Determinants of initial technology adoption and intensification: evidence from Latin America and the Caribbean

Waters, James

20 January 2015

Determinants of initial technology adoption and intensification: evidence from Latin America and the Caribbean

20th January 2015

Working paper – comments welcome

James Waters[1]

ABSTRACT

In this paper we examine determinants of initial adoption and subsequent intensification of corporate use of business practices employing the internet. In contrast to previous examinations that have looked at highest income countries, we study companies in Latin America and the Caribbean. Many variables such as company size and industry use previously identified as influential in high income regions continue to be important determinants. Novel determinants are also found, including informal sector competition and exporting. There are sharp differences in determinants between the two adoption types.

Keywords:

Technology, internet, adoption, intra-firm, intensification, developing countries

[1] james.m.waters@hotmail.co.uk

1. Introduction

Initial technology adoption is the first adoption of a technology by an agent, while intensification of use describes the subsequent extent of technology adoption by the agent. Initial adoption has been subject to many theoretical and empirical studies (Geroski 2000; Meade and Islam, 2006), establishing regularities such as the existence of an S-shaped diffusion curve. Intensification has had far fewer studies, although there has been a recent increase in the number of empirical studies of it (Battisti et al, 2007; Fuentelsaz et al, 2003; Hollenstein and Woerter, 2008).

Separate examination of intensification by companies is appealing for many reasons. By definition, it is necessary to describe the full process and extent of adoption of a technology, and except for very small companies most diffusion occurs under an intensification rather than initial adoption process. The examination is informative of the constraints faced by companies on their adoption, is helpful to companies looking to estimate the potential and dynamics of the market, and serves as a guide for policy for governments and others looking to influence diffusion.

The interpretations and policy recommendations given to date on intensification are most relevant to highly developed countries, as the prior empirical literature has focussed on data from these states. For example, Antonelli (1985) uses data from US and Western European companies, Battisti et al (2007) work with British and Swiss data, Battisti and Iona (2009) employ UK data, Bocquet and Brossard (2007) use French data, Fuentelsaz et al (2003) have Spanish data, and in Hollenstein and Woerter (2008) Swiss data is used. As a result of the previous geographic focus in the literature, many interesting questions about intensification relevant in lower income countries do not arise in the countries examined, and cannot be examined with data from them. For example, frequent interruption of power supplies may differentially affect companies' choices of initial adoption and intensification in developing countries, but the consideration does not arise in high income countries where power supplies are guaranteed. Similarly, corruption is often found in surveys to be a more significant issue outside of Western Europe and the US, and companies outside these regions may reflect the issue in the extent to which they adopt management practices.

In this paper we attempt to fill part of the gap by examining determinants of initial technology adoption and intensification in regions other than the highest income countries previously examined in the literature. We address the following questions. Do the determinants of initial adoption and intensification already identified as applying in highest income countries also apply in poorer countries? What other determinants are significant in these poorer countries?

We work in the theoretical framework of Karshenas and Stoneman (1993), which divides influences on diffusion into rank, stock, order, and epidemic effects. The framework is applied to initial adoption and intensification separately, as in Battisti et al (2007) and Hollenstein and Woerter (2008). We keep determinant variables commonly recognised in the literature and introduce new rank and epidemic determinant variables that influence technology use in lower income countries particularly. The model is estimated using a dataset of companies from Latin America and the Caribbean in the year 2009/10.

We show that commonly included variables from the prior literature on the two types of diffusion in high income countries continue to have validity in lower income regions. These variables are company size, company ownership, experience with precursor technology, and industry experience with the technology. We further show the influence of national development, through the role of newly introduced rank variables measuring competition against informal companies and presence in a capital city. Novel epidemic variables measuring international experience (exporting) and regional use are also found to have significant effects. The determinants of initial adoption and intensification are quite distinct. The former is affected by more variables, including national development variables, while the latter is mainly influenced by epidemic effects and foreign ownership.

Section 2 gives our theoretical framework, section 3 describes our data, and section 4 presents our empirical method. Section 5 gives results, section 6 presents extensions to the basic results, and section 7 concludes.

2. Theoretical framework

Our theoretical framework is derived from a classification of influences on diffusion given in Karshenas and Stoneman (1993). The approach identifies rank, stock, order, and epidemic effects as possible influences on inter-firm diffusion. It was used in an empirical analysis of intra-firm diffusion in Battisti and Stoneman (2003), and then for larger inter- and intra-firm comparative investigations in Battisti et al (2009), Battisti et al (2007), and Hollenstein and Woerter (2008), and with a variation to allow for technological fit in Bocquet and Brossard (2007).

In the formulation of Battisti et al (2009), the extent of use of a technology may be written as

$$x_i(t) = G(\tilde{F}_i(t), \tilde{F}_N(t), y_N(t), E_i(t), E_N(t), P_i(t)) \qquad (1)$$

where

$x_i(t)$ is the extent of use of technology by company *i* at time t,

G is a non-negative function,

$\tilde{F}_i(t)$ is a vector of company characteristics,

$\tilde{F}_N(t)$ is a vector of industry characteristics,

$y_N(t)$ is the extent of industry use of the technology,

$E_i(t)$ is a measure of the firm's own experience relevant to the technology,

$E_N(t)$ is a measure of the experience relevant to the technology that the firm gains from observing others, and

$P_i(t)$ is the expected adoption cost of a unit of the new technology.

$\tilde{F}_i(t)$ and $\tilde{F}_N(t)$ capture rank effects expressing that different firm and industry characteristics affect the profitability and so level of adoption for individual companies. $y_N(t)$ captures stock and order effects, where profitability and extent of adoption is impacted by previous adoption decisions taken by others. $E_i(t)$ and

$E_N(t)$ indicate epidemic effects, where companies learn about the technology internally or from the experience of others.

The equation is time dependent, but in this paper we hold *t* constant and estimate it in cross-section. This procedure allows us to test empirically for influences on diffusion, even though we only have cross-sectional data. The same approach is common in diffusion estimation, including Battisti et al (2007) and Hollenstein and Woerter (2008).

In our estimations we take two measures for $x_i(t)$, reflecting initial adoption and intensification of commercial use of the internet. To measure initial adoption by a company, we create a variable equal to one if a company has internet access, and zero otherwise. For intensification, we create a variable lying between zero and three, and equal to the number of commercial practices followed by the company that use the internet, from following list:

1. making purchases for the company,
2. delivering services to clients, and
3. doing research and developing ideas on new products and services.

For the rank variables, we consider commonly used variables, and variables describing the influences of ownership and national development. For stock, order, and epidemic variables, the influences of internal, industrial, local, and international sources are considered. As in Battisti et al (2007) and Hollenstein and Woerter (2008) we do not separate the negative impact of stock and order effects from the positive impact of epidemic effects, as they both act through the number of previous adopters in a cross-sectional analysis. Accordingly, we label the corresponding variables as epidemic effects and recognise that their coefficients describe net impacts, with a positive coefficient showing that epidemic effects are significantly stronger than stock and order effects, and a negative coefficient showing the opposite (in section 6 we change the epidemic variable definitions a little to see the impact of stock and order effects more clearly). Table 1 summarises the variables and their expected effects, which are described in more detail next.

Table 1, part i

Explanatory variables and their expected effect

Variable	Description	Expected sign: initial adoption / intensification [a]
Rank effects		
Company size	Dummies for medium (20 to 99 employees) and large companies (100 or more). Reference group is companies with 19 or fewer employees.	+ / ?
Start year	The year in which the company began operations in the country	? / ?
Ownership		
Part of larger firm	Is the company part of a larger firm? (yes = 1, no = 0)	+ / 0
Foreign owner share	Percentage of company owned by private foreign institutions (0 to 100)	+ / 0
State owner share	Percentage of company owned by a government (0 to 100)	? / ?
National development		
Financial obstacles	Is access to financing a major or very severe obstacle to operations? (yes = 1, no = 0)	- / 0
Power outages	Over the last fiscal year, what was the typical number of monthly power outages?	0 / -
Compete against informal firms	Does the company compete against unregistered or informal firms? (yes = 1, no = 0)	- / 0
Capital city	Is the company resident in the capital city? (yes = 1, no = 0)	? / ?
Epidemic effects		
Internal experience		
E-mail use	Is e-mail used in communication with clients or suppliers? (yes = 1, no = 0)	+ / +

Table 1, part ii

Explanatory variables and their expected effect

International experience		
Exporter in 2000	Did the company start exporting by the year 2000 (and is still exporting)? (yes = 1, no = 0)	+ / +
Initial use		
Industry use	Proportion of other companies using the internet in the same two digit ISIC industry in the country (0 to 1)	+ / 0
Regional use	Proportion of other companies using the internet in the same region in the country (0 to 1)	+ / 0
Intensity		
Industry intensity	Average intensity of use by other companies in the same two digit ISIC industry in the country (0 to 1)	0 / +
Regional intensity	Average intensity of use by other companies in the same region in the country (0 to 1)	0 / 0

[a] + denotes a positive expected effect, - denotes a negative expected effect, 0 denotes no effect, and ? denotes that the theory gives an ambiguous prediction.

Company size

We measure company size by two dummy variables, taking the values of one if the company has between 20 and 99 employees, or 100 or more employees. Companies with fewer than 20 employees are left as a reference group. There are a number of reasons why large companies may be more likely to adopt a technology before small ones (Mansfield, 1963). Technologies may show positive scale effects in adoption, making costs and risks relatively lower for large companies. They are also more likely to have conditions suitable for adoption somewhere in their company, and have more frequent requirements for replacement. Many studies have provided empirical support for a positive link between firm size and initial adoption (Mansfield, 1963b; Davies, 1979; Karshenas and Stoneman, 1993; Battisti et al, 2007). We expect a positive relation.

The argument for a particular direction of influence between size and intensification is less clear-cut. The empirical literature does not give a clear guidance either. The early work by Mansfield (1963a) finds no significant effect of size of intensification rates, and the same result is in Battisti et al (2007). However, Battisti and Stoneman (2005) find a positive relation, while Hollenstein and Woerter (2008) report mixed results and Fuentelsaz et al (2003) give a negative relation. We do not have prior expectations for the relation between size and intensification.

Start year

We measure a company's start year as the year it began operations in its country of residence. An older company may have more experience than a newer one, allowing it to better assess new technologies and adopt them with less risk. However, it may be more institutionally committed to an existing technology. Battisti and Stoneman (2003) find that older firms have higher level of intra-firm adoption than new firms, but Battisti and Stoneman (2005) find no significant relation. We do not have any prior expectations for the relation between start year and either interfirm or intrafirm diffusion.

Being part of a larger firm

We measure being part of a larger firm by a dummy taking the value of one if the company is part of a larger firm, and zero otherwise. Being a subsidiary may accelerate the initial diffusion of technology to a company. As larger firms are often found to be earlier adopters of a technology than smaller firms, subsidiaries may have earlier exposure to the technology than independent companies, and benefit from internal expertise in adoption in order to reduce costs, or have adoption mandated by central control. Antonelli (1985) finds that firms with highly centralised structures have accelerated diffusion of technology to different business functions. We therefore expect subsidiaries to have a higher rate of initial adoption. For intensification, these arguments still hold, and in Bocquet et al's (2007) study independent companies have less intensive use. However, the local conditions for subsidiaries may be very different to those prevailing centrally, and so the initial exposure does not necessarily entail that subsequent intensification will be optimal or selected. We therefore expect no relation between being part of a larger firm and intensification.

Being foreign owned

We measure foreign ownership by the percentage of the company owned by private foreign individuals, companies, or organisations. Companies which choose to have an international presence are plausibly more willing and able to manage new technologies than businesses that stay at home. The literature on international (typically aggregated) technology diffusion suggests that foreign direct investment can result in technology spillovers (Keller, 2004). We can reason in the same way as when a company is a subsidiary, so that initial adoption would be increased by foreign ownership and intensification is left unchanged, except that initial adoption is perhaps even more strongly increased due to the presumed innovativeness of companies with overseas operations. Hollenstein and Woerter (2008) find that e-commerce intensification is not affected by foreign ownership but, contrary to their theoretical expectations, initial adoption is reduced. We expect initial adoption to be more likely under foreign ownership, however, and intensification rates to be unchanged.

Being state owned

State ownership is measured by the percentage of the company owned by government. Government ownership may be less efficient than private ownership (Megginson and Netter, 2001), and pressure to adopt new technologies may be lessened if, for example, there is less pressure to adopt them in response to commercial pressures. On the other hand, government ownership may bring access to foreign exchange necessary to purchase foreign technologies in the presence of capital controls, and other access privileges. We do not take any prior position on how government ownership will affect initial adoption or intensification.

Financial obstacles

We measure the severity of financial obstacles faced by a company by a dummy variable dependent on how severe an obstacle is access to financing, including availability and cost. The dummy takes the value of one if a major or very severe obstacle is reported, and zero if the lower ratings of no obstacle, minor obstacle, or moderate obstacle are given. We also used fuller dummy sets and obtained similar results. If a company experiences difficulty accessing finance for new technology or find it more expensive to finance, they are less likely to acquire it. The problems may

be may more difficult outside of the richest developed countries, as Beck et al (2006) report that lower levels of national financial and institutional development are associated with worsened financing problems for companies there. Battisti and Stoneman (2005) find that higher cost for a technology reduces intensification, while in Fuentelsaz et al (2003) greater company liquidity accelerates it. However, for the technologies we consider, the biggest capital expenditure by far occurs with the initial adoption (for internet connection) and smaller expenditures are incurred by its various uses. Thus, we expect financial obstacles to slow initial diffusion but not intensification, in our case.

Power outages

Our next determinant variable is the number of power outages experienced by the company in a typical month over the last fiscal year. Power outages are a frequent occurrence in developing countries. For example, in the World Bank Enterprise Surveys used in this paper, Latin American and Caribbean companies have 1.9 outages per month on average. If there are more power outages, then a company may be more reluctant to adopt use of a power-dependent technology like the internet. Disruptions to internet access through power failure seem less likely to discourage use if the use is casual rather than for a systematic business purpose like maintaining client contact. We therefore expect power outages to be associated with lower intensification, but have no effect on initial adoption.

Power outages are potentially endogenous with internet initial adoption or intensification, since companies may acquire electricity in order to then get internet access (and so outage counts may only increase from zero as the internet is acquired). We could not find a strong instrument that was also exogenous, and so we initially ran the equations without any instrumentation on our full sample. Power outages exerted no effect on initial adoption, and were associated with an increase in intensification. This latter result is best explained by the reverse causality, so companies that use the internet have electrical power more often which breaks more often. We address the endogeneity by restricting the sample to companies that are highly likely to use electricity irrespective of their internet usage. As this procedure greatly reduces the sample size, we report the results in section seven looking at extensions to our model. In the main section we exclude power outages as a determinant variable.

Competing against informal firms

We include a dummy variable equal to one if the company has competition from unregistered or informal firms, and zero otherwise. Extra competition against companies who do not incur formal sector costs is likely to make it more difficult for a company to accumulate for technological investment. Moreover, when informal companies are competitors, markets tend to have lower entry costs (González and Lamanna, 2007) indicating that internet technology may not be an important part of operations. Our expectation is that competition against informal firms will be associated with lower initial adoption. If the initial adoption has been made, then the argument is less compelling that internet use has no value in the market. We expect informal competition will have no relation with intensification.

Capital city

We include a dummy for whether the company is based in the capital city. A capital city may benefit from economies of scale in provision of goods and services. Additionally, the presence of a bias in developing countries towards policies supporting urban development in preference to rural development has been frequently argued (Bezemer and Headey, 2008), which may manifest itself in provision of far better facilities than in rural areas. Thus, it may be less costly for companies to obtain internet connection. On the other hand, in a capital city it is likely to be much easier to interact face-to-face with suppliers and buyers compared with rural areas, so the internet may be used less as a means of connecting with them. We do not have an expectation on the link between being resident in a capital city and either initial adoption or intensification.

E-mail use

Another determinant is a dummy indicating whether the company uses e-mail. Using e-mail is likely to be a precursor technology to full internet adoption within a company, since e-mail is available publicly at internet cafes or from personal provision. Experience with a precursor technology should increase familiarity with the operation of the technology itself, and we expect it to influence positively both initial adoption and intensification. Hollenstein and Woerter (2008) find that use of a

precursor tends (with mixed significance) to increase both e-commerce adoption and intensification.

Exporting

Our next measure is a dummy variable indicating whether the firm is a current exporter (either direct or indirect) and started exporting by the year 2000 at the latest. Exporters may learn about new technologies from their buyers, or may have to invest in new technologies to enter export markets. Some papers in the international technology transfer literature suggest that exporting boosts productivity (Blalock and Gertler, 2004; Girma et al, 2004), but the overall evidence is mixed (Wagner, 2007). We expect positive, possibly weak, relations between exporting and initial adoption and intensification.

We selected the variable form to minimise its endogeneity in the estimation equation. We also considered the export share as a determinant. This quantity is likely to be endogenous, as the intensive use of internet technologies gives companies the ability to market their goods internationally. We looked for available instruments in our cross-sectional dataset, and found the most likely candidate to be the average number of days taken for exports to clear customs. While the exogeneity of this instrument was not rejected under a Wald test, it was found to be very weak by examination of first stage regressions, and resulting second stage estimates had no parameter certainty.

Industry use

A further determinant is average initial adoption across all companies in the two digit ISIC industry in the country in which a company is based, with the averages excluding the contribution of the company itself. A company may learn from the initial adoption of other companies and emulate them. Battisti et al (2007) find that initial adoption of technologies by other firms in the same industry increases initial adoption by a company, with a weak negative effect on intensification. Hollenstein and Woerter (2008) find some evidence for the former link, and no evidence for the latter. We expect to see initial adoption within the industry affect a company's initial adoption positively, and intensification in the industry leave it unchanged.

Regional use

We include a variable equal to the average initial adoption of the internet in the region of the country in which the company is based, excluding the contribution of the company itself. Billon et al (2008) find that internet adoption is subject to geographic clustering, while in Baptista (2001) geographic proximity of previous adopters reduces the time until a company adopts. Our reasoning for the effect of regional use is the same as with industry use, and we expect regional use to influence positively initial adoption but not intensification.

Industry intensity

We measure industry intensity as the average intensity across all companies in the two digit ISIC industry in the country in which the company is based, excluding the contribution of the company itself. In Hollenstein and Woerter (2008), a company tends to more intensified internet e-commerce use if other firms in the industry are also more intensified in their use, but the initial adoption of these other firms does not influence intensification. The same is found in Battisti et al (2007). Our expectations are the same.

Regional intensity

Regional intensity is measured as the average intensity across all companies in the region of the country in which the company is based, excluding the contribution of the company itself. The conditions that lead industrial intensity to influence company intensification, such as relevance of detailed experience and market standards, do not so clearly apply between companies who happen to be geographically located. So there is less reason to expect that regional intensity of use will influence intensification, and we expect it to have no relation with either intensification or initial adoption.

Country and sector dummies

Dummies are included for each country, which are intended to cover fixed effect differences in the national provision of the internet. We do not include dummies for a company's industry. Although industry dummies could capture the different rates of internet use across industrial sectors, the use and intensity of other companies in the industry are both included in the determinants so using industry dummies as well

would cause perfect collinearity. We do include a dummy for whether a company is a manufacturer, with service sector companies as the reference group.

3. Data

The data used in this paper is from the World Bank Enterprise Surveys (www.enterprisesurveys.org). It consists of country-level surveys of companies, describing their characteristics and those of the business environment. We select the subset of surveys taken in Latin American and Caribbean countries (and listed in Appendix A). The surveys were undertaken in 2006 and 2009/10, with a much wider number of countries examined in the 2009/10 wave. We can not match companies that occur in both periods, so to avoid unrecognised duplication and to ensure common time effects throughout the data we use data from the last wave only.

The survey sample is drawn from lists of all eligible firms at the national statistic office, other government agencies, or sometimes from business associations or manual construction. The surveys use stratified random sampling, based on firm size, business sector, and geographic region, with a sample size per stratum sufficient to ensure a 7.5 percent precision in 90 percent confidence intervals. Non-response is generally handled by substitution with other companies in the same stratum. In our estimates, all standard errors are adjusted for the stratification.

Companies are required to have at least five employees, and are drawn from the manufacturing and services sectors. Our final dataset is on companies in the ISIC codes 15-31, 33-37, 45, 50-52, 55, 60, 63, and 72. There are 7,933 companies in total.

Table 2 shows the percentages of companies who have adopted the internet, and of these adopters, their distribution across the different levels of intensification of internet-based business practices. For the entire set of companies, the rate of initial adoption is high at 84.1 percent. The rate for small companies is lower, with over a quarter not using the internet, while almost all large companies have adopted it. The rate of initial adoption in the manufacturing sector is slightly higher than that in the service sector.

In the set of all adopters, many companies have highly intensive use, with 80 percent using two or three internet-based business practices. Small companies have a lower rate of intensification, and large companies have a higher rate. Manufacturing has a higher level of intensification than the service sector. Thus, company size seems to exert a positive influence on initial adoption and intensification, and industrial sector also seems to affect them.

Table 2

Number of companies who use the internet and the level of their intensification

	Number of users and non-users	Internet use (% of all companies)		Number of internet-based business practices (% of users)			
		Non-users	Users	0	1	2	3
All companies	7933	15.9	84.1	4.6	15.4	28.5	51.4
By size							
Small companies	2872	27.3	72.7	5.1	18.6	31.4	44.9
Medium companies	2942	12.5	87.5	4.7	14.4	27.4	53.5
Large companies	2119	5	95	4.1	13.4	27	55.6
By sector							
Manufacturing	5846	14.4	85.6	4	14.7	27.7	53.6
Services	2087	19.8	80.2	6.6	17.6	30.9	44.9

Small companies have 19 or fewer employees, medium companies have 20 to 99 employees, and large companies have 100 or more employees.

4. Econometric method

We estimate the initial adoption and intensification decisions as a probit and ordered probit system. The initial adoption decision variable y_i for company i is given by $y_i = 0$ if no initial adoption occurs and $y_i = 1$ if it does. It has a standard probit model:

$$y_i^* = x_i'\beta + \varepsilon_i$$

$y_i = 0$ if $y_i^* \leq 0$ and 1 otherwise.

where y_i^* is an unobserved latent variable,

x_i is a vector of the explanatory variables including a constant term,

β is a parameter vector, and $\varepsilon_i \sim N(0,1)$.

The intensification decision variable z_i is equal to zero, one, two, or three depending on how many of the internet-based commercial practices listed in section 2 are adopted. The model for the variable is the ordered probit:

$$z_i^* = w_i'\delta + u_i$$

$$z_i = 0 \text{ if } -\infty < z_i^* \leq \mu_1$$

$$z_i = 1 \text{ if } \mu_1 < z_i^* \leq \mu_2$$

$$z_i = 2 \text{ if } \mu_2 < z_i^* \leq \mu_3$$

$$z_i = 3 \text{ if } \mu_3 < z_i^*$$

where z_i^* is an unobserved latent variable, w_i is a vector of the explanatory variables including a constant term, δ is a parameter vector, and $u_i \sim N(0,1)$.

The intensification equation is potentially subject to a selection effect as the intensification choice is only observed if initial adoption occurs. If the error terms ε_i and u_i are correlated, the coefficient estimates in the intensification equation may be biased. The inverse Mills ratio correction can not be used here because of the non-linear form of the intensification equation (see Greene (2008), ch.24, on sample selection in non-linear models). Ideally, we would estimate the probit-ordered probit system simultaneously allowing for the correlation along the lines described in Greene (2008), but we encountered difficulties in achieving convergence in the resulting maximum likelihood estimation. However, we were able to calculate selection effects for slightly reduced systems. A high intensity decision variable was constructed with value of one if two or three internet-based commercial practices are adopted, and zero otherwise (the results were unchanged if three practices were required). The initial adoption and high intensity decision variables form a bivariate probit system which could be estimated. The error terms across the two equations were not significantly correlated, so we can have some confidence that the equations

in our original initial adoption-intensification system can be treated as stochastically independent (as in Battisti and Stoneman (2005), Battisti et al (2007), and Hollenstein and Woerter (2008)). We therefore estimate the initial adoption and intensification equations separately.

Endogeneity is another potential problem. As we have cross-sectional data, lagged variables are not available as instruments, and other variables in the dataset were usually found to be weak instruments for variables most likely to be subject to endogeneity. Accordingly, we have formulated the hypotheses in terms of variables that are less susceptible to endogeneity. The strongest candidates for endogeneity are exporting (since internet use may facilitate export promotion), e-mail use (since internet adoption allows e-mail to be used), and the number of power outages (since internet use may encourage electricity to be adopted if it has not already been). For exporting, our variable measures whether exports were occurring by the year 2000 and so before widespread adoption of the internet (source: databank.worldbank.org), so we consider endogeneity to be less of a problem. There are possibly some companies who were exporting in 2000 and stopped exporting by 2009-10 because they were not on the internet, which would be another route for endogeneity, but as exports and internet use (source: databank.worldbank.org) were growing over the decade this route is probably less important than internet use leading to exports. E-mail use seems highly likely to occur before more advanced applications of the internet, and is more widespread than internet adoption, so we do not consider endogeneity necessarily to be a serious concern here either. However, we also ran our regressions excluding exports and e-mail use, and found similar results to those reported here. To deal with possible endogeneity of power outage counts, we later restrict the sample to only the industrial sectors of metals and machinery, electronics, and chemicals and pharmaceuticals. Companies in these sectors require electricity independently of whether they also use the internet, so that the reverse causality from internet use to electricity adoption can be excluded. As the restriction to these industrial subsectors greatly reduces the sample size, we discuss these results only after our full sample estimates are presented.

5. Results

Table 3

Results for estimations of initial adoption and intensification

	Initial adoption		Intensification	
	Coeff.	St. error	Coeff.	St. error
Rank effects				
Company size				
Medium co	0.405***	0.124	0.229*	0.133
Large co	0.621***	0.173	0.275	0.208
Start year	-0.004	0.004	-0.002	0.003
Manufacturing	0.314	0.238	-0.173	0.378
Ownership				
Part of larger firm	0.522***	0.181	-0.053	0.136
Foreign owner share	0.003	0.003	-0.007***	0.002
State owner share	0.03	0.027	-0.004	0.012
National development				
Financial obstacles	-0.007	0.124	0.208	0.132
Compete against informal firms	-0.309**	0.134	0.022	0.133
Capital city	-0.215*	0.119	-0.017	0.125
Epidemic effects				
Internal experience				
E-mail use	2.002***	0.162	1.67***	0.367
International experience				
Exporter in 2000	0.191	0.166	0.233**	0.116
Initial use				
Industry use	3.023***	0.920	1.341	1.282
Regional use	3.276***	0.992	0.119	0.808
Intensity				
Industry intensity	-0.099	0.459	2.136***	0.592
Regional intensity	0.476	0.639	0	0.570
Country dummies	Yes		Yes	
N	7933		6675	
F test	F(35,71437)=12.897; p=0		F(35,70179)=3.876; p=0	

* denotes ten percent significance, ** denotes five percent significance, and *** denotes one percent significance.

Table 3 shows our results. There are some common factors influencing both initial adoption and intensification, but also many distinct influences. The factors relating to

national development are notably different in their effect. We describe in more detail all the estimated effects and how they compare with our expectations.

Company size has a positive effect on initial adoption and less significantly on intensification. We expected the former finding, and left the impact on intensification open to empirical determination. Firm age has no significant link with initial adoption or intensification. We did not have any prior expectation on the links. Being a manufacturing company rather than service company does not significantly affect either form of adoption.

In the ownership variables, being part of a large firm increases initial adoption, but has no effect on intensification. Both of these links were anticipated. The foreign ownership share has no effect on initial adoption whereas we expected a positive effect, and it has a negative effect on intensification while we expected no effect. The results are consistent with a foreign owner providing the results of internet usage to a subsidiary instead of the subsidiary using it themselves. The state ownership share has no effect on either form of adoption, and we had no prior expectations about it.

In the national development variables, financial obstacles are not associated with changes in either initial adoption or intensification; we expected initial adoption may be decreased. When companies compete against informal businesses, initial adoption is reduced and intensification is not affected, as we expected. Being in a capital city lowers initial adoption and there is no link with intensification. We did not have any prior expectation of the direction of any connections.

Among the epidemic effects, e-mail use is associated with increased initial adoption and intensification, as expected. Exporting has no effect on initial adoption and increases intensification, where we expected both relations to be positive. Industry use increases initial adoption, as expected, and also increases intensification, which was not expected. Use in the region increases initial adoption but doesn't affect intensification, as expected. Industry intensity has no relation with initial adoption and increases intensification, both of which were expected. Regional intensity has no effect on either form of adoption, as anticipated.

Overall, initial adoption is influenced by the a number of rank factors: the commonly identified factor of company size, as well as being part of a larger firm, and factors relating to national development (informal sector competition, and being in a capital city). Among the epidemic effects, initial adoption is influenced by internal experience with e-mail, and use by other companies in the same industry and region. Intensification is influenced by the following rank factors: the company's size (among the commonly identified factors), and foreign ownership (among the ownership factors). However, none of the factors influencing national development affect intensification, in contrast to initial adoption. It seems that once a company has adopted the internet, there is no further influence of national development characteristics on its use, perhaps because there are larger capital outlays at initial adoption relative to intensification. The epidemic influences on intensification are experience with e-mail, a history of exporting, and industry intensity. The first of these influences is shared with initial adoption. Thus, many of the variables that are most characteristic to technology adoption in developing countries (those relating to national development) affect only initial adoption, with other differences between initial adoption and intensification in the effect of ownership and international, regional, and industrial learning effects. There are only a couple of similarities in influences, relating to firm size and internal experience.

Do the determinants of initial adoption and intensification previously identified as applying in highest income countries also apply in poorer countries?

We can answer our question of whether the determinants of initial adoption and intensification previously identified as applying in highest income countries also apply in poorer countries. Company size is a positive influence on initial adoption as in much of the literature (for example, Karshenas and Stoneman (1993)), and on intensification as in Battisti and Stoneman (2005) (although the literature findings are not strong, as we also find). Firm age does not affect intensification, echoing the findings of Battisti and Stoneman (2005). We find that being part of a larger firm increases initial adoption but has no effect on intensification, which contrasts with Bocquet et al's (2007) finding on ICT intensification. Foreign ownership is associated with reduced intensification only. Our result is perhaps surprising given the importance of foreign direct investment for technology transfer in the aggregate technology diffusion literature, but has similarities with Hollenstein and Woerter's

(2008) finding that e-commerce intensification is unaffected by foreign ownership and reduces initial adoption. Prior experience (with e-mail) increases both initial adoption and intensification, similar to Hollenstein and Woerter's (2008) results on internet e-commerce precursors. Industry use increases a company's use and industry intensity increases a company's intensity, in line with the results found in the literature (Battisti et al, 2007; Hollenstein and Woerter, 2008). Thus, many of the causes of initial adoption and intensification that we find are similar to those in the prior literature.

What other determinants are significant in these poorer countries?

We can also answer the question of what other determinants are significant, particularly in countries poorer than those previously examined in the intra-firm diffusion literature. Among the rank effects, state ownership is insignificant in its effect on either form of adoption. Among the variables relating to national development, financial obstacles have no effect on initial adoption or intensification. While not exactly equivalent, our intensification result contrasts with Battisti and Stoneman's (2005) finding that higher costs reduce intensification in the UK. However, the intensification in our case potentially involves adoption of different, cheaper techniques (more advanced skills of internet use) than initial adoption (basic skills of internet use and possibly acquisition of an internet connection), whereas in Battisti and Stoneman (2005) the intensification is of the same technology as the initial adoption. Thus, the intensification we consider is probably less likely to be financially constrained if the initial adoption isn't. Competition against informal firms is associated with reduced initial adoption but unchanged intensification. We read the results as indicating either that capital accumulation for technology purchases can be difficult in markets with many low cost competitors, or that markets with informal competition often have low entry costs and do not readily benefit from internet adoption. Being in a capital city reduces initial adoption without effect on intensification, consistent with the idea that dense personal interactions in urban areas (and capital cities in particular) can substitute for interaction via the internet.

Our split of epidemic effects into more components than in previous work is justified by the statistical significance of the coefficients associated with them. Of the epidemic effects less commonly studied in the literature on individual technologies, exporting affects intensification and regional use affects initial use, although regional

intensity however does not. Exporting has a marginally significant positive effect on intensification, echoing the qualified findings in the aggregate technology diffusion literature. Regional use is positively related with initial adoption, consistent with Billon et al (2008) and Baptista (2001). Regional economic connections are important in developing countries where limited national infrastructure or high transport costs limit national connections. However, regional intensity has no effect on intensification, suggesting that there is a limit to the relevance of experience of geographic neighbours when it comes to advanced use of the internet.

6. Extensions

6.1 The effect of power outages

In this section we consider several extensions to our base model. In the first extension, we consider how power outages affect initial adoption and intensification. Section two suggested that power outages are expected to be associated with lower intensification, but to have no effect on initial adoption. However, the variable is likely to be endogenous because companies that adopt the internet may adopt electricity in order to do so, and then experience power outages. Our uncorrected estimates suggested that this reverse causality was dominating the results. To deal with issue, we ran the estimations using only companies in the metals and machinery, electronics, and chemical and pharmaceutical sectors. These companies employ electricity heavily, and so are likely to adopt electricity irrespective of their internet use. Thus, for them power outages are far less likely to be endogenous. Columns two to five of table 4 show the results. Power outages have no effect on either adoption or intensification.

6.2 Are regional effects incorrectly assigned to industrial effects?

In section five we found that regional use is associated with increased initial adoption by a company. As industries are often clustered in a region, it is possible that some of the importance of industrial adoption in explaining adoption (found in Battisti et al (2007), for example) may be due to regional effects operating in the presence of industrial clustering. To investigate this hypothesis in Latin America and the Caribbean, we re-ran the model excluding regional use and intensity. If the impact of industrial adoption is picking up the impact of regional adoption, then we would expect that the coefficients on industrial use and intensity would change substantially

in value or significance between the estimations with and without regional effects. The results are shown in columns six to nine of table 4. The model coefficients and significances on industrial use and intensification variables change little compared with the corresponding columns in table 3. Thus, regional experience seems to be distinct from industrial experience as an influence on adoption.

6.3 How do experience effects change when industrial competition is tighter?

In section two we said that we did not distinguish between epidemic effects on one hand and stock and order effects on the other, given the variables we employed. The variables of industry use and intensification were used to measure these net effects of industry on company adoption. Here, we change the variables in order to make stock and order effects more significant relative to epidemic effects. The variables are defined for industrial use and intensification in the regions where a company is based, rather than across the whole sample. The idea is that other companies in the same industry and region will be close competitors to the original company, and so the company's technology decisions will consider how to gain a market advantage over these rivals.

Columns ten to fourteen of table 4 show the results of the regression. Local industrial use no longer has any effect of a company's initial adoption. However, it does increase a company's intensification. The company's behaviour is consistent with intensifying in order to stay technologically ahead of rival companies. Local industrial intensity on the other hand is not associated with increased intensification by a company.

Table 4, part i

Extensions

	With power outages				No regional effects				Industries divided by country			
	Initial adoption		Intensification		Initial adoption		Intensification		Initial adoption		Intensification	
	Coeff.	St. error	Coeff.	St. error	Coeff.	St. error	Coeff.	St. error	Coeff.	St. error	Coeff.	St. error
Rank effects												
Company size												
Medium co	0.544***	0.197	0.53***	0.160	0.427***	0.123	0.23*	0.132	0.359***	0.116	0.266**	0.126
Large co	0.462**	0.223	0.336*	0.199	0.623***	0.183	0.274	0.213	0.683***	0.167	0.37**	0.174
Start year	0.007	0.005	-0.001	0.004	-0.004	0.004	-0.002	0.003	-0.003	0.003	-0.003	0.003
Manufacturing	-0.419	0.687	-0.229	0.651	0.38	0.240	-0.171	0.379	0.727**	0.303	-0.933**	0.374
Ownership												
Part of larger firm	0.502	0.374	0.517***	0.152	0.538***	0.183	-0.051	0.138	0.583***	0.171	-0.05	0.140
Foreign owner share	0.003	0.004	-0.006***	0.002	0.004	0.003	-0.007***	0.002	0.003	0.003	-0.007***	0.002
State owner share					0.032	0.028	-0.004	0.012	0.032	0.029	-0.004	0.013
National development												
Financial obstacles	-0.301*	0.167	0.478***	0.164	-0.02	0.119	0.207	0.132	0.032	0.120	0.172	0.125
Power outages	0.016	0.018	-0.003	0.011								
Compete against informal firms	-0.351**	0.167	0.374**	0.155	-0.318**	0.140	0.021	0.133	-0.34**	0.138	-0.013	0.124

Table 4, part ii

Extensions

	With power outages				No regional effects				Industries divided by country			
	Initial adoption		Intensification		Initial adoption		Intensification		Initial adoption		Intensification	
	Coeff.	St. error	Coeff.	St. error	Coeff.	St. error	Coeff.	St. error	Coeff.	St. error	Coeff.	St. error
Capital city	0.069	0.193	-0.109	0.133	-0.047	0.120	-0.015	0.122	-0.201*	0.113	-0.079	0.112
Epidemic effects												
Internal experience												
E-mail use	2.416***	0.297	0.736*	0.388	2.025***	0.163	1.672***	0.367	1.987***	0.153	1.728***	0.389
International experience												
Exporter in 2000	0.064	0.237	0.053	0.177	0.234	0.165	0.234**	0.117	0.098	0.165	0.226**	0.111
Initial use												
Industry use	0.481	2.550	-2.966	1.944	2.945***	0.925	1.334	1.255	-0.555	0.534	1.083**	0.523
Regional use	1.653	1.476	-1.899	1.466					3.441***	1.019		
Intensity												
Industry intensity	6.149***	1.665	1.045	1.920	-0.045	0.476	2.13***	0.596	0.134	0.422	-0.456	0.293
Regional intensity	-0.188	1.075	0.045	0.901					0.738	0.671		
Country dummies	Yes		Yes		Yes		Yes		Yes		Yes	
N	1841		1685		7933		6675		7860		6629	
F test	F(34,71430)=5.133; p=0		F(34,71274)=2.114; p=0		F(33,71439)=12.716; p=0		F(33,70181)=4.020; p=0		F(60,71387)=10.157; p=0		F(64,70152)=16.083; p=0	

* denotes ten percent significance, ** denotes five percent significance, and *** denotes one percent significance.

7. Conclusions

In this paper we have examined the determinants of initial adoption and intensification of business use of the internet in countries with less economic development than those previously examined in the literature. A cross-sectional dataset of Latin American and Caribbean companies was used for investigating the relevance and impact of the determinants. We found that many of the determinants previously used in the inter-firm and intra-firm literature for the highest income countries continue to be relevant in lower income countries. We also found that other variables relating to the level of national development are helpful in explaining use, and exporting and the level of adoption in the region in which the company is resident are also important.

There are many policy implications that can be tentatively drawn from the study. From the ownership variable effects, we have found that being part of a larger firm may increase initial adoption, but larger shares of foreign ownership may reduce intensification. Encouragement of multinational entry into a country may thus lead to increased initial adoption of the internet but reduced intensification of use, with an ambiguous overall effect. Furthermore, state ownership is not found to be adverse for initial or intensification of internet usage, and nor are power outages.

Financial obstacles are not associated with changes in either initial adoption or intensification. However, businesses in competition with informal firms have lower initial adoption but unaffected intensification, which is plausibly due to lower levels of accumulated funds in such businesses. For these businesses, extension of finance may allow them to overcome funding constraints. Facilitating the initial purchase of (or collective access to) the internet may then result in intensive use without more support, possibly because intensive use occurs at a lower cost to initial adoption. Experience with e-mail is associated with increased initial adoption and intensification. Providing facilities for access to e-mail may support later adoption of the internet.

A marginal finding is that capital cities have a lower rate of internet adoption. It may be that this result arises because they have more face-to-face interaction, and the internet is a substitute for it in less urbanised areas. Supporting internet supply and

acquisition in rural areas may be a way of allowing rural companies to interact more fully, as is possible in capital cities.

Exporting is associated with increased intensification, but not initial adoption. The results echo those in the international aggregate technology diffusion literature, and suggest that internet intensification is a beneficial side-effect of exporting, which can have wider productivity consequences. Support for exporting may thus offer direct and indirect technological benefits to the exporting companies and wider industry.

Regional use increases initial adoption. If companies may be able to use the technology profitably but have not already done so, then initial adoption may be encouraged by supporting the co-location with other companies who have already adopted. Whether the internet is then intensively used does not depend on regional use, so the clustering acts only as a seeding method for the technology.

Further work could examine to what extent industrial epidemic effects are partially attributable to regional effects. This paper indicates that for our dataset of Latin American and Caribbean companies the two effects are distinct and significant. In other data, the effects may overlap. The initial adoption of internet technology examined here and its intensification require different levels of capital expenditure. Future work could examine adoption of a technology whose price and type does not vary across the initial adoption and intensification stages. Future work could also look at the relative impact of epidemic and rank effects in highest income regions, by comparison with lower income regions. Information may move more fluently in higher income countries with more developed communications networks, so that rank effects are perhaps relatively more important there than in lower income countries.

Appendix A

Table A1

Countries in our sample

Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
Dominican Republic
Ecuador
El Salvador
Guatemala
Honduras
Jamaica
Mexico
Nicaragua
Panama
Paraguay
Peru
Trinidad and Tobago
Uruguay
Venezuela

References

Antonelli, C., 1985. The diffusion of an organizational innovation. International Journal of Industrial Organisation 3, 109-118.

Battisti, G., Canepa, A., Stoneman, P., 2009. e-Business usage across and within firms in the UK: profitability, externalities and policy. Research Policy 38, 133-143.

Battisti, G., Hollenstein, H., Stoneman, P., Woerter, M., 2007. Inter and intra firm diffusion of ICT in the United Kingdom (UK) and Switzerland (CH): An internationally comparative study based on firm-level data. Economics of Innovation and New Technology 16, 669-687.

Battisti, G., Iona, A., 2009. The intra-firm diffusion of complementary innovations: Evidence from the adoption of management practices by British establishments. Research Policy 38, 1326-1339.

Battisti, G., Stoneman, P., 2003. Inter- and intra-firm effects in the diffusion of new process technology. Research Policy 32, 1641-1655.

Battisti, G., Stoneman, P., 2005. The intra-firm diffusion of new process technologies. International Journal of Industrial Organization 23, 1-22.

Beck, T., Demirgüc-Kunt, A., Laeven, L., Maksimovic, V., 2006. The determinants of financing obstacles. Journal of International Money and Finance 25, 932-952.

Bezemer, D., Headey, D., 2008. Agriculture, Development, and Urban Bias. World Development 36, 1342-1364.

Blalock, G., Gertler, P.J., 2004. Learning from exporting revisited in a less developed setting. Journal of Development Economics 75, 397-416.

Bocquet, R., Brossard, O., 2007. The variety of ICT adopters in the intra-firm diffusion process: Theoretical arguments and empirical evidence. Structural Change and Economic Dynamics 18, 409-437.

Davies, S.W., 1979. Inter-firm diffusion of process innovations. European Economic Review 12, 299-317.

Fuentelsaz, L., Gomez, J., Polo, Y., 2003. Intrafirm diffusion of new technologies: an empirical application. Research Policy 2003, 553-551.

Geroski, P.A., 2000. Models of technology diffusion. Research Policy 29, 603-625.

Girma, S., Greenaway, D., Kneller, R., 2004. Does Exporting Increase Productivity? A Microeconomic Analysis of Matched Firms. Review of International Economics 12, 855-866.

González, A.S., Lamanna, F., 2007. Who Fears Competition from Informal Firms? Evidence from Latin America. World Bank Policy Research Working Paper 4316.

Greene, W.H., 2008. Econometric Analysis (6th ed.). Pearson International Edition.

Hollenstein, H., Woerter, M., 2008. Inter- and intra-firm diffusion of technology: The example of E-commerce: An analysis based on Swiss firm-level data. Research Policy 37, 545-564.

Kashenas, M., Stoneman, P.L., 1993. Rank, Stock, Order, and Epidemic Effects in the Diffusion of New Process Technologies: An Empirical Model. RAND Journal of Economics 24, 503-528.

Keller, W., 2004. International Technology Diffusion. Journal of Economic Literature 42, 752-782.

Mansfield, E., 1963a. Intrafirm rates of diffusion of an innovation. Review of Economics and Statistics 45, 348-359.

Mansfield, E., 1963b. The Speed of Response of Firms to New Techniques. Quarterly Journal of Economics 77, 290-311.

Meade, N., Islam, T., 2006. Modelling and forecasting the diffusion of innovation – A 25-year review. International Journal of Forecasting 22, 519-545.

Megginson, W.L., Netter, J.M., 2001. From State to Market: A Survey of Empirical Studies on Privatization. Journal of Economic Literature 39, 321-389.

Wagner, J., 2007. Exports and Productivity: A Survey of the Evidence from Firm-level Data. The World Economy 30, 60–82.