
19.50%
7%
3.05%
17.21%
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14.48%
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N. Ireland
Belgium
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Italy
Austria
W. Germany
COUNTRY

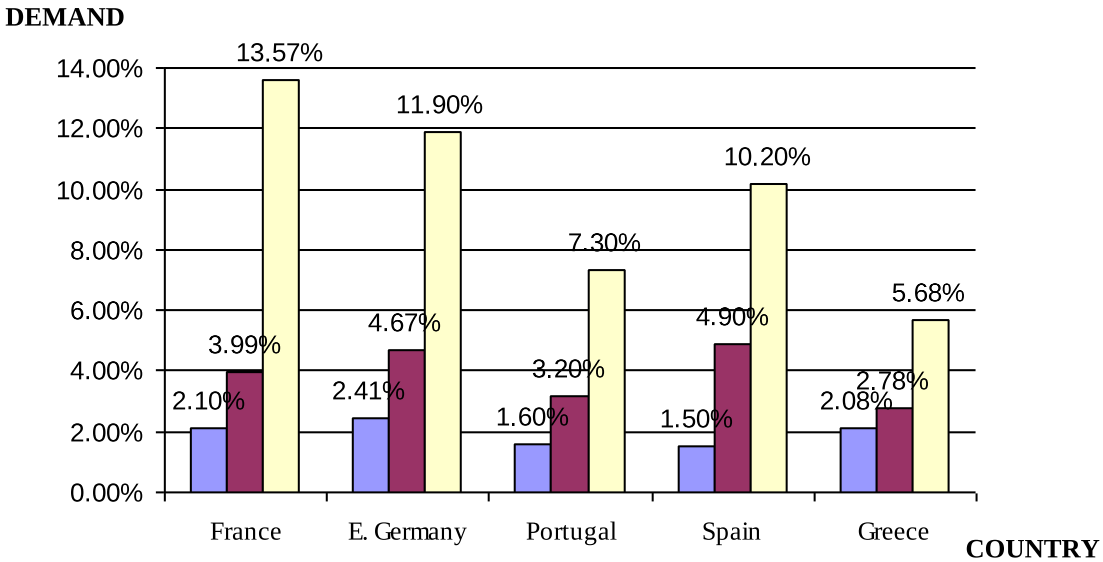


Figure 4.4. Internet access demand by country

Occupation status of the respondent was tabulated into 7 categories, as shown in figure 4.5[15]. Descriptive statistics shows that special occupational categories, like managers, students, white collars and self-employed are more likely to be Internet users than individuals who belong to the manual worker, house persons, unemployed and retired category. In the analysis, the reference category is the self-employed.

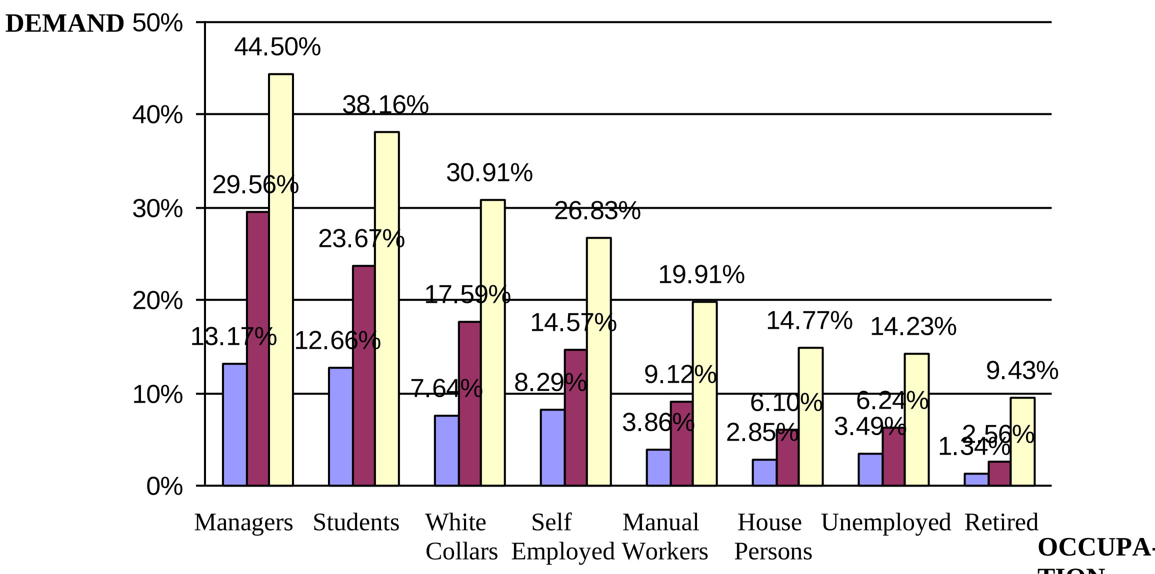


Figure 4.5. Internet access demand by occupational status

[15] Self-employed: farmers, shop owners, business proprietors, lawyers, etc; Managers: directors, middle and junior managers; White Collars: office employees; Manual workers: salesmen, restaurant employees, unskilled workers etc; Retired includes people unable to work.

Moreover, figure 4.6 shows the relation of age with the dependent variable is negative and linear. This is consistent with the low access level of retired people. In addition, people between 30 and 35 are more inclined to demand the service. However, as figure 4.7, shows years of schooling and internet access has a rough U-shape relation. The trend with the highest penetration corresponds to year 2000, the middle one to 1998 and the lowest to 1997.

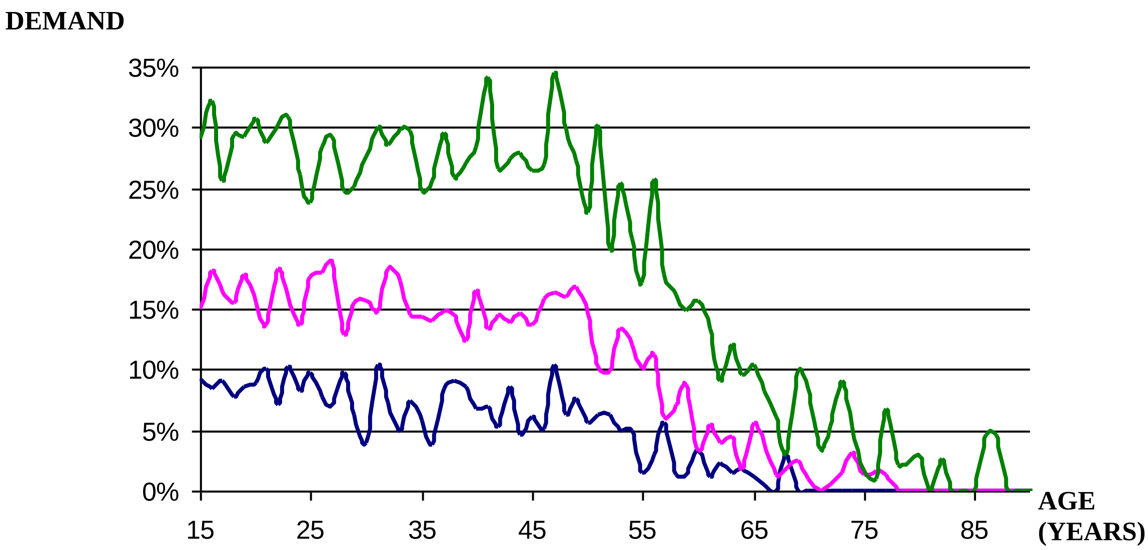


Figure 4.6. Internet access demand by age

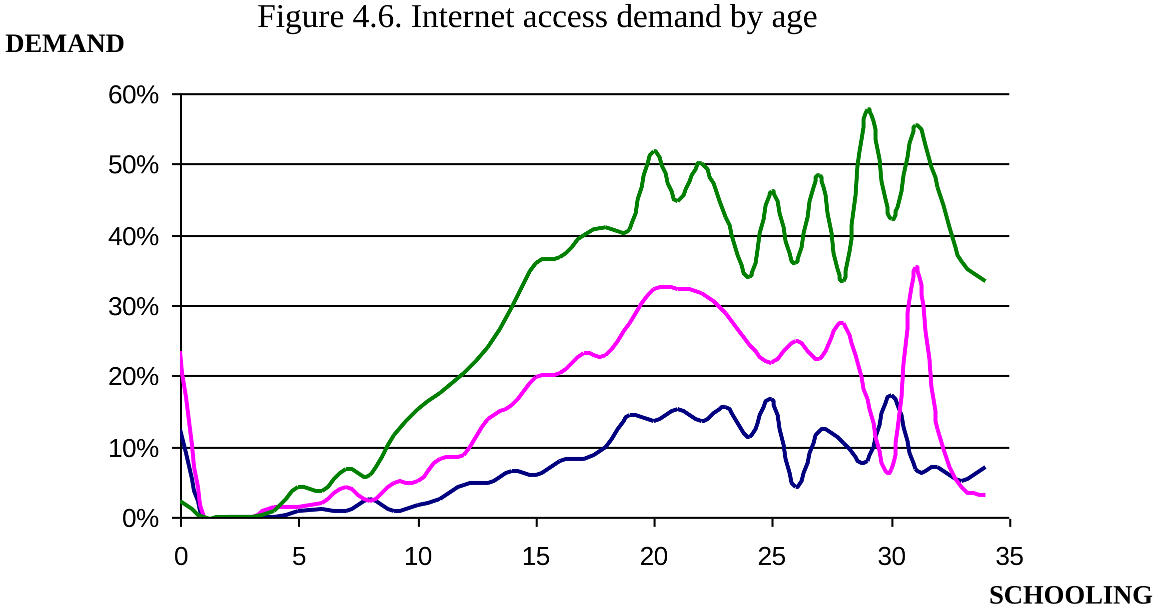


Figure 4.7. Internet access demand by years of schooling

Political affiliation is considered to examine whether ideological idiosyncrasies of people affects Internet access[16]. By considering the above figure it seems that people from the right and left are in a marginal lead over the people from the centre. However, since missing values in that variable are quite a lot: 8913 in the pooled sample, the interpretation would be made somewhat different, as it is not sensible to delete 8913 observations. Hence, it seems that, as figure 4.8 illustrates, the more easily people admit their ideological background, the more internet access services they demand; probably because they are more activists that those who prefer silence. Additionally, they are more likely to be systematic consumers of media commodities, such as newspapers.

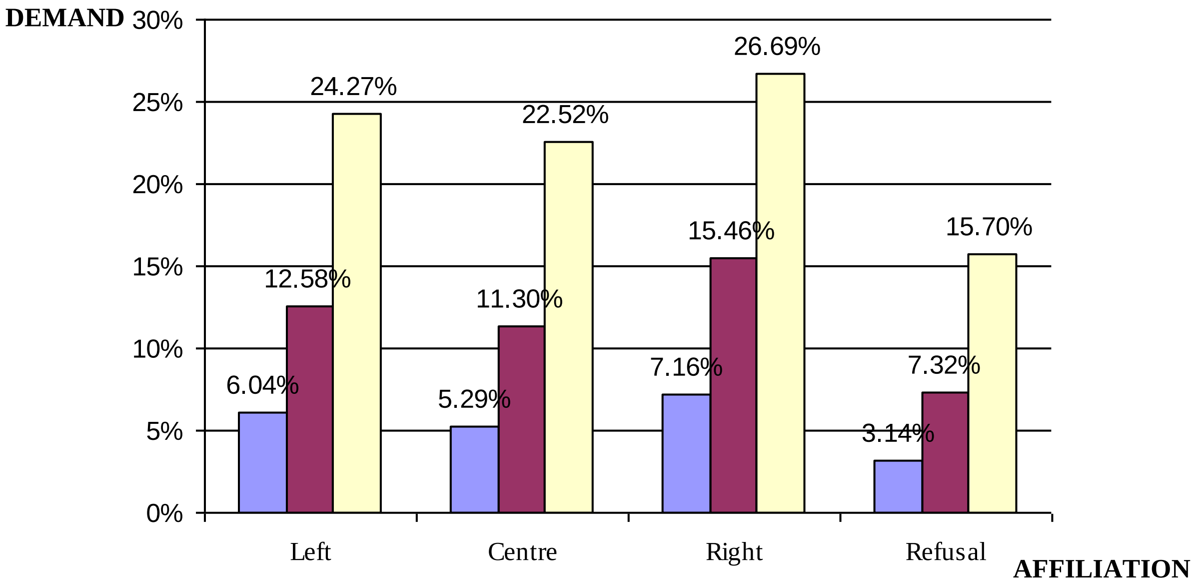


Figure 4.8. Internet access demand by political affiliation

Figure 4.9 presents Internet access penetration by gender and marital status. Male coded as 1 and female as 2, whereas single as 1 and married as 2[17]. It is shown that males are more likely to access the Internet. A similar argument goes for the unmarried people.

[16] It is a dummy variable representing placement on a 1-10 scale. Left, centre and right are between 1-4, 5-6 and 7-10 and are coded as 1, 2 and 3 respectively.

[17] The "divorced, separated and widowed" categories coded as 1; the "living as married" as 2. Refusal (less that five) to specify marital status was assigned the code 1.

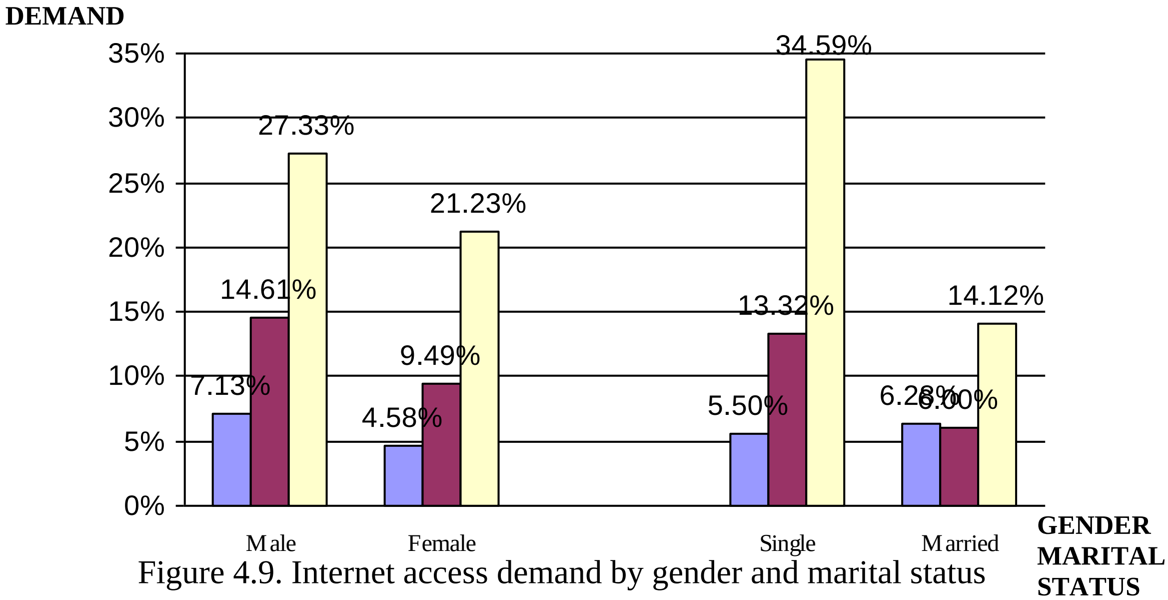


Figure 4.9. Internet access demand by gender and marital status

Finally, the household size and household children below fifteen 15 are discussed[18]. Figure 4.10 shows the existence of a bell-shaped relation with the demand for access. Given that the majority of respondents reported that no children below 15 exist in household, household children variable is a dummy one coded as 0 if no child exist and 1 if at least one child exists[19]. It is interesting to examine whether households with children are more likely to be internet consumers compared with households with no children. Indeed, figure 4.10 suggests that this is true.

[18] The last category of household size includes six or more persons.
[19] Missing values recoded as 1.

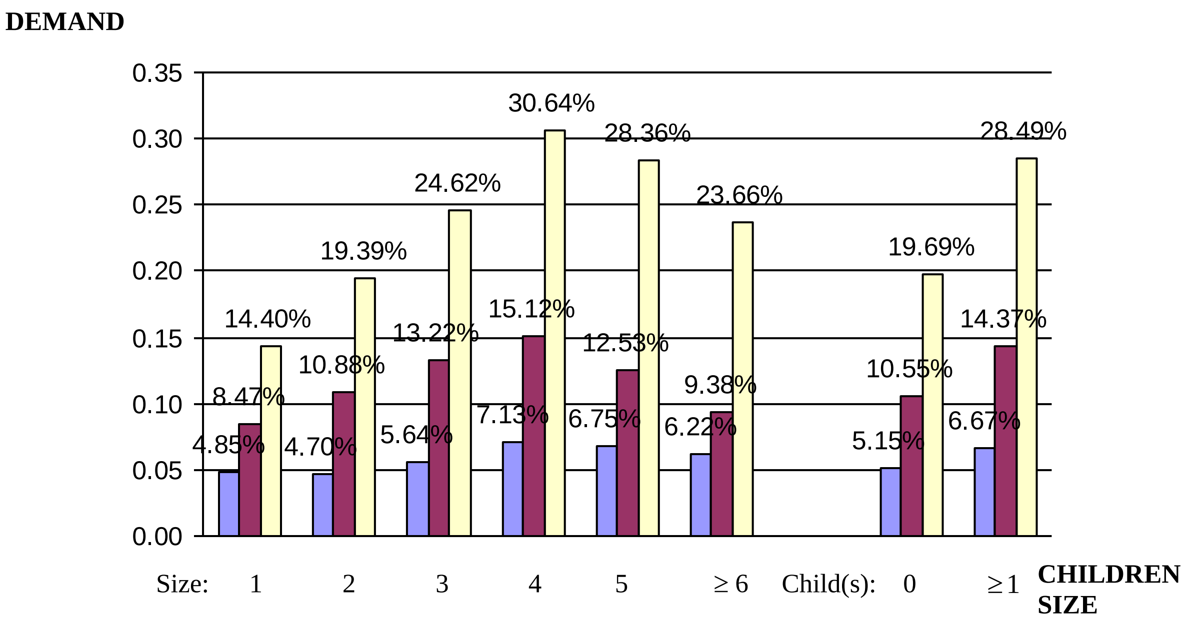


Figure 4.10. Internet access demand by household size and children

SECTION 4.2. THE EMPIRICAL MODEL AND DISCUSSION

4.2.1. MODEL ESTIMATION

Table 4.4 presents the estimation results of the coefficients for two models on the pooled set of data. Model 1 refers to residential Internet access demand. Model 2 refers to internet access demand at the workplace. Table 4.4 shows the coefficients and the marginal effects of the independent variables of the two models. In addition, it indicates the level of significance of the standard error, by considering the Wald statistic. At the bottom of the table the diagnostic statistics and some other information related to the models are shown.

Table 4.4. Logit regressions for the probability of internet access

	MODEL 1			MODEL 2		
Independent Variable	**Coefficient**	**Standard Error**	**Marginal Effect**	**Coefficient**	**Standard Error**	**Marginal Effect**
Price	-0.0063	(0.0033)**	-0.00019	0.0081	(0.00343)**	0.00012

Size (hosts)	0.0052	(0.0190)*	0.00015	0.0052	(0.0021)**	0.00008
Network fault rate	0.0070	(0.0104)	0.00021	0.0395	(0.0112)*	0.00059
Household income (++)	0.7381	(0.0617)*	0.02171	0.5344	(0.0678)*	0.00797
Household income (+)	0.2323	(0.0622)*	0.00683	0.1101	(0.0690)	0.00164
Household income (--)	0.0067	(0.0753)	0.00020	-0.1928	(0.0900)*	-0.00287
New high-tech index (+)	-3.1334	(0.0623)*	-0.09218	-1.6109	(0.0556)*	-0.02401
Old high-tech index (+)	-0.2179	(0.0608)*	-0.0064	-0.4798	(0.0693)*	-0.00715
Belgium	-0.6299	(0.1925)*	-0.01852	-0.1895	(0.2067)	-0.00282
Denmark	-0.0582	(0.1482)	-0.00171	0.3216	(0.1573)**	0.00479
West Germany	-0.7517	(0.1819)*	-0.02211	-0.1562	(0.1905)	-0.00233
Greece	-1.1459	(0.1896)*	-0.03370	-1.2924	(0.2123)*	-0.01926
Italy	-0.4828	(0.1478)*	-0.01420	-0.3872	(0.1656)**	-0.00577
Spain	-1.2390	(0.1641)*	-0.03645	-0.8262	(0.1850)*	-0.01231
France	-0.9909	(0.1693)*	-0.02915	-0.6952	(0.1860)*	-0.01036
Ireland	-0.1887	(0.1581)	-0.00555	-0.2336	(0.1727)	-0.00349
Northern Ireland	0.2090	(0.1948)	0.00615	-0.4512	(0.2392)	-0.00672
Luxemburg	0.1238	(0.1520)	0.00364	0.04501	(0.1716)	0.00067
Netherlands	-0.1208	(0.1520)	-0.00355	0.3261	(0.1684)**	0.00486
Portugal	-1.0292	(0.1977)*	-0.03028	-1.1634	(0.2109)*	-0.01734
Great Britain (reference)	-		-	-	-	-
East Germany	-0.9053	(0.1823)*	-0.02663	-0.4079	(0.1950)**	-0.00608
Finland	-0.3419	(0.2083)	-0.01006	0.3275	(0.2265)	0.00488
Sweden	0.9373	(0.1416)*	0.02757	1.1428	(0.1562)*	0.01703
Austria	-0.4443	(0.1721)*	-0.01307	0.4472	(0.1797)*	0.00667
EU15 x time dummy 1998	-0.0074	(0.0096)	-0.00022	0.0013	(0.0094)	0.00002
EU15 x time dummy 2000	-0.0301	(0.0101)**	-0.00091	-0.0114	(0.0100)	-0.00017

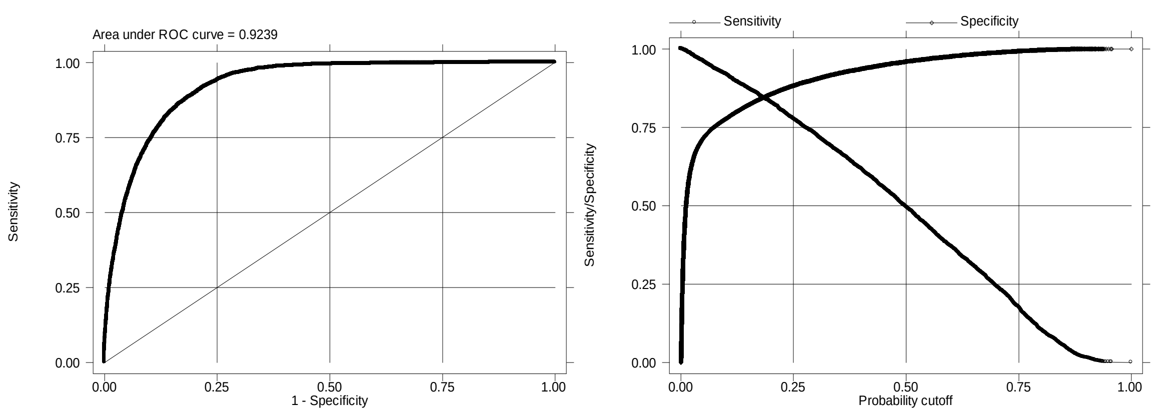
TABLE 4.4. (Continued)

Self-employed (reference)	-	-	-	-	-	-
Managers	-0.0331	(0.0819)	-0.00091	0.7441	(0.0781)*	0.01108
Students	1.2882	(0.3243)*	0.03789	1.5297	(0.3724)*	0.02280
White collars	-0.1935	(0.0853)**	-0.00569	0.5638	(0.0812)*	0.00840
Manual workers	-0.4659	(0.0816)*	-0.01371	-0.5223	(0.0829)*	-0.00778
House persons	-0.0930	(0.1055)	-0.00274	-2.8401	(0.2633)*	-0.04233
Unemployed	-0.4850	(0.1213)*	-0.01425	-2.6481	(0.2638)*	-0.03947
Retired	-0.7397	(0.1079)*	-0.02176	-3.4697	(0.2648)*	-0.05171
Age	-0.0130	(0.0021)*	-0.00039	-0.0103	(0.0022)*	-0.00015
Years of schooling	0.0944	(0.0277)*	0.00278	0.1812	(0.0313)*	0.00270
Years of schooling sq.	-0.0013	(0.0006)**	-0.00004	-0.0028	(0.0007)*	-0.00004
Right	0.1780	(0.0765)**	0.00524	0.2477	(0.0866)*	0.00369
Centre	0.1982	(0.0746)*	0.00583	0.1870	(0.0853)**	0.00279
Left	0.3013	(0.0783)*	0.00887	0.2455	(0.0881)**	0.00366
Refusal (reference)	-	-	-	-	-	-

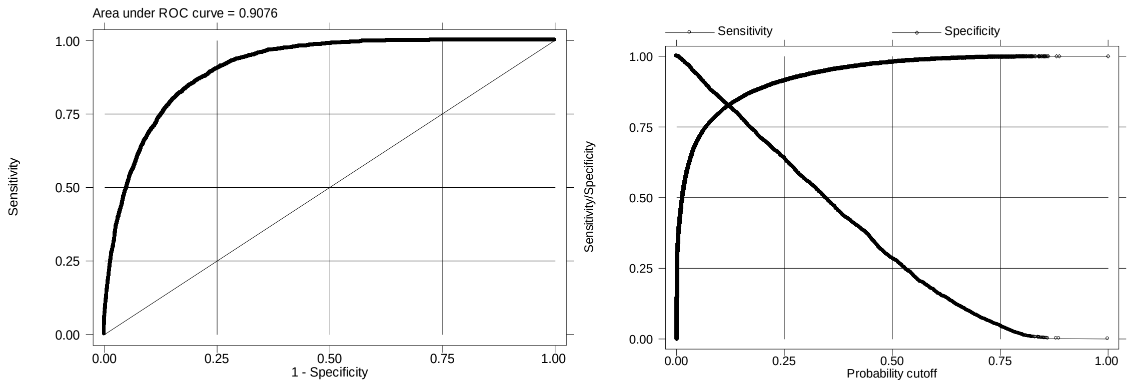
Male	0.1905	(0.0433)*	0.00560	0.2398	(0.0458)*	0.00357
Unmarried	-0.1825	(0.0569)*	-0.00537	0.0659	(0.0616)	0.00098
Household size	0.0129	(0.8290)	0.00038	-0.1815	(0.0901)**	-0.00270
Household size sq.	-0.0081	(0.0119)	-0.00024	0.0167	(0.0132)	0.000249
Household children <15	0.8211	(0.0569)	0.00241	-0.0264	(0.0612)	-0.00039
Time dummy 1997	-2.4780	(0.4453)*	-0.07289	-4.8825	(0.4985)*	-0.07277
Time dummy 1998	-1.5638	(0.4537)**	-0.04591	-4.1932	(0.5053)*	-0.06250
Time dummy 2000	-0.3704	(0.4506)	-0.01090	-4.0442	(0.5088)*	-0.06027
Diagnostics						
Log-likelihood function		-7807.94		-6803.28		
Number of observations		34349		34412		
Correct classification (%)		89.63		91.61		
Sensitivity (%)		49.67		28.51		
Specificity (%)		96.00		98.15		
Area under ROC curve (%)		92.39		90.76		

Note: * Significant at the 1% level
** Significant at the 5% level

The diagnostics and classification statistics suggest that the fitness of the model is good, while the coefficients are jointly significant. Figure 4.11 depicts the plots of ROC curve and classifications in the two models. Then, it is right to proceed with the interpretation of the models.



Model 1



Model 2

Figure 4.11. The ROC curve, sensitivity versus specificity in model 1 and 2

4.2.2. MODEL INTERPRETATION

In model 1 the estimated coefficient for the price term is –0.0063 with standard error 0.0033 significant at 5% level. The marginal effect of price is –0.0002 at sample mean value price of $49.89, which indicates that the demand for internet access in Europe is highly inelastic. This means that, a one-pound increase in access price reduces the probability of internet access by 0.02%, ceteris paribus. The corresponding figure in model 2 is still small; 0.01% at same mean value price.

On the other hand the addition of one more host per 1000 people in the network at mean host number of 37.5 increases the probability of the demand for access by 0.015% ceteris paribus. However, the fault rate is insignificant in first model, but significant in the second one. Its sign is positive, but it was expected to be negative. This suggests that more accurate data on service quality should be used.

In overall, by including attributes of the decision-maker in the model, the attributes of the choice deemed to become insignificant at the 1% level, except the network size. However, in the residential access model, by comparing the marginal effects of the internet size with the marginal effects of socio-economic variables, like occupational status (student, 3.79%), income (highest quartile 2.17%) and new high-tech index (9.21%) it seems that the evidence for access externality is small in magnitude.

How consistent is this finding with the economics of networks that considers the network size to be the dominant driver of Internet access demand? Consistency will occur, if the network size is interpreted in qualitative and not in quantitative terms. It is not the number of already subscribers as such that the individual considers when facing the decision of accessing the internet. It is rather *who* the already-existing users are (access qualitative externality) and *why* are they online (usage qualitative externality). These kinds of qualitative externalities are known in the literature of telecommunications demand as the dynamics of information exchange and search (Taylor; 1994). In other words, since most people belongs to groups (either occupational, social or political), and each group has a community of interest within itself, it is plausible to assume that the number of the people in the group entering the network is critical for the rest members of the group whether to do the same or not. For instance, a professor is better off by accessing the internet if people with similar interests have done the same, or if he/she can access a critical amount of *certain* web documents, like online journals (dynamics of information search). Therefore, he/she can search and exchange information, communicate with colleagues (dynamics of information exchange) at a lower cost and effort than the traditional ways. For example, library search and telephone network.

The highest quartile of income is highly significant. By holding the means of the other income quartiles constant, then as income enters the fourth percentile, the probability of access increases by 2.17%. That the likelihood of internet subscription declines with poorer households was an expected result and confirms findings from other studies (Taylor et al, 1999).

Since other ways of Internet access were inexistent in the period 1997-2000, a PC is the essential device for Internet access. Households with increased probabilities of access can be expected to possess multiple consumer durables of communications. As the new high-tech changes from 1 to 0, then the probability of access decreases by 9.21%. In addition, households with access to older forms of information technologies are more inclined to access the Internet, than those who traditionally have not consumed these commodities. In addition, familiarity with high technologies helps the individual to learn how to use the new ones.

Country differences in internet access demand remain statistical significant even after controlling for social and economic backgrounds of the respondent. This indicates that the structure of opportunities within countries and the technological endowments influences internet demand. For instance, being in Greece it reduces the probability of access by 3.37%. Hence, a randomly selected company manager in Copenhagen is more likely to consume internet access services both at home and at work than an equivalent randomly selected individual in Athens. Key telecommunications companies, like Nokia and Ericsson are situated in the Scandinavian countries and individuals are more familiar with information technologies (Henten and Kristensen, 2000). Then, it is highly possible that residuals factor, such as research & development in each country to be important predictors of demand (Bauer, Berne and Maitland, 2002). In addition to this, Scandinavian countries and obviously the UK have increased probabilities of demand since the English language is widely understood. In addition, in the UK Dixon's free internet services since 1999 induced access demand to increase even more (Crackenell and Majurdam, 2002).

However, the case of low demand in France and Germany is somehow striking. Being in France reduces probability of access by –2.9%. Many studies attributed it partly to the lack of knowledge of the English language and that Minitel is still considered as a substitute to Internet[20] (Rogers, 1995). Additionally, the low demand in southern countries is partly due to the bad network performances. However, among all the EU

[20] Minitel is a Teletel network and exists in France since 1983. By the end of 2000 there were more than 15 million users.

countries, Greece, Portugal and Spain showed the highest levels of people interested in accessing the internet (Eurobarometer 112, 2001). Therefore, it seems that people in this countries are possibly constrained by the know-how in using this technologies. For instance, in Greece there were only 52 subcriptions to ADSL during 1999 (Sarikakis and Terzis, 2000). In addition, the interaction of time dummies and countries shows that internet connectivity has increased, in overall, since 1997.

Among the most connected groups are students and professional individuals that are conducting office-related activities. In model 2 when the employment status changes to manager, then the probability of access increases by 1.11%, while it decreases by 0.7% if the status is manual worker. In model 1, managers are less active consumers of internet access, probably due to time constraints from their increased management responsibilities. Moreover, professional and managerial jobs, unlike manual employments, provide the individuals with training assistance and technical support. Furthermore, they provide salaries affording consumer durables such as computers. It seems that there is a spurious correlation between income, years of schooling and occupation.

Moreover, schools and colleges provide an environment that is exceptionally rich in all forms of info-tech and indeed are the first institutions to be online. Commonly, they provide students with free email and web hosting facilities and direct hands-on experience information search and exchange (Norris, 2000). Being a student increases the probability of access by 3.79%. Retired and unemployed people have the lowest connectivity among the other groups when the reference category is the self-employed status.

Age continues to be a significant determinant for internet access. That young people are more likely to access the internet is not difficult to explain. Elderly people are not familiar with the new forms of technology. For a child, learning how to write with a pencil is as new as learning how to type on the keyboard. The writing of a letter as new as electronic mail. However, for the elderly it is not so simple to change norms and ways of doing things. Although the internet should suit well to their needs, because of considerable leisure time for social networking and online activities.

Political affiliation still persists. Internet offers opportunities in public life engagement. For instance, Norris (2001) shows that people who use the Internet feel that they have more knowledge of the EU institutions and vote more often to the European parliamentary elections than non-users. If status changes from refusal to admittance the probability that the individual is an internet consumer increases at least 0.5%.

In addition, single males are more likely to access the Internet than married females. This is possibly explained by special idiosyncrasies attributed to men. For example, it is argued that women are more restrained towards the use of technology and telecommunications service than the men, due to the “technology fear”. In addition, Internet as a diversified mean of communication, that is, through voice, text and visual data transmission, may be more valuable for single persons than persons with families.

Notably during 1997-2000 internet is not yet considered as a service for the whole family. This is confirmed by the insignificance of the household size coefficient, which is accordance with Taylor’s study (Taylor et al, 1999). It seems that the TV is still the traditional medium that the household gathers around to view. Finally, the effect that children have on the household decision to consume internet services is negligible when conducting the logit analysis.

4.2.3. POLICY IMPLICATIONS

The European information society policy involves a combination of market and state initiatives aiming at reducing the costs of Internet access and making terminals available in public places like unemployment offices, libraries and schools (e-Europe 2005, 2002).

If the estimation results persist under further investigation, policy issues, such as universal access to the Internet, pricing issues and ISP competition can be addressed. These issues have been considered extensively at the Lisbon Summit in 1999 when drafting the e-Europe Action Plan 2002.

The first priority should be placed on increasing the social dimension of the policy. Patterns of behaviour indicate that usage is correlated to structural levels of economic and social development. There is a huge economic deficit that de facto reduces many people's opportunities offered by the new technologies. Usage of IT can become a constituting element for a new categorisation of social classes, unless specific policies are put into place (Ricci, 2000; Servaes, 2002). For example, the British government adopted state initiatives in that direction. The department of Trade and Industry introduced schemes like redistribution of reconditioned computers to poor households.

Demand for Internet access is directly affected by the regulations governing the retail prices of telecommunications services, such as local telephone prices. In Europe, local telephony access charges are very high compared to the US. In addition, the dominant ISPs are subsidiaries of divisions of incumbent telephone companies. Therefore, by decreasing the cost of access and increasing the competition in the ISP market, it is possible that more people will afford it and hence demand internet services.

Furthermore, evidence suggests that English language ability and the American culture of the Internet seems to be some of the reasons why access at the EU level is not so widespread as the US. Therefore, the European Commission should carry initiatives in developing websites with local content available in all the European languages. According to Eurobarometer data, after the recent development of the EU official website into a multi-lingual one, visits on the Europa server have been increased.

It is necessary that EU initiatives in networking public and private junior schools should be continued. It should be noted that in schools, PC's are used quite effectively as teaching instruments. It is a belief that if children learn how to use the computer and the internet, then residential demand is highly possible to increase. However, there is the other side of the coin. Internet may be harmful for children if used inappropriately. At present, most public schools are censoring the Internet by filtering its context. This guiding principle is sometimes subject to criticism, as being against the freedom of the individual.

PHASE V: CONCLUSION

SECTION 5.1. PROJECT EVALUATION

Given that the utility difference derived from the demand of internet access services and the non-subscription to the network is unobserved, this project estimated the predicted probabilities of access using a logit model. In this model internet access is measured as a dichotomy. The building blocks of the model were based on the economics of networks. For that reason, the attributes of choice are the network size, quality of service and access price. However, in overall, the attributes of the decision-maker are more important determinants of the demand that the attributes of choice. To summarise, three major findings stand out: Internet access demand is driven by (a) non-price factors (b) qualitative access and usage externalities and (c) human capital factors.

Internet access demand is driven by non-price factors. The price of access does not persist statistically at the 1% level as most of the other variables. This is in accordance with the theory proposed by network economics. Therefore, in spite of the general pattern of falling access prices observed in Europe in the period under examination, the increase in demand for internet access is principally driven by the attributes of the decision-maker who has to make stochastic choices. In turn, the output data gives rise to a qualitative rather than a quantitative measure of the network size.

Internet access demand is driven by qualitative access and usage externalities. The network size is significant at the 1% level, even after controlling for of the decision maker. However, its marginal effect is relatively small in magnitude compared with the effects of certain the socio-economic characteristics, like occupational and marital status. Yet, the theory of network externalities, does not fail. Demand for access is induced by internet endogenous growth. This is to say utility derived from internet access, after taking into account the negative externalities from access and usage, interdepends on the *characteristics* and *size* of online population. In terms of usage, the individual is better off if the internet provides the means to develop information exchange and search in accordance to his own special needs.

Internet access demand is driven by human capital factors. The statistical significance of education, age and the new high-tech index at 1% confirms the existence of relative views of complicatedness of internet technologies. It is suggested that computer literacy and training are factors that constrain individuals from consuming internet access services. In the new economy, as it is termed by many, the building blocks of growth are not simply land and capital; the know-how of the necessary equipment is equally important. Any initiative in the direction of computer training, for example through education, will induce more people to demand internet access. Additionally, as human capital factors are spuriously correlated with the household income, it is also necessary to increase the competition in the internet service provider (ISP) market and hence reduce the cost of access.

SECTION 5.2. FUTURE RESEARCH

For future research on this topic, it would be important to address internet usage externalities in more detail, because are part of the network effect. In addition, a model to analyse between the choice of broadband and narrowband connection types is necessary. Moreover, research should be extended in other countries and also within countries. Future and more detailed research is required because internet is a fast diffusing and evolving service; empirical research need to be updated continuously under the light of new developments.

To account for usage externalities, the model should include the time spent online, the amount and type of data transferred and what the actual uses of the internet are after the implementation of access. Eurobarometer surveys are detailed enough to provide the necessary data. It should be interesting to account whether the internet is changing individuals' norms and attitudes. Does the fast ways of communication, the existence of vast information streams and the diversification of online usage services are calibrating individual behaviour in consuming and forming habits? Surveys need to go deeper and search whether the information society is evolving into a knowledge society. High Internet penetrations means little if internet is used as an entertainment machinery and not as a tool of managing and producing knowledge.

Some studies indicated that price effect, in a model of internet access demand, is highly significant when considering the introduction of high-speed services[21] (Taylor et al, 2002). Broadband prices are extremely high for the moment. The question to answer is, therefore, if externalities will still remain significant in the access demand analysis. The cost of access will now be correlated with the speed and therefore with the quality and the utilisation of service. A host with low-speed connection cannot

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[21] For instance, $y = (j : j = 0,1,2)$; 0=No Internet Access, 1=Dialup Access, 3=ADSL Access. Hence, $\Pr(\text{choice}_j) = e^{\beta_j' x} \Big/ \sum_j e^{\beta_j' x}$.

perform as good as a host with high-speed connection. Given that technology is unchanged, then the individuals while forming their decision to access the internet or not might give more weight on the cost of access devices (price effect), rather than on the characteristics of the already existing subscribers (network effect). For instance, as a measure to avoid discriminations in the internet speed connection, the Commission motivated the Member States to install broadband connections in public administrations by 2005 (e-Europe 2005, 2002).

Econometric models should also include country regions. For instance, in the east territories of Germany consumption of internet services is 12%, whereas in the west is 14%. At the same time, models should be developed to measure demand in the new member-states and in the candidate countries for accession. This will form the basis for a more informative information society policy-making. Possibly, qualitative network effects will prevail in a similar way as in this study. Furthermore, internet is a global and not a European medium, therefore its effects are global. Therefore, this project has set the agenda for techno-economic analyses of internet access demand on a world scale. As figure 1.1 shown, access services have been consumed only by 10% of the worldwide population until the end of 2002.

Internet economics undergo ongoing research developments. It is thus a fruitful and promising area for further research in terms of both theory and practice. For the time being, only pricing internet issues have been addressed. Most of the economists, like Varian, has proposed different pricing schemes for the internet in remedying congestion. This constitutes an amalgamation of economic and engineering techniques. Yet, many other issues, such as welfare internet economics, are untouched. As the results suggest, to induce further internet demand it is necessary to examine in greater depth the demand determinants. More qualitative information about individuals and both theoretical and empirical work will help uncover the answers to this question.

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