Open access • Journal Article • DOI:10.1080/10438590600984026

Inter and intra firm diffusion of ict in the united kingdom (uk) and switzerland (ch) an internationally comparative study based on firm-level data — Source link

Giuliana Battisti, Heinz Hollenstein, Paul Stoneman, Martin Woerter

Institutions: Aston University, ETH Zurich, University of Warwick

Published on: 01 Oct 2007 - Economics of Innovation and New Technology (Routledge)

Topics: Diffusion of innovations and Comparative research

Battisti, Giuliana; Hollenstein, Heinz; Stoneman, Paul; Wörter, Martin

Working Paper

Inter and intra firm diffusion of ICT in the United Kingdom (UK) and Switzerland (CH): An internationally comparative study based on firm-level data

KOF Working Papers, No. 111

Provided in Cooperation with:
KOF Swiss Economic Institute, ETH Zurich

Suggested Citation: Battisti, Giuliana; Hollenstein, Heinz; Stoneman, Paul; Wörter, Martin (2005) : Inter and intra firm diffusion of ICT in the United Kingdom (UK) and Switzerland (CH): An internationally comparative study based on firm-level data, KOF Working Papers, No. 111, ETH Zurich, KOF Swiss Economic Institute, Zurich, https://doi.org/10.3929/ethz-a-005104767

This Version is available at:
http://hdl.handle.net/10419/50862

KOF Konjunkturforschungsstelle
Swiss Institute for
Business Cycle Research

Arbeitspapiere/ Working Papers

Giuliana Battisti, Heinz Hollenstein, Paul Stoneman and Martin Wörter

Inter and Intra firm Diffusion of ICT in the United Kingdom (UK) and Switzerland (CH)

An Internationally Comparative Study Based on Firm-level Data

No. 111, November 2005

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Inter and Intra firm Diffusion of ICT in the United Kingdom (UK) and Switzerland (CH)

An Internationally Comparative Study Based on Firm-level Data

Giuliana Battisti*, Heinz Hollenstein**, Paul Stoneman***, Martin Woerter**

* Aston Business School, Birmingham -UK
** Swiss Federal Institute of Technology, Zurich -CH
*** Warwick Business School, Coventry -UK

Abstract

This paper attempts to at least partially redress a paucity of current literature on the joint analysis of inter and intra firm diffusion of innovations within as well as across countries. In particular, by using two datasets derived from independent country-specific surveys, it undertakes an international comparison of inter and intra firm diffusion of ICT use in the UK and Switzerland. This allows one to address many of the problems that have prevented general conclusions on the drivers of inter and intra firm ICT adoption decisions. An encompassing model is proposed which gives quite satisfactory results for both countries. It is found that inter and intra firm ICT adoption decisions are driven by different factors, confirming the findings of Battisti and Stoneman (2003, 2005) and Hollenstein and Woerter (2004) that ”first use’’ and ”intensification of use” represent independent choices. The study also suggests that significant differences exist between the UK and Switzerland, probably as a result of their differing diffusion stages. Besides, the importance of new organisational and managerial practices as drivers of diffusion stressed by recent theoretical and empirical work is supported for both countries. Overall the findings suggest that comparative research is a promising way to identify robust relationships and should be explored further.

JEL Classification: O3

Key Words: Technological diffusion, ICT and e-business activities, international comparison
Corresponding author: G. Battisti , OIM group, Aston Business School, Aston University Birmingham B4 7ET, UK; Tel. 0121 204 3028; Fax.0121-359 5271, email: g.battisti@aston.ac.uk

Introduction

In the last few years, research has made great progress in understanding and modelling the factors that lead to first adoption of an innovation, i.e. inter firm diffusion (see Karshenas and Stoneman, 1995 and Hall, 2004 for surveys). However, as emphasised by Battisti and Stoneman (1997, 2003, 2005), if one is interested in the benefits generated by an innovation within an economy, it is also important to understand the determination of the extent of use by adopting firms after first adoption (intra firm diffusion)[1] but the literature on intra firm diffusion is still quite limited. After the seminal work of Mansfield (1968) and Stoneman (1981), based upon learning and information acquisition, further theoretical developments have been made by Battisti (2000) and Battisti and Stoneman (2005), based upon profitability considerations, while the empirical analysis of intra firm diffusion of IT technologies has been advanced by among others Astebro (2004), Battisti, Canepa and Stoneman (2004) hereafter BCS (2004), Fuentelsaz et al. (2003), Hollenstein (2004) and Hollenstein and Woerter (2004). Moreover, most theoretical and empirical work upon diffusion seems to focus either solely on inter or solely on intra firm diffusion rather than recognising that the two processes often have common features and may well interact. Exceptions are the work of Battisti and Stoneman (2003, 2005) on the diffusion of CNC as well as BCS (2004), Hollenstein (2004) and Hollenstein and Woerter (2004) on the diffusion of the internet, E-purchasing and E-selling.

One of the causes of the paucity of intra firm studies is to be found in limited data availability. In fact, data on the within firm extent of use of a new technology over time is not systematically collected by any statistical agency and ad hoc national surveys are the only (rare) source. It is even more difficult to find cross-country comparative data and thus to have the possibility to control for country-specific factors such as institutional arrangements that may obscure the real importance of other variables. As a result cross-country comparisons tend to be based upon surveying existing national studies of specific innovation, these often being based on slightly different definitions, different datasets (panel data or cross section) and model specifications (dependent variables, explanatory variables, etc.) thereby restricting the validity of any cross-country conclusions drawn (see for example Canepa and Stoneman (2004) on the diffusion of AMT). Even rarer is data on the diffusion of multiple innovations within a

[1] See Battisti and Stoneman 2003 for further details on the extent of the importance of inter and intra firm diffusion over time.

country where innovations can be analysed in parallel using the same model, exceptions being the work of Stoneman and Toivanen (1997) on the simultaneous adoption of multiple technologies in the UK or the studies based on sub-categories of AMT (Arvanitis and Hollenstein, 2001, Colombo and Mosconi, 1995) or ICT (Hollenstein, 2004) or E-commerce (Hollenstein and Woerter, 2004, BCS, 2004). Recently Comin and Hobijn (2004) have made available a multi-technology, multi-country diffusion data set that will to some degree alleviate some of the problems. Even this data set however, like all the internationally comparative data sets known to us to have been used in published research, is confined to inter firm diffusion and as far as we are aware there are no internationally comparative studies of intra firm diffusion. In that sense this paper is unique.

In this paper we analyse *inter* and *intra firm* diffusion of ICT in the UK and Switzerland by applying the same model specification and the same estimating procedure to both countries. Most empirical studies of diffusion in Economics tend to focus on *one (or perhaps two) alternative specific model(s) of diffusion, e.g.* probit or epidemic models (see Karshenas and Stoneman, 1995 for a survey and classification of models). It would be better to test either an encompassing model or use a general to particular methodology (see, for example, Karshenas and Stoneman, 1993 and Colombo and Mosconi, 1995), which is an approach extended by Stoneman and Battisti (1997) to intra firm diffusion. That is what we intend to do here.

The model specification and the variable selection criterion is based upon BCS (2004), that propose an "integrated" equilibrium diffusion model that extends the list of determinants of the intra firm diffusion of ICT to those factors that have traditionally been shown to affect inter firm diffusion i.e. rank, epidemic, stock and order effects. This model allows one to control, inter alia, for country specific factors as well as other key drivers of the inter and intra firm diffusion of ICT technology in the two countries.

Among the key determinant of diffusion, particular emphasis is here put on the role of organisational and managerial innovation. This is to reflect the increasing interest in the current literature on the economics of technology diffusion on *organisational and/or managerial changes* as a means to better exploit potential efficiency gains arising from the adoption of an innovation. Milgrom and Roberts (1990) strongly argued for the complementarity of ICT-based innovations in a firm's activities in manufacturing, engineering, marketing and organization (management style, workplace organization,

user/supplier relationship), presenting a theoretical model of a firm optimising its activities in the presence of such complementarities (see also Milgrom and Roberts, 1995). Brynjolfsson and Hitt (2000) make a strong case for the complementarity of investments in ICT and organization (and other intangible assets) based on a review of empirical evidence from case studies and microeconometric work. Bresnahan et al. (2002), among others (e.g. Greenan and Guellec, 1998 or Gretton et al., 2004), find a significantly higher return on investment in ICT in firms that have established more flexible and decentralised forms of workplace organization than in those sticking to a more traditional centralised organisational design. However, the relationship between organisational change (at the managerial level or at the workplace) and technology diffusion has yet to be established, based on an "integrated" diffusion model (as proposed by BCS, 2004), although some previous work is available (see for example Battisti and Stoneman, 2005 on the impact of new managerial practices, Battisti et al., 2005 on joint design and CAD, or Hollenstein, 2004 on the relationship between decentralised workplace organization and the use of ICT, with the two last-mentioned papers dealing with the problem of causality between technological and organisational innovations). In the present context, most importantly, it has to be established whether the impact of organisational and managerial changes do differ between inter and intra firm diffusion. This is therefore specifically approached in the modelling.

Initially a bivariate probit model allowing for sample selection is estimated which is built upon the assumption that intra firm diffusion is co-related to the decision to first adopt. However, since the two decisions turn out to be independent, we re-estimate each of the two steps using separate independent probit models: one for adoption (inter firm diffusion) and one for the extent of use of ICT (intra firm diffusion). In so doing, we address at least some of the above mentioned problems that have prevented general conclusions on the drivers of intra and inter firm technology diffusion.

The UK dataset used in this paper is basically a cross section outsourced from the third UK Community Innovation Survey (UK-CIS3). The Swiss data comes from the Swiss Community Innovation Survey carried out in 1999 (CH-CIS) and the ICT survey conducted in 2000. However, some firms as well as some variables were present in only one of the two datasets. Moreover, in order to match the information contained in the UK-CIS3 dataset, firms with less than 20 employees and some industries had to be dropped. This has reduced the usable sample to 479 Swiss firms. The UK dataset has been adjusted accordingly leading to a usable sample of 4642 UK enterprises.

The paper is structured as follows: Section 2 and 3 are devoted to a description of the database and the pattern of ICT usage in UK and Switzerland. Section 4 describes the conceptual framework and presents the empirical model. In section 5 the estimation procedures are discussed and the empirical results are presented. Finally, in Section 6 we summarise and assess the main findings of the paper.

2. The datasets

The data used in this paper derives mainly from the Community Innovation Survey (CIS) which is part of a series of Pan European surveys of the extent of innovation activities carried out by European firms. The CIS contains data upon a number of indicators of innovativeness and firm characteristics. In the UK the survey was administered by the Office of National Statistics on behalf of the Department of Trade and Industry (DTI). Particularly interesting to our study is the third UK CIS survey (UK-CIS3) as it contains information on both inter firm and intra firm usage of e-business.[2] In particular question 17 requests information upon extent of the enterprise's use of e-business activities over the period 1998-2000. This allows one to measure the extent of adoption of e-business via the number of firms that are using the internet (inter firm diffusion) and the extent of their internet use (intra firm diffusion) which we define as either 'basic' or 'enhanced'[3] (see BCS, 2004 for further details on this classification). We therefore define three mutually exclusive categories of users: i) *Non users*: those firm that had not adopted the internet by 2000; ii) *Basic users,* those firms that report

[2] We tried matching the information available in the UK-CIS2 for those firms present in the UK-CIS3 but the resulting cohort of firms reduces to an extent that would cast serious doubts on the significance and representativeness of the population of UK firms (see also footnote 8). At the time of the writing of this paper the ONS is carrying out the fourth CIS survey in the UK. This could have provided us with the longed longitudinal time dimension had the question on the extent of use of e-business not been omitted from the questionnaire.

[3] Intra firm diffusion is often measured by indicators such as the proportion of the firm's capital stock that embodies the new technology, or the proportion of output produced using the new technology, or, say, in the current situation, the proportion of employees connected to the internet (see, for example, Arvanitis, 2005). The UK data does not provide information on such measures. We are able however to consider intra firm diffusion via a different metric. As e-business spreads, one might not only expect the number of users in the firm to increase but also for the range of tasks that they perform using the technology (also or alternatively) to increase and/or for the tasks that they perform using the technology to increase in sophistication. Although respondents to the questionnaire were asked to tick all that apply, it was clear that respondents did not follow this instruction. We are thus unable to use the number of tasks performed by users as a metric for intra firm diffusion in this research. We are thus limited to using the sophistication of tasks performed as a measure of intra firm diffusion. This is very similar to Forman et al. (2002, 2003) who, using similar data to that available here, and looking at internet usage in the US,

only a basic internet presence and use the internet only for information and other basic applications (e.g. e-mail); and iii) *Enhanced users,* those firms that engage in more complex transactions allowing customers to place orders and/or who commerce with other businesses through the internet site. From an original sample of 126,775 records on the UK Inter Departmental Business Register, the UK-CIS3 questionnaire was sent to a stratified sample (by industry and firm size) of 19,602 enterprises with more than 10 employees and located in industries 10 to 74 of the SIC 92 industrial classification (see Appendix 1). Of the original sample, 8,173 responses were eventually registered. We have no reason to believe that there are any particular biases in this final sample, although we are not aware of any formal checking of this for CIS3; a post survey random sample of 317 non respondents in CIS2 showed no bias in the returned sample (see Economic Trends, Office for National Statistics, October 1998).

The pattern of ICT usage in the Swiss business sector is based on matched data derived from two surveys carried out in 1999 and 2000 respectively. The earlier survey focused on the innovation activities of Swiss firms (CH-CIS), while the latter dealt with ICT and workplace organization. The two surveys were based on the same sample of firms covering manufacturing, construction and (commercial) services. The sampling frame of the CH-CIS survey was determined by stratifying 28 industries and 3 industry specific firm-size classes, with full coverage of large firms. The ICT survey was sent to a sample of 6717 firms with more than 5 employees, yielding a response rate of about 40% (2641). The survey on innovation was sent to 6435 firms with more than 5 employees; the response rate amounts to 33.8% (2172). On both surveys a non-response analysis was undertaken in order to correct for "unit" non-response. Some selectivity bias was found in both surveys, which has been corrected by a suitable weighting scheme (see Donzé, 1998 for the procedure).[4]

Similar to the UK-CIS3, the CH dataset contains information on the extent of intra firm use of e-business that allows one to use the BCS (2004) classification reflecting whether by 2000 firms are: *i) Non-users*: when the firm has not introduced the internet up to 2000; ii) *Basic users***:** when the firm has introduced the internet by 2000 but does not

---

draw a distinction between participation (is the internet used) and enhancement (how extensive are the uses to which it is put).

4 "Item" non-response is a further problem of survey data. The usual procedure dropping observations with incomplete data may produce biased estimates. Therefore, we substituted imputed for missing values using the "multiple imputation" method proposed by Rubin (1987). The corrections for the two types of non-response was necessary in order get reliable information on the diffusion of ICT.

use it as an enhanced user does, but instead uses it, for example, to search for information in general, advertising, online discussions, further education; ii) *Enhanced users*: when a firm has introduced the internet by 2000 and use it for one of the following internet-applications: buying of products or services **or** arranging payments **or** usage of virtual markets for firms (Business-to-Business) **or** other internet-applications in order to obtain goods/services **or** selling (without online-payment) **or** selling (with online-payment).

To keep the Swiss data comparable with that from the UK the two samples had to be restricted to the industries in the UK dataset which involved excluding industries 10-14 of the SIC92 classification for the UK and removing data from the CH dataset for industries 50 (part of wholesale), 52 (retail), 55 (hotels and restaurant), and 93 (personal services). In addition, the Swiss organisational variables were available only for firms with at least 20 employees. This has led to a further adjustment in the UK sample size. The resulting working samples are 4642 observations for the UK and 479 observations for CH.[5]

3. Patterns of ICT use in the UK and Switzerland

As emphasised by Battisti and Stoneman (2003) the diffusion pattern of an innovation can be decomposed into two components: inter and intra firm diffusion. Inter firm diffusion is essentially the degree of penetration of the innovation across the firms within an industry which we measure by the within industry proportion of firms that have adopted ICT by 2000. Intra firm diffusion is essentially the extent of use of the innovation by the adopting firms which we measure here as the proportion of firms that use ICT at a basic or enhanced level. In Tables 1a and 1b we report such diffusion patterns in 2000 based upon the information contained in the CH and the UK datasets respectively.

The first row of Tables 1a and 1b indicates that by 2000, while non-users are the smallest group in both countries, the percentage of basic users in the UK (62.3%) corresponds almost to the percentage of enhanced users (74%) in CH. On the contrary

[5] The UK sample size used in this paper equals that in BCS (2004) 'minus' those firms with less than 20 employees and those firms belonging to sector 10-14. This is one of the reasons why the UK results quoted here differ from those in BCS (2004).

the group of enhanced users in the UK (28%) is approximately as large as the group of basic users (17%) in CH. This suggests that despite the extent of inter firm diffusion being about the same in both countries (93% CH and 90% UK), the extent of intra firm diffusion of ICT differs markedly between the UK and CH. In particular, ICT was in 2000 used far less intensively in the UK than in Switzerland.

Insert Table 1a and 1b here

The second part of Tables 1a and 1b shows the distribution of use by industry. In both the UK and Switzerland the service sector uses ICT more intensively than manufacturing industries. In fact, both countries the SIC categories with the highest percentage of enhanced users are in the service sector (see SIC 60 to 74) while the SIC categories 30-33 and 23-29 comprise the largest percentage of enhanced users in the manufacturing sector. The percentage of basic users in Switzerland is relatively high only in SIC 40-41 (manufacturing) followed by SIC 51 (services). In the UK this percentage is particularly high in manufacturing (SIC 30-33 up to SIC 40-41) and construction (SIC 45) but not in services. Non-users are found predominantly in the construction sector which has also the smallest group of enhanced users. Therefore despite there being differences in the intensity of use between the UK and CH, there is consistency across sectors in the two countries.

The last part of Tables 1a and 1b shows the distribution of use by firm size. In both the UK and Switzerland larger firms seem to be more likely to have adopted ICT by 2000. However, basic users and enhanced users are rather equally distributed across the different size classes with enhanced users being slightly more likely to be observed in medium to large firms (250 employees and above). The largest percentage of non-users is associated with the class of firms with 20-49 employees.

The similarities in the inter firm diffusion pattern across sectors and firm size classes in the two countries seem to suggest that ICT usage depends to a large extent on market specificities, technological opportunities and on general structural characteristics. However, the fact that the UK reports a lower level of intra firm diffusion in all sub-categories suggests that comparative modelling will be necessary to understand the nature and the drivers of such differences across the two countries.

4. Conceptual framework: an integrated model of diffusion

The conceptual framework adopted in this paper is taken from Battisti and Stoneman (1997 and 2003) and later extended by BCS (2004) on the diffusion of e-business activities. They construct an encompassing model reflecting the different strands in the inter firm diffusion literature and then let the data indicate whether these strands are empirically relevant to intra firm diffusion. In both inter and intra firm dimensions the model is designed to reflect several equilibrium (i.e. rank, stock and order) approaches and disequilibrium (i.e. epidemic learning) modelling traditions (see Karshenas and Stoneman, 1993 for a classification of such effects).

The essence of the BCS (2004) model is that firm i in industry j will first adopt or extend use of a technology when the marginal profit gain in time t, $\Pi_{ij}(t)$, from either first use or the extension of use by one unit is greater than the expected adoption cost $P_i(t)$ of a unit of that technology (all potential adopters being assumed price takers on all markets). It is assumed that $\Pi_{ij}(t)$ is a function of:

i. the extent of adoption and/or use of the new technology $\mathbf{x_i(t)}$ by firm i in time t;

ii. a vector of firm, $\mathbf{R_i}(t)$, and environmental/industrial, $\mathbf{R_j(t)}$, characteristics reflecting the concept of *rank effects*;

iii. the extent of industry usage of the new technology $\mathbf{y_j(t)}$ reflecting between-firm *stock* and *order* effects, upon the basis that the payoff to the firm depends upon what rival firms are doing. These effects are generally expected to be negative unless network effects are particularly strong;

iv. two "experience" terms, to reflect *epidemic* arguments, the first being a measure of the firm's own experience, $\mathbf{E_i(t)}$, (often proxied by time since own first adoption), the second being the experience that the firm gains from observing other users, $\mathbf{E_j(t)}$, (often proxied by the extent of diffusion in time t).

We therefore write:

$$\Pi_{ij}(t) = \Pi_{ij}\{x_i(t), R_i(t), R_j(t), y_j(t), E_j(t), E_i(t)\} \quad (1)$$

The essence of any diffusion model is that it is dynamic providing insights into the spread of a technology over time. However the data available to us are single cross sections that provide snap shots of the state of that dynamic process in the year 2000. It is thus obviously not possible to explore the dynamics of the process. Instead we intend to use the model to predict the factors that should be considered as determinants of in inter and intra firm usage in the year 2000 in the two countries. The cross section approach is also used by Forman et al. (2002, 2003), BCS (2004) and Hollenstein (2004) in similar analyses (a rare example of an analysis based on longitudinal data is Battisti et al., 2005).

Under appropriate assumptions BCS (2004) show that using (1) the extent of use may be determined as (2):

$$x_i(t) = G\{R_i(t),\ R_j(t),\ y_j(t),\ E_j(t),\ E_i(t),\ P_i(t)\} \qquad (2)$$

which we take to be our estimating equation[6] of the determinants of e-business usage in 2000. Using (2) and following Battisti and Stoneman (2003, 2005) we thus specify two models with common sets of covariates and dependent variable based on the definition of non-users, basic users and enhanced users present in the CH and the UK datasets. In the first model the dependent variable "ADOPTION" represents users (whether basic and/or enhanced = 1 and zero otherwise) vs. non-users of the internet. The dependent variable "ENHANCED" represents for those firms that have adopted the innovation, the intensity of use i.e. whether enhanced or basic users of the internet. "ADOPTION" clearly measures inter firm diffusion, "ENHANCED" mirrors the intra firm diffusion of ICT.

We model the remaining covariates based upon the existing inter firm literature as well as data availability. A summary of the variables specification is reported in Table 2.

Insert Table 2 here

[6] It is here assumed that the actual usage $x_i(t)$ does not diverge from the desired optimal level of use $x_i^*(t)$. This is the essence of an equilibrium model of instantaneous adjustment according to which one may directly apply equation (2) to the cross section data (all rhs variables are dated at time t). If, however, there is some time intensive adjustment process that leads to divergences between $x_i^*(t)$ and $x_i(t)$ then such an application will yield biased estimates. In the absence of any insight or data that would enable us to explore any such divergences we proceed assuming that they are not present and thus $x_i^*(t) = x_i(t)$ and we proceed by using (2).

We model the extent of rank effects, $\mathbf{R_i(t)}$, via the following firm specific indicators:

i. Firm size as measured by the number of employees (greater than 20) in full-time equivalents (divided by five) in 1999 for CH and 1998 for the UK. An extensive literature suggests that larger firms are more likely to adopt an innovation. We therefore expect the size of the firm to exert a positive impact upon inter firm diffusion. With respect to intra firm diffusion Battisti (2000) found that although large firms adopt innovations more frequently than smaller firms, once the technology is adopted smaller firms use it more intensively than larger firms. This finding has also been found in studies of the diffusion of e-commerce where the size coefficient often has turned out to be negative or not significant in the intra firm diffusion equation (see BCS, 2004, Hollenstein and Woerter 2004, Hollenstein, 2004, etc). We therefore expect to find a significant positive sign upon size in the inter firm model and a negative (not necessarily significant) sign in the intra firm model.

ii. a series of *innovation variables* reflecting whether the firm has recently introduced any process or product innovation(s) new to the industry (in the CH case: "new to the firm") or whether the firm has been conducting any R&D activities in the previous years. We name such variables *ProcNov, ProdNov* and *R&D*. We have introduced them, following Cohen and Levinthal (1989), on the grounds that innovative firms may have a greater "absorptive capacity" for new technologies. Consequently, they may adopt ICT and E-commerce more frequently than firms which do not innovate. We expect them to exert a positive impact upon inter and the intra firm diffusion.

iii. Education measured by the proportion of employees with a degree in science and engineering (PropSci) and in other subjects (PropOther) in the UK firms; and by the proportion of employees with university or non-university tertiary degree, e.g. a polytechnic degree, a degree in non-university business administration, not differentiated by type for CH. Such variables are used as a proxy for *human capital and skills.* They are expected to exert a positive impact on the adoption and extent of use of diffusion of ICT (see BCS, 2004, Hollenstein, 2004, Hollenstein and Wörter, 2004), or Arvanitis and Hollenstein (2001) in the case of AMT.

iv. Organisational factors (Org) are believed to influence the likelihood of adoption and intensity of use of a new technology. The profit seeking firm will most likely

adopt ICT once new organisational practices are introduced (see Milgrom and Roberts, 1990, Greenan and Guellec, 1998, Brynjolfsson and Hitt 2000, Bresnahan et al. 2002, Gretton et al., 2004, etc). In this case, the UK and the CH specifications of the variable Org are not identical, but sufficiently similar to compare the effects. In the CH case, we use a combined measure based on the introduction of team-working, decentralised decision-making and flattening hierarchical structure. Hollenstein (2004) found that these three elements are the most relevant dimensions of organisational change favouring adoption of ICT. In the UK case we use a variable reflecting whether advanced management techniques and new organisational structures (such as knowledge management, quality circles, the "Investors in People" scheme, diversification, etc.) were introduced between 1998 and 2000. Arvanitis (2005) found for Switzerland that new workplace organization (alone or combined with human capital) have a positive impact on firm performance. BCS (2004) showed for the UK that ICT is most likely adopted once new organisational practices are introduced. We therefore expect a positive sign of the variable measuring organisational change. Besides, one could argue that a positive influence is more likely in case of intra than inter firm diffusion, since adoption costs are much higher if a thorough redesign of a firm's organization is required than for incremental adjustments of organization which, in most cases, are sufficient at the stage of (first) adoption. Therefore, we would not be surprised if organisational factors impact positively only on intra firm diffusion, whereas they are insignificant (or their impact is only weak) in the inter firm equation (for a discussion of small adjustments vs. systemic changes of organization see, for example, Milgrom and Roberts, 1995). Finally, it could be argued that "organisational change" in a cross-section analysis of ICT diffusion may cause endogeneity problems. Due to data limitations this issue cannot be tested. However, Battisti et al. (2005) found that organisational changes and ICT adoption do not take place simultaneously. They also found that the adaptation of organisational structures tends to take longer than the introduction of ICT (see for similar results Bresnahan et al., 2002, Hollenstein, 2004 or Hempell et al., 2004). We therefore assume that the firm's organization changes in a more sluggish way than the adoption/diffusion of ICT.

In order to control for environmental and market characteristics $\mathbf{R_j(t)}$ we include the following sector specific rank effect:

v. Sector dummies (Sic_j, where j=15, 16…74) as well as wider sector classification reflecting whether the firm belongs to *manufacturing* (MANUF - Sic 15 to 41) or *services* (SERVICES - Sic 51 to 74) leaving construction as a reference sector (see Appendix for Sic'92 classification). They reflect the fact that opportunities for using ICT and payoffs differ by sector (as suggested by the pattern of usage shown in Table 1a/b). We leave to the empirics to determine their magnitude and sign.

In equation 2 the remaining terms $\mathbf{y_j(t)}$ and $\mathbf{E_j(t)}$ reflect the within industry extent of use of the new technology by rival firms. In particular $y_j(t)$ accounts for between firm *stock* and *order* effects, also called *pecuniary effects*, while $E_j(t)$ reflects the epidemic type of learning from the experience of the others or *network effects* (see BCS, 2004 for a definition of pecuniary and non-pecuniary or network effects). As standard practice in the literature we measure such effects via the extent of industry usage proxied by the number of users in the sector to which the firms belongs. In particular we measure:

vi. the proportion of firms with enhanced use of internet in the particular SIC category (Intra)

vii. the proportion of firms with at least basic use of internet in the particular SIC category (Inter).

As it improves numerical stability of the model without significantly affecting other parameter estimates, these variables are entered as logit transformations (see also BCS, 2004). Unfortunately this approach will not be able to separate out the negative impact of the stock and order effects from the positive impact of learning and network externalities. We therefore leave to the empirics to determine whether there are externalities and which effect dominates in the diffusion of ICTs.

The remaining variables in (2) are $\mathbf{E_i(t)}$ and $\mathbf{P_i(t)}$.

$E_i(t)$ is a measure of the firm's own "experience" of the new technology aimed to reflect the intra firm *epidemic* learning argument. However, given the cross sectional nature of the dataset and the lack of information on the date the firm first introduced the innovation, we cannot test its impact.

The other term, $P_i(t)$, is the cost of acquiring the new technology. Astebro (2004) in his inter firm study on the adoption of CNC and CAD specifically separates out capital and non capital costs of adoption. For e-business the capital costs might be quite a small proportion of total adoption costs. However, as we are unable to measure adoption costs in total or by sub division we just talk of adoption costs in aggregate. In addition we assume that the adoption cost is the same for each firm and thus include its impact in the constant term. However to the extent that this cost may differ across firm size it will be reflected in the parameter on the firm size variable.

5. Estimation procedure and results

In order to model the extent of ICT diffusion by 2000 we use the bivariate probit model with sample selection (FIML estimation) with the set of explanatory variables X_1 and X_2 and latent variables z_1 and z_2:

$z_1 = b_1'X + e_1$ $\quad$ $y_1 = 1$ (ENHANCED) if $z_1 > 0$, 0 else (3a)

$z_2 = b_2'X + e_2$ $\quad$ $y_2 = 1$ (ADOPTER) if $z_2 > 0$, 0 else (3b)

where $[e_1,e_2]$ are bivariate normal with mean zero, variance equal to 1 and correlation rho measuring the extent to which y_1 and y_2 are related (sample selection). This specification is chosen to reflect the nested nature of the model where y_1 (ENHANCED) is observed only when y_2 (ADOPTER) equals 1. This model has been estimated over the samples of 479 Swiss and 3852 UK firms. For both countries the best estimates are obtained when the industry dummies are specified by wide industry groupings, i.e. Manufacturing and Services. The results are reported in the first two columns of Table 5. For this model the Wald test of independence of equation (3a) and (3b) cannot be rejected (see the last row of Table 3). In line with the findings of Battisti and Stoneman (2003, 2005), that suggests that the intra and the inter firm adoption decisions are independent and that to be an adopter does not necessarily mean to be an extensive user (see also Hollenstein and Wörter, 2004 for similar results).

Insert Table 3 here

The last two columns of Table 3 report the single probit models estimated under the assumption of independence of the intra firm model (a) and the inter firm model (b). It is on these sets of results that we concentrate the remaining part of the paper.

Before proceeding further it is worth noticing that in both inter and intra firm modelling the dependent variable is the state of diffusion in year 2000 while some of the independent variables refer to the year 2000 (e.g. *PropSci* and *PropOther)* and some other to the period 1998-2000 (e.g. Org). We define the former as potentially endogenous while the latter are potentially 'weakly endogenous' variables. However, with the exception of the few variables which we lag and use as an instrument, the potential endogeneity issue relating to these variables cannot be fully addressed. Data limitations are such that earlier data is not available for other firm characteristics. Moreover, the aggregated nature of the partially endogenous variables (i.e. those referring to 1998-2000) cannot be further decomposed. In order to test model stability and potential bias we have estimated the model omitting the potentially endogenous variables (those specified at time 2000). In the UK as well as in the CH case CH case we find that they do not affect the other parameter estimates[7].

5.1. Inter firm diffusion

In both countries the inter firm diffusion of ICT in 2000 is very high (91% in Switzerland and 90% in the UK see Tables 1a and 1b) and almost close to their saturation points. However, as reported in the bottom part of Table 3, the factors driving the inter firm diffusion process differ quite significantly between the two countries.

In *Switzerland*, adoption is mostly driven by sector characteristics, firm size and human capital. That suggests that non-users (in our interpretation, firms with hardly any scope for using the internet) are predominantly small firms in construction, but also to some extent (low-tech) manufacturing firms, and small businesses in traditional services. There is not much scope for inter firm epidemic effects.

In the *UK,* contrary to Switzerland, firm size and industry structure do not suffice to explain adoption. Rather organisational change, absorptive capacity (R&D and human

[7] In the UK case we have tried to use the variables present in the CIS2 to instrument the variables at time 2000 in the CIS3 survey. Unfortunately, merging the CIS2 and CIS3 gives a longitudinal sample of only 10% the size of the observed CIS3 sample. Of these enterprises, 31% did not report on internet usage in 1996 reducing the usable sample from 4642 to about 300 enterprises. Therefore we did not consider this possibility further.

capital), inter firm epidemic learning and knowledge spillovers (Inter) are important determinants of first adoption. While organisational factors influence adoption only in the UK, human capital plays an important role in both countries. The differences in the pattern of explanation probably reflect specificities of the business environment and the nature of the knowledge base of the economic activities of the adopting firms in the two countries.

The intra firm effect shows a negative sign across specifications in both countries. This means that extensive use by rival firms slows down inter firm diffusion by reducing the expected gains from adoption. However, such stock effects do not appear to be strong enough to become statistically significant for firms' adoption decisions in year 2000.

5.2. Intra firm diffusion

In the year 2000, although both countries still have scope for increasing the degree of intra firm diffusion, in Switzerland the extent of use of ICT[8] is greater than in the UK (75.4% of the Swiss and 28% of the UK firms in the sample are enhanced users see table 1a and 1b). This is reflected in a number of ways in the diffusion modelling.

As shown in the top part of Table 3, for the UK the significant intra firm diffusion drivers are: (i) the firm's innovative capability as indicated by whether the firm has introduced any process innovations and undertakes R&D (ii) epidemic learning from the experience of other enhanced users (Intra). Note however that the employees' education levels are not significant (as it is the case in the adoption decision). Also the size of the firm is not significant – although the coefficient is negative the estimate is very imprecise. This is as predicted.

In the CH case, contrary to the UK, firms that have not conducted R&D seem to be more likely to extensively use ICT. This is probably because in the year 2000 R&D intensive firms are already using ICT at high intensity. Increasing the number of adopters among rival firms seem to generate a significant negative inter firm stock effect upon the decision to extensively use a new technology. As such it slows down the intra firm diffusion process in the year 2000. In the UK equation, the same negative

8 In case of intra firm diffusion, the CH results are the same in case of ICT as a whole (Hollenstein, 2004) and E-selling (Hollenstein and Wörter, 2004), but not in case of E-purchasing (no significant impact of an innovation variable); the difference between E-selling and E-purchasing seems plausible in view of the higher complexity of setting up an electronic platform for E-selling (Hollenstein and Woerter, 2004).

effect exists but it is not significant. Learning effects and knowledge spillovers seem to play a certain role in the CH economy as well but they are not statistically significant as in the UK case.

In the Swiss model the structural variables (industry dummies, firm size) affecting the adoption decision loose their explanatory power in case of intra firm diffusion, while behavioural factors such as the introduction of new organisational practices gain in importance in the decision to use the innovation more intensively. This result is not surprising since the scope for deepening intra firm diffusion is much higher than in case of the first use of ICT where the saturation point more or less is reached.

In summary, the insignificant size effect in case of intra firm diffusion we find in both countries supports the proposition that smaller firms once having adopted ICT use it (at least) to the same extent as large companies. This result is common to previous intra firm studies based upon the behaviour of UK and CH firms (Battisti, 2000, BCS, 2004, Hollenstein, 2004, Hollenstein and Woerter, 2004). Negative between-firm stock and order effects (Inter) as well as positive intra firm learning effects (Intra) seem to be relevant to some extent in both countries; however, the former are statistically significant only in the CH case (Inter), the latter in the UK (Intra). Organisational factors are the only statistically significant intra firm diffusion driver common to both countries. This is an important finding that is in line with recent studies on the importance of organisational change as a factor determining intra firm diffusion of ICT (see the references in Section 4). We note, however, that the adoption of ICT (inter firm diffusion) is influenced by organisational factors only in the UK. The fact that we do not find such a positive influence in the CH case may reflect the insight that a fundamental redesign of organization becomes necessary only beyond a certain minimum level of ICT use (Milgrom and Roberts, 1995).

6. Conclusions

This paper explores the joint analysis of inter and intra firm diffusion of innovations within as well as across countries. By using two datasets derived by two rare independent country specific surveys it undertakes a comparison of inter and intra firm diffusion of ICT use in the UK and Switzerland based on: a) the same model specification i.e. common theoretical background and variable specification as in

Battisti, Canepa and Stoneman (2004); and b) the same general to specific modelling procedure initially proposed by Battisti and Stoneman (2003, 2004, 2005) and later by Hollenstein (2004) as well as Hollenstein and Woerter (2004). The latter first allows for sample selection to be estimated built upon the assumption that intra firm diffusion is co-related to the decision to first adopt. However, since the two decisions turn out to be independent, each of the two steps is re-estimated using separate independent probit models: one for adoption (inter firm diffusion) and one for extent of use of ICT (intra firm diffusion). In so doing, we address at least some of the problems that have prevented general conclusions on the drivers of intra and inter firm technology diffusion. Most importantly this setting also allows to explore the role of new organisational practices upon the use of ICT and whether organisational factors impact differently on inter and intra firm adoption decisions.

Overall the models give satisfactory results for both countries. The main drivers of the diffusion pattern are consistent with theory, although not all covariates turn out to be significant. Between-firm stock and order effects are an obstacle to the intra firm diffusion (although statistically significant only in the CH case). Learning effects and spillovers from the experience of rival firms are highly relevant in the UK case, to some extent (statistically not significant) in the CH case as well (intra firm diffusion). In general, behavioural variables, as compared to structural factors such as industry affiliation and firm size, are more important in intra than in inter firm diffusion, in particular in the CH case where the extent of ICT use is significantly higher than in the UK. In both countries about 90% of firms use ICT, but in Switzerland the proprotion of enhanced users is much higher than in the UK, i.e. 75% vs. 28%. With respect to the remaining variables, at any point in time, the inter and intra firm adoption decision seem to be driven by different factors. This confirms the important findings of Battisti and Stoneman (2003, 2005) as well as Hollenstein and Woerter (2004) that ”adopting’’ and ”intensifying’’ innovation activities are independent choices.

The role of new organisational and managerial practices in decisions on inter and intra firm diffusion deserves particular interest in view of the growing body of literature dealing with the impact of organisational change and ICT on productivity where “organisation capital” and “ICT capital” are conceptualised as complementary assets (see the formal model of Milgrom and Roberts, 1990), although the empirical evidence with regard to interaction effects on productivity are mixed (see Arvanitis, 2005 for a synopsis of recent studies). We find that organisational innovations are positively

related to both inter and intra firm diffusion in the UK, whereas in the CH case organisational change favours enhanced use of ICT (intra firm diffusion) but not its adoption. The different results for the two countries may reflect the higher level of diffusion in the Swiss economy. Although we could not strictly control for potential endogeneity of organisational innovations as explanatory variable, the problem does not seem too serious according to some indirect tests. This result may reflect the notion of a more sluggish adaptation of organisational structures as compared to ICT use (see Milgrom and Roberts, 1995, Breshnahan et al., 2002, Hollenstein, 2004) and is consistent with Battisti et al. (2005) who did not find a clear precedence in the adoption of ICT and new organisational practices.

Given that the UK is at a relatively early stage of intra firm diffusion this study seems to suggests, as already mentioned, that significant differences in the explanatory pattern exist between the UK and Switzerland depending on their diffusion stage. However, taking into account the different levels of diffusion, the model estimates yield quite consistent results suggesting that comparative research is a promising way to identifying robust relationships and should be explored further.

One of the most important shortcomings of this paper is to be found in the cross-sectional nature of this study. In an ideal world one would use panel data or longitudinal data to investigate the diffusion pattern over time. However, due to the cross sectional nature of the international data available to us we are not able to unravel the dynamic of the diffusion process in the two countries over time or to deal effectively with the potential endogeneity of some of the variables. Therefore, an extension towards an analysis of longitudinal data (panel estimations), provided suitable data become available, would be highly desirable.

References

Arvanitis, S. (2005). Computerization, Workplace Organization, Skilled Labour and Firm Productivity: Evidence for the Swiss Business Sector, *Economics of Innovation and New Technology*, Vol. 14 (4), pp. 225-249.

Arvanitis, S.and Hollenstein, H. (2001). The Determinants of the Adoption of Advanced Manufacturing Technology, *Economics of Innovation and New Technology*, Vol. 10, pp. 377-714.

Astebro, T. (2004). Sunk Costs and the Depth and Probability of Technology Adoption, *Journal of Industrial Economics,* Vol. 52, pp. 381-399.

Battisti, G. (2000). *'The Intra firm Diffusion of New Technologies'*, PhD Thesis, Warwick University.

Battisti, G., Canepa, A. and Stoneman, P. (2004). *Profitability, Externalities and Policy in the Inter and Intra Firm Adoption of New Technology: The Example of E-Business Activities in the UK*. Paper Presented at the 8th Conference of the European Network on Industrial Policy (EUNIP), Birmingham, 13-15 December.

Battisti G., Colombo M. and Rabbiosi L. (2005). *Antecedents or Consequences of Innovation Activities: a Causality Test*, Working Paper WP.05.03, pp. 1-29, Quaderni CIRET, Dipartimento di Ingegneria Gestionale, Universita' Politecnico di Milano -Italy.

Battisti G. and Stoneman P. (2003). Inter and intra firm effects in the diffusion of new process technology, *Research Policy,* No. 32, pp. 1641–1655.

Battisti G. and Stoneman P. (2005). The Intra firm Diffusion of New Process Technologies, *International Journal of Industrial Organisation,* No. 23, pp. 1-22.

Bresnahan T.F., Brynjolfsson E. and Hitt L.M. (2002). Information Technology, Workplace Organisation, and the Demand for Skilled Labor: Firm-level Evidence, *Quarterly Journal of Economics,* No. 112, pp. 339-376.

Brynjolfsson E. and Hitt L.M. (2000). Beyond Computation: Information Technology, Organizational Transformation and Business Performance, *Journal of Economic Perspectives,* No. 14, pp. 23-48.

Canepa, A. and Stoneman, P. (2004). Comparative International Diffusion: Patterns, Determinants and Policies, *Economics of Innovation and New Technology*, Vol. 13, No. 3, pp. 279-298.

Cohen, W.M. and Levinthal, D.H. (1989). Innovation and Learning: the two Faces of R&D, *Economic Journal*, Vol. 99, pp. 569-596.

Colombo, M.G. and Mosconi, R. (1995). Complementarity and Cumulative Learning Effects in the Early Diffusion of Multiple Technologies, *The Journal of Industrial Economics*, Vol. XLIII, No. 1, March.

Comin, D and Hobijn, B (2004), Cross Country Technology Adoption: making the theories face the facts, *Journal of Monetary Economics*, 51, 39 – 83.

Donzé, L. (1998). *Développement et Entretien du "Panel d'Entreprise" du KOF/ETHZ. Une Étude Méthodologique*, Swiss Institute for Business Cycle Research, ETH Zurich, Zurich.

Greenan, N. and Guellec, D. (1998). Firm Organization, Technology and Performance: An Empirical Study, *Economics of Innovation and New Technology*, Vol. 6, pp. 313-347.

Gretton, P., Gali, J. and Parham, D. (2004). The Effects of ICTs and Complementary Innovations on Australian Productivity Growth, in: OECD (ed.), *The Economic Impact of ICT. Measurement, Evidence and Implications*, OECD, Paris, pp. 105-130.

Forman C., Goldfarb A., and S. Greenstein (2002). *Digital Dispersion: An Industrial and Geographic Census of Commercial Internet Use*, NBER WP 9287, Oct.

Forman, C., Goldfarb, A., and S. Greenstein (2003). *How did Location Affect Adoption of the Commercial internet: Global Village, Urban Density and Industry Composition*, NBER WP 9979, Sept.

Fuentelsaz, L., Gomez, J. and Polo Y., 2003. Intra firm Diffusion of New Technologies: An Empirical Application, *Research Policy,* Vol. 32, pp. 533-551.

Hall, B. (2004). *Innovation and Diffusion*. *NBER Working Paper* No.10212, NBER, Cambridge Mass.

Hempell, T., van Leeuwen, G., and H. van der Wiel (2004). ICT, Innovation and Business Performance in Services: Evidence for Germany and the Netherlands, in: OECD (ed.), *The Economic Impact of ICT. Measurement, Evidence and Implications*, OECD, Paris, pp. 131-152.

Hollenstein H. (2004). Determinants of the Adoption of Information and Communication Technologies (ICT) – An Empirical Analysis Based on Firm-level Data for the Swiss Business Sector, *Structural Change and Economic Dynamics*, No. 15, pp. 315-342.

Hollenstein H.and Woerter M. (2004). The Decision to Adopt Internet-based E-Commerce. An Empirical Analysis Based on Swiss Firm-level Data., *KOF Working Paper No. 89,* Zurich.

Karshenas, M. and Stoneman, P. (1993). Rank, Stock, Order and Epidemic Effects in the Diffusion of New Process Technologies: an Empirical Model, *Rand Journal of Economics*, Vol. 24, No. 4, pp. 503.528.

Karshenas, M. and Stoneman, P. (1995). Technological Diffusion, in: Stoneman, P. (ed.), *Handbook of the Economics of Innovation and Technological Change*, Blackwell, Oxford, pp. 265-297.

Mansfield E. (1968). *Industrial Research and Technological Innovation*, W.W. Norton, New York.

Milgrom, P. and Roberts, J. (1990). The Economics of Modern Manufacturing: Technology, Strategy and Organization, *American Economic Review*, Vol. 80, No. 3, pp. 511-528.

Milgrom, P. and Roberts, J. (1995). Complementarities and Fit. Strategy, Structure and Organizational Change, *Journal of Accounting in Economics*, No. 19, pp. 179-208.

Rubin, D.B. (1987). *Multiple Imputation for Nonresponse in Survey*s. John Wiley & Sons, New York.

Stoneman, P. (1981). Intra Firm Diffusion, Bayesian Learning and Profitability, *Economic Journal*, Vol. 91, pp. 375-388.

Stoneman, P. and G. Battisti (1997). Intra firm Diffusion of New Technologies: the Neglected Part of Technology Transfer. *International Journal of Industrial Engineering*, Vol. 4, No.2, pp. 270-82.

Stoneman P. and Toivanen O. (1997). The Diffusion of Multiple Technologies: An Empirical Study, *Economics of Innovation and New Technology*, Vol. 5, pp. 1-17.

APPENDIX 1: 1992 SIC CODES BY WIDE INDUSTRY GROUPING.

SIC92 CODE	Industry
10	Mining of Coal
11	Extraction of Oil and Gas
14	Other Mining and Quarrying
15	Food & Beverages
16	Tobacco
17	Textiles
18	Clothes
19	Leather
20	Wood
21	Paper
22	Publishing
23	Coke, Petroleum & Nuclear Fuel
24	Chemicals
25	Rubber and Plastic
26	Other Non-Metallic Mineral Products
27	Basic Metals
28	Fabricated Metal Products
29	Machinery and Equipment
30	Office Machinery and Computers
31	Electrical Machinery
32	Radio, Television & Communication
33	Medical / Optical Instruments
34	Motor Vehicles
35	Other Transport
36	Furniture
37	Recycling
40	Electricity, Gas and Water Supply
41	Collection, Purification & Distribution of Water
45	Construction
51	Wholesale
60	Land Transport
61	Water Transport
62	Air Transport
64	Post & Telecommunications
65	Financial Intermediation
66	Insurance & Pensions
67	Financial Intermediation (Activities Auxiliary)
70	Real Estate
71	Renting of Machinery and Equipment
72	Computer & Related Activities
73	Research & Development
74	Business Activities

Table 1a: Pattern of ICT usage in Switzerland in year 2000 (20 and more employees)

	Non users (%)	Basic users (%)	Enhanced users (%)	Row Total =100% (*Count*)
All firms	8.7	16.8	74.5	1550
Within industry distribution of use (within industry distribution of adopters; SIC classification[a])				
15-22	10.9	12.7	76.4	*229*
23-29	5.9	17.6	76.5	*421*
30-33	6.2	16.2	77.6	*161*
34-35	10.5	21.1	68.4	*19*
36-37	11.1	16.7	72.2	*36*
40-41	3.6	32.1	64.3	*28*
45	21.5	16.0	62.5	*200*
51	5.8	23.0	71.2	*139*
60-64	10.0	20.0	70.0	*100*
65-67	1.5	13.0	85.5	*69*
70-74	4.1	13.5	82.4	*148*
Total	*8.7*	*16.8*	*74.5*	*1550*
Usage by size (number of employees - full time equivalent)				
20-49	13.9	16.7	69.4	*533*
50-249	7.4	16.9	75.8	*735*
250-499	4.6	14.6	80.8	*151*
500-999	0.0	23.0	77.0	*74*
1000+	0.0	15.8	84.2	*57*
Total	*8.7*	*16.8*	*74.5*	*1550*

Table 1b: Pattern of ICT usage in the UK in year 2000 (20 and more employees)

	Non users (%)	Basic users (%)	Enhanced users (%)	Row Total =100% (*Count*)
All firms	9.7	62.3	28.0	4642
Within industry distribution of use (within industry proportion of adopters; SIC classification[a]).				
15-22	12.1	60.7	27.2	*636*
23-29	10.0	61.1	28.9	*699*
30-33	4.0	66.9	29.1	*378*
34-35	5.0	71.8	23.1	*238*
36-37	9.3	68.5	22.1	*289*
40-41	8.6	65.7	25.7	*35*
45	14.8	68.6	16.7	*474*
51	8.8	58.4	32.8	*570*
60-64	10.6	55.4	34.0	*462*
65-67	8.5	55.9	35.6	*247*
70-74	8.8	62.5	28.7	*614*
Total	*9.7*	*62.3*	*28.0*	*4642*
Usage by size (number of employees, full time equivalent)				
20-49	14.0	60.1	25.9	1546
50-249	8.4	65.6	26.0	1826
250-499	5.5	62.4	32.1	654
500-999	7.1	62.0	31.0	368
1000+	6.0	52.8	41.1	248
Total	*9.7*	*62.3*	*28.0*	*4642*

Table 2: The explanatory variables: definitions and expected sign

Variable	Description	Applied	Expected sign adoption/enhanced use
Rank effects $R_i(t)$ firm specific			
Size	Number of employees in full-time equivalents divided by five in 1999 (CH) and 1998 (UK)	UK/CH	+ if adoption; - or insignificant if enhanced use
ProcNov	Firm has introduced process innovation(s) new to the industry between 1998-2000 (UK) and new to the firm between 1997-1999 (CH); yes=1, no=0	UK/(CH)	+
ProdNov	Firm has introduced product innovation(s) new to the industry between 1998-2000 (UK) and new to the firm between 1997-1999 (CH); yes=1, no=0	UK/CH	+
R&D	Firm has conducted R&D activities during the period 1998-2000 (UK) and 1997-1999 (CH); yes=1, no=0	UK/CH	+
Org	Firm has introduced advanced management techniques (e.g. knowledge management, quality circles) or changed significantly organisational structures between 1998-2000 (UK); firm hasintroduced team working or decentralised decision-making or changed the number of management layers between 1998-2000 (CH); yes=1, no=0	UK/CH	+ / insignificant if adoption; + if enhanced use
PropSci	Proportion of employees with a degree in 2000 in science and engineering subjects	UK	+
PropOth	Proportion of employees with a degree in 2000 in subjects other than propsci	UK	+
Propall	Proportion of employees with university or non-university tertiary degree (e.g. polytechnics degree, degree in non-university business administration) in 1999	CH	+
***Rank effects* – $R_j(t)$ Environmental factors**			
manufact	Firm is affiliated to the manufacturing sector; yes=1, no=0; (reference sector construction)	UK/CH	+/-
Services	Firm is affiliated to the service sector; yes=1, no=0; (reference sector construction)	UK/CH	+/-
Epidemic and Stock effects			
Intra	Proportion of firms with enhanced use of internet in the particular sic category (logit transformation)	UK/CH	+/-
Inter	Proportion of firms with at least basic use of internet in the particular sic category (logit transformation)	UK/CH	+/-

NOTE: Brackets in column 3 indicate that the variable was not used in every equation..

Table 3: The estimated equations: United Kingdom and Switzerland

	BIVARIATE PROBIT (with Sample Selection)				PROBIT (Independent equations)			
	CH		UK		CH		UK	
	Coeff	Robust s.e	Coeff	Robust s.e	Coeff	Robust s.e	Coeff	Robust s.e
Intra firm diffusion					(a)			
Size	0.001	0.001	-0.00003	0.0001	0.000	0.001	-0.00001	0.0001
Innovation: process	-	-	**0.291***	**0.089**	0.024	0.194	**0.335***	**0.084**
Innovation: product	0.189	0.209	0.056	0.071	0.202	0.203	0.052	0.074
R&D	-0.373	0.268	**0.137***	**0.067**	**-0.390***	**0.200**	**0.188***	**0.055**
Organization	**0.451***	**0.158**	**0.121***	**0.068**	**0.446***	**0.158**	**0.186***	**0.048**
High qualifications science	-	-	-0.001	0.002	-	-	-0.0001	0.002
High qualifications others	-	-	0.000	0.001	-	-	0.0001	0.001
High qualification all	0.009	0.011	-	-	0.008	0.005		
Manufacturing	0.504	0.827	-0.231	0.148	0.424	0.390	-0.183	0.152
Services	0.659	0.747	-0.093	0.173	0.595	0.465	-0.016	0.170
Intra firm effect	0.596	0.672	**0.393***	**0.158**	0.650***	0.467	**0.351***	**0.163**
Inter firm effect	**-0.589****	**0.319**	**-0.133****	**0.070**	**-0.615***	**0.221**	-0.088	0.068
Const	1.037	1.443	0.245	0.418	**1.170***	**0.415**	-0.144	0.366
Inter firm diffusion					(b)			
Size	**0.018***	**0.007**	0.0004	0.0004	**0.018***	**0.007**	0.0004	0.0004
Innovation: process	0.305	0.256	0.143	0.128	0.309	0.236	0.148	0.129
Innovation: product	-0.028	0.304	-0.034	0.103	-0.015	0.263	-0.043	0.103
R&D	0.040	0.252	**0.178***	**0.070**	0.055	0.219	**0.180***	**0.072**
Organization	0.081	0.300	**0.225***	**0.059**	0.102	0.217	**0.224***	**0.059**
High qualifications science	-	-	**0.006***	**0.003**	-	-	**0.006***	**0.003**
High qualifications others	-	-	0.001	0.002	-	-	0.001	0.002
High qualifications all	**0.025***	**0.011**	-	-	**0.025***	**0.011**	-	-
Manufacturing	**1.223***	**0.565**	0.277	0.197	**1.243***	**0.501**	0.278	0.197
Services	0.898	0.742	0.336	0.223	0.930	0.617	0.350	0.222
Intra firm effect	-1.247	0.824	-0.321	0.222	-1.253	0.828	-0.330	0.222
Inter firm effect	0.442	0.531	**0.268***	**0.091**	0.409	0.377	**0.264***	**0.091**
Const	-0.181	0.544	0.031	0.489	-0.151	0.482	0.020	0.490
Sample size	N=479		N=3852		(a) N=451 (b) N=479		(a) N=3484 (b) N=3852	
LR	Wald test $\chi^2(9)=19.47$		Wald test $\chi^2(11)=31.15$		(a) $\chi^2(10) = 29.38$ (b) $\chi^2(10) = 19.68$		(a) $\chi^2(11) = 94.72$ (b) $\chi^2(11) = 51.85$	
Log Pseudo-Likelihood	-235.4123		-3220.62		(a) -175.08 (b) -88.350		(a) -2037.94 (b) -1182.99	
Wald test of indep. Eqns.(ρ=0)	$\chi^2(1) = 0.01$		$\chi^2(1) = 1.56$		-		-	

NOTE: Level of significance are indicated by * up to 5%; ** between 5% and 10%.