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Diffusion and use of financial telecommunication: An empirical analysis of SWIFT adoption

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Diffusion and use of financial telecommunication: An empirical analysis of SWIFT adoption

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Abstract

The purpose of the current work is to investigate how country-level and region-specific characteristics influence the adoption of a major financial telecommunication innovation and standard (SWIFT) in the banking sector. Using annual data on the diffusion and usage intensity of SWIFT between more than 100 countries, this study finds that, along other characteristics, economies with higher GPDs and closer to the innovation source have on average a faster adoption rate than smaller, distant economies, all else equal. The analysis also shows that even though financial institutions differ considerably, network effects persist and dominate firm heterogeneity. The results are overall consistent with other findings using similar estimation techniques, and provide a stronger test by focusing on one specific innovation in the financial services industry rather then aggregate IT measures.

Keywords: Financial telecommunication, diffusion, network effects, ICT adoption, usage intensity, SWIFT

JEL Classification: O33, N20, L1

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1. Introduction

The rate at which information and communication technologies (ICTs) are diffused and used across countries is a significant part of the process of technological change, and therefore, it has attracted the attention of a number of economists and ICT scholars. To contribute to the understanding of the diffusion and usage of financial telecommunication and payment systems innovations, the current paper introduces a study on the largest and most significant cross-border financial telecommunication

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network in financial services: the Society for Worldwide Interbank Financial Telecommunication (SWIFT).

SWIFT presents an ideal case study on the diffusion of financial telecommunications mainly for two reasons. Firstly, it has been introduced recently and it has been well documented since the beginning. Secondly, SWIFT provides a clear case of a network technology and a financial messaging standard. This allows for the identification of possible network effects that may arise as the number of adopters and network usage increases.

So far most of the works that look into the adoption of technological innovation usually examine only the speed of diffusion or the asymptotic value of the potential adopters in the market. In parallel, it seems that there is very little research on the diffusion of financial telecommunication innovation and the adoption of ICT in the banking sector (Frame and White 2004).

The current work is quite distinctive from the previous studies and addresses their limitations by introducing a new set of data that incorporates innovation adoption decisions and aggregate country usage data of around 8,000 financial institutions in more than 200 countries. That way it is possible to not only to identify variables that can explain the speed of diffusion in particular countries, but also to uncover a better measure of technological success that builds onto the average usage intensity during a number of years (1999-2006). Following Grajek and Kretschmer (2009) an attempt is made to expose and distinguish between the effects of user heterogeneity and network externalities onto the diffusion path of SWIFT and raise some conclusions regarding the underlying drivers of innovation diffusion. Apart from the one-off adoption of SWIFT, usage dynamics of the actual technology can provide better insights into sustainable goods where their consumption can be separated between a one-off (usually hardware) purchase and subsequent purchases of services. Hence it is possible to identify intensive and non-intensive users instead of just looking at the initial decision to adopt or not a technology.

Due to the span of the data it becomes possible to study these matters across a number of countries and regions and make comparisons. Based onto the diffusion of innovations literature, this work is one of the very few[1] (and to my knowledge the only using financial innovation data) that includes usage intensity to describe the diffusion process of technology adoption.

In order to address these objectives and (a) identify a set of variables that will help to explain the speed and shape of SWIFT diffusion in a region of countries as well as (b) distinguish between the effects of user heterogeneity and network externalities by using information from the average usage intensity, I suggest a simple linear model. Within this context, I employ an estimation technique which is based on Caselli and Coleman (2001), and which takes into account the trade-off between efficiency and consistency in random effects (RE) and fixed-effects (FE) estimators. Consequently a middle solution is proposed that entails fixed region effects and random country effects.

A number of different specifications are being used to investigate the determinants of differences in SWIFT adoption and usage and to capture the potential network effects that may overshadow customer heterogeneity. The paper unfolds as follows. At first, a review of the economics of technology diffusion is presented, followed by a section that contains a brief portrayal and short history of SWIFT and the global financial telecommunications industry. Then, the determinants of SWIFT diffusion are outlined and a description of the empirical data follows in the next section. Finally, the last two parts include the specifications used and the discussion of the results along with the conclusions.

2. Economics of technology diffusion

Within the last few decades many economists as well as ICT scholars have attempted to model innovation diffusion based on a set of economic factors that explain the tendency to adopt a new technology[2]. These factors are typically presented as economic determinants that influence the individual decisions of adopters and usually

[1] Apart from Grajek and Kretschmer (2009) and Ward and Woroch (2005).

[2] The words “innovation” and “technology” are often used interchangeably in the economics of technological diffusion literature. This is mainly because a large number of innovations that have been studied by researchers are technological innovations and therefore are referred to as “technology” in general. While clearly the two terms can mean very different things, innovation usually represents a much broader concept and includes novel ideas, business processes in addition to new technologies.

include the relevant costs and benefits that the innovation embodies. According to the relevant literature, those can be affected either by the demand and/or the supply side of the innovation, highlighting both the role of firms (or individuals) and technology vendors.

The first economist to perform an empirical study on the economics of innovation diffusion was Griliches. In his seminal work published in Econometrica (1957)[3], Griliches examined the determinants that were responsible for the "wide cross-sectional differences in the past and current rates of use of hybrid seed corn" in the US. This type of empirical research, which was later adopted by many researchers looking at many different sectors and technological innovations (Mansfield 1961), confirmed the formation of the sigmoid curve and provided multiple explanations for this prevailing stylized-fact.

Overall, there are a number of modelling approaches that economists have used to analyze technology adoption. Geroski (2000) argues that the two most common types of models with which to approach technology diffusion are the epidemic models[4] and the probit (or rank approach) models. While the former focuses on the description of the communication transmission (information diffusion), the latter concentrates on the differences between the characteristics of potential adopters (adopter heterogeneity) and how these can explain the variation in the timing of adoption decisions[5] (Stoneman 2002).

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[3] Griliches, Zvi. 1957. Hybrid Corn: An Exploration in the Economics of Technological Change. *Econometrica* 25, no. 4: 501-522.

[4] An early example of this approach is the above-mentioned work of Griliches (1957). Epidemic models assume that the newly-introduced technologies spread among firms as an "infection in a population" (Stoneman 2002). This implies that there is an upper limit of a population that can potentially adopt a particular innovation. The number of adopters increases mainly due to the interaction between individuals (or firms) that learn about the existence of the new technology. The more people communicate the higher the probability that they will adopt. Thus, over time the number of users will increase reducing the number of non-adopters. As such, the diffusion process forms the well-known S-shaped diffusion curve reaching to equilibrium only once the whole population has adopted the innovation (during the process disequilibrium is maintained). The problem with this approach is that it does not examine the decision of individuals or firms to adopt and it assumes that the "epidemic" function is the only that counts and shapes the diffusion.

[5] Probit models are types of equilibrium models that largely deal with the limitations of the so-called "epidemic" approach by looking at firm (or individual) characteristics that influence the decision to adopt. Consequently, the "diffusion path" is based on the dynamic characteristics of the innovation itself and the perceived benefits from the large heterogeneous population. In these models information diffusion does not matter and it is usually assumed that firms have all the information about the product

Of particular interest in the diffusion literature is the notion of network effects or externalities that are created from the widespread adoption of innovations. Network effects usually appear due to the "high degree of interrelation" among technological standards and networks which increase the value of the technology for each user as the number of adopters raises (Hall and Khan 2002). These externalities can be experienced in two fundamental ways: direct network effects and indirect network effects. Direct externalities take place when the value from adopting an innovation increases "directly" as the number of adopters increases. A simple example often used in the literature is that of the telephone. It is logical that the utility of this technology largely depends on how many subscribers can be reached via its infrastructure. Indirect network effects also depend on the size of the network but for different reasons. These arise mainly because of the availability of complementary goods that relate to the network innovation. A good example is the relationship between hardware and software. As the use of a particular hardware innovation increases, additional software is being developed that boosts the utility of the hardware components. This is very common in many innovations that are usually seen as opportunities for other vendors to develop applications that are compatible with such products[6].

It is apparent that any of the two types of network effects can have considerable influence on technology adoption as they impact the benefits that the innovation delivers. A large number of empirical studies have confirmed this statement. Coincidently, the most influential works come from the financial services sector and the Automated Teller Machine (ATM) adoption by banks. Saloner and Shepard (1995) first found evidence that linked the probability of ATM adoption with the size of the bank branch network in various locations and their customer deposits. Their duration model, which was tested with US bank data varying from 1971 to 1979, revealed that, the larger the anticipated benefits from the use of ATM networks, the soonest banks would adopt and spread the cash machines among their branches. This

since the beginning, and thus are not "infested" as time goes by, but rather choose to adopt or not at certain times.

[6] Recent examples that come immediately to mind are: DVD players and DVDs, game consoles and games, iPhone devises and apps, etc. In the case of SWIFT the various SID terminals that were developed in the early years, as well as other more recent external vendor applications are also parallel examples.

result indicates a clear example of network effects as the bank network increases in the sample.

Empirical studies of technology diffusion in financial services

Prior to Saloner and Shepard's study on network effects (1995), diffusion scholars had used the same data on ATM machines to identify patterns of adoption among banks (Frame and White 2004). More explicitly, Hannan and McDowell (1984) found that larger banks and "banks operating in more concentrated local banking markets" had greater probability of adopting ATMs conditioning on a number of other factors[7]. In a later paper (1987) they also argued that the adoption of ATMs was positively correlated to competitor banks' adoption. Again using the same dataset, Sinha and Chandrashekaran (1992) identified that the banks' growth and income had a positive influence on its probability of adoption, whilst (unlike other studies) they found a negative impact of bank size. Additional research using alternative ATM data from other countries largely confirms a positive correlation between bank size and technology adoption (Ingham and Thomson 1993, Gourlay and Pentecost 2002).

Apart from the ATM diffusion studies, Akhavein et al. (2005) also investigate the adoption of a small-business credit scoring technology from large banks in the US between 1993 and 1997. As in the above studies, the authors use a hazard model that reveals that banks with more branches located closer to the New York Federal Reserve district have a higher probability of adopting the technology sooner. In addition, they confirm their results using a Tobit model. A very similar study on credit scoring is presented by Bofondi and Lotti (2006) who use a survey of Italian banks to verify a set of Schumpeterian propositions[8]. In a very different setting, Weber (2006) examines the adoption of electronic trading at the International Securities Exchange (ISE). Using both OLS and Tobit models the author identifies a set of significant firm-specific factors that account for a large proportion of the models' ability to explain the adoption decisions of brokerage firms. Furthermore,

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[7] In their study, Hannan and McDowell used a survivor function to estimate the "hazard rate" which describes the probability of a firm to adopt an innovation at time t. Hazard models of this kind combine the epidemic modelling approach with firm-specific characteristics that can bring equilibrium at any point throughout the diffusion process (depending on the firms' decision to adopt or not based on the costs and benefits at each point in time).

[8] Schumpeterian hypothesis argues that larger and more profitable firms tend to innovate earlier. For a detailed discussion on this see Schumpeter (1943), Mansfield (1963) and McNulty (1974).

network externalities are recognized as the volume and liquidity of the ISE increase. In the banking sector additional studies have looked at online and telephone banking adoption from retail customers (Lambrecht and Seim 2006, Khan 2004).

Despite the acknowledged importance of technological change in the financial services industry, the amount of research that examines the diffusion of technological innovations in the sector is a surprisingly limited[9]. Putting aside the small number of single-country (individual-level or firm-level) studies, there are only a few papers that look into the cross-country diffusion of such technologies and identify regional characteristics that influence the spread of innovation in banking[10]. In line with the broad diffusion literature, this stream of research employs OLS, hazard, and Probit or Tobit approaches to model these relationships using a variety of variables.

Antonides et al. (1999) investigate the adoption of four payment innovations in ten countries using a hazard rate model. From their analysis they find that the alternative payment systems have different speeds of adoption, with banker's cards spreading faster than ATMs. Their results also indicate that the level of acceptance of a payment system can influence the diffusion of another system under certain circumstances. In addition, Bech and Hobijin (2007) examine the diffusion of an RTGS technology among central banks in 174 countries between 1970 and 2005. Their results show that the adoption rate of RGTS follows an S-shaped diffusion curve which is influenced by a number of country-level variables like the GDP per capita, the country population, and other spillover factors.

3. SWIFT and the global financial telecommunications industry

[9] Frame and White (2004) list a number of reasons that could explain the lack of extensive empirical research in the area of financial innovation. Perhaps the most striking is the relevant shortage of directly useful data on technologies used in the finance sector. Even though financial institutions have a good record of keeping data on accounts, trades and other financial measures, it is rear that a bank would maintain in its reports consistent information on technological developments and innovative activity. For that reason many diffusion scholars have focused on data that describe non-financial innovations.

[10] There is a number of cross-country studies that focus on the diffusion of general-purpose innovations economy-wide, like personal computers (Caselli and Coleman 2001), or in other instances the Internet, e-business, and mobile phones (Lee and Brown 2008, Forman 2005, Kiiski and Pohjola 2002, Zhu, Kramer et al. 2006, Grajek and Kretschmer 2009). These studies often use as point of reference the individual or household and less often the organisation.

During the last fifty years, network innovations and related technological developments have revolutionized financial telecommunications and transformed the nature of banking operations and fiscal transactions worldwide. As financial institutions, markets, and systems became more globalised, the demand for cross-border linkages that facilitated international business and the exchange of services increased dramatically (Berger et al. 1999, Wong and Fong 2010). This led to the development and adoption of high-value electronic fund transfers (EFT) and global payment systems that promised faster, safer and lower-cost transactions (Scott and Zachariadis 2010).

Founded in Brussels in 1973, the Society for Worldwide Interbank Financial Telecommunication (S.W.I.F.T.) is a co-operative organization serving as a shared global communications link and a messaging standard for international financial transactions. SWIFT was initially founded with the objective of automating and potentially replacing the *telex* as a mean of communication between banks[11]. Hence, the operations and business requirements of banks remain its primary focus. Dedicated to the promotion and development of standardized global interactivity for financial transactions, the Society operates a focal service for the exchange of financial messages such as payments, confirmations, settlement messages, letters of credit, securities transactions, and other types of standardized messages.

The operation of its network started in 1977 and was initially supported by 518 Banks in 22 countries. Since then, the use and size of its platform has expanded rapidly and it has evolved from a mere tool for bankers into a broadly based institution serving the financial community. Today, SWIFT is headquartered in Brussels with possessing data centres in Belgium and the United States. It has more than 8,000 live users connecting from more than 200 countries which may sound relatively modest until one realizes that a “user” is an organization and there may be thousands of employees within a single organisation using SWIFT at any one time. In the three decades of its operation, SWIFT has assumed a dominant presence the financial sector and has created a powerful infrastructure of interconnectivity between its members who benefit from the

[11] The *telex* was a system that used telephone-like rotary dialling to connect teletypes. Subscribers to a telex service could exchange textual communications and data directly with one another.

significant economies of scale that have been created through the spread of its network.

However, SWIFT's expansion has not always been smooth. Just a few months after the network started its operations, member banks realised that the general legal principles of international business practices were insufficient to deal with the new technology of SWIFT transactions. Towards the end of the 1970s the community employed new SWIFT-specific rules that defined users liabilities and responsibilities in more explicit terms. Nevertheless, additional problems surfaced due to the sizeable and remarkably diverse membership of banks that had different sizes and expectations. Finally, the complicated administrative and political structure of the Society also made things more challenging (Scott and Zachariadis 2010, Winder 1985).

Since its launch in 1973, SWIFT has largely maintained its identity within the financial services industry as a "proprietary communications platform" that allows financial institutions to "connect and exchange financial information securely and reliably"[12]. Various attempts to create similar networks prior to the launch of SWIFT failed due to lack of collaboration between banks who initially competed to provide connectivity products and services[13]. The establishment of SWIFT marked a concord which has meant that for the most part the banking community does not attempt to develop alternatives. There are some business and connectivity "solutions" in the tech market that compete with SWIFT, however they account for a small fraction of business and don't offer a comparable level of services or global coverage to SWIFT.

By looking at the history of SWIFT (Scott and Zachariadis 2010) it has been possible to identify a number of things that have undoubtedly affected its membership growth and the use of its network over time. Firstly, SWIFT was founded in an attempt to replace the outdated technology of Telex. Nevertheless, in spite of its advanced operational features, it also managed to inherit a number of Telex-related characteristics that later presented obstacles to development. In addition, the historical narrative also revealed political issues between the countries involved in the development process. As mentioned above, SWIFT was considered from the very

[12] Source: http://www.swift.com
[13] For a detailed historical study on the origins and development of SWIFT see also Scott and Zachariadis (2010).

beginning to be a European "invention" that would compete with the emergence of proprietary networks in the US. This account may have also influenced the rate of adoption, at least in the early years of its operation.

Likewise, a number of other features that related to the innovation of SWIFT itself and the political tensions surrounding them may have provoked or interrupted its assimilation around the world. Figure 1 presents some of the events that are believed to have played a decisive role in the ongoing development of SWIFT. These are mapped onto the diffusion curve of SWIFT since the beginning of its operation in 1977 until 2008 in order to show a clear picture of the dynamic relations over the years.

As we can see from the figure below, there are three distinct aspects that can be related to the immediate or long-term growth of SWIFT. Primarily, the role of technology, and more specifically subsequent network upgrades, had an instantaneous effect on the capacity of the infrastructure supporting the additional number of users and transactions. This was explicitly profound in the case of SWIFT II, the X.25 platform, which was announced in 1983 and was fully functional in 1990. Its deployment was deemed necessary in order to manage "greater capabilities" (Crockett 1990) and deal with the increasing client demands. Rosenberg (1972) and Hall and Khan (2002) categorize this effect as part of the "supply side", where improvements and technology upgrades are important determinants of the adoption of an innovation. In the situation of SWIFTNet however the results seem to be different. Even though the announcement of the IP platform coincided with what it seems to be a period of expansion, the migration seemed to have a negative effect on the growth rates. This can be attributed to the somewhat increased cost of ownership that the new technology brought to its users as they had to upgrade their equipment and software to keep up with the latest developments. It might be the case that light users of SWIFT chose to leave the network as their connection was not longer cost effective[14].

[14] Around that time SWIFT went on to design new connectivity products that met the requirements of smaller banks and "lighter" users.

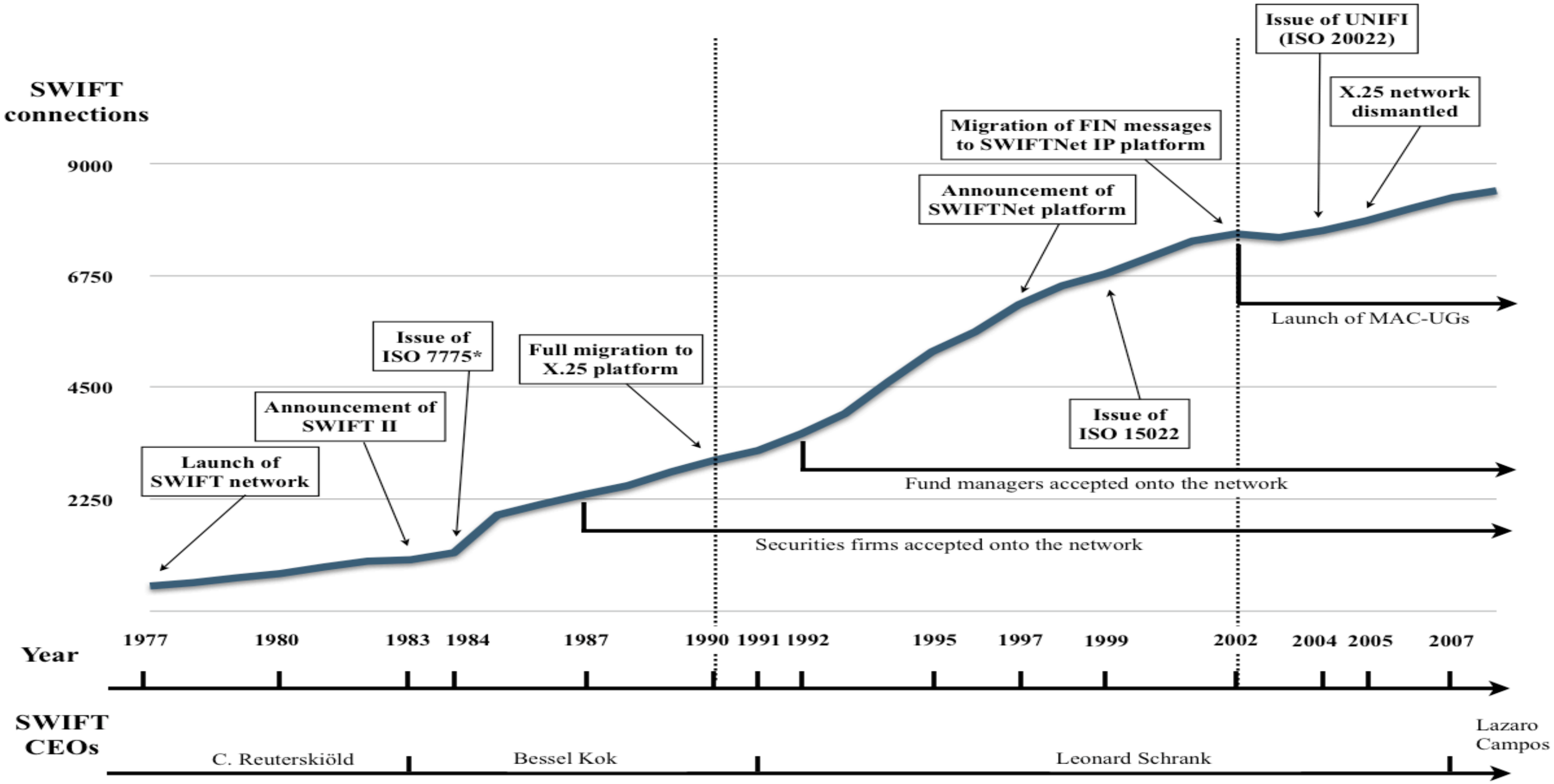

Figure 1. Diffusion of SWIFT[15]

[15] Diffusion data are based on the number of SWIFT network users since 1977. These were mainly acquired from SWIFT annual reports and online datasets. The data are also presented in Table 3.

In parallel to the technological advancements, the development of new and superior standards also played an important part in the expansion of the SWIFT user base. Their transmission over the network not only offered more interoperability benefits to its users but also introduced new products and services that did not exist before. In that respect, a broader range of solutions attracted more clients that were keen to join the network. Finally, acceptance of new types of users onto the system is another factor that might have affected SWIFT growth since the beginning. Nevertheless, it was only through the combination of all the above that SWIFT achieved recognition and expanded in the financial services industry. For example, the introduction of new standards (like ISO 7775) attracted more securities firms once they were allowed onto the network. Consequently, the new firms pushed for further technology upgrades that were considered as necessary to satisfy their needs and the increasing volumes.

In spite of this thorough analysis of the historical facts, there is still uncertainty about how this combination of causes affected SWIFT diffusion among different countries and regions. Additional exogenous factors might have also influenced the observed patterns. Events like the "dot-com bubble" rupture that took place in 2000 resulting in a market crash that lasted until 2002, or the 9/11 incident that resulted in the cancellation of SIBOS in 2001, might have had a major influence leading to a drop in the absolute number of adopters in 2003[16].

Nevertheless, it is suggested that SWIFT growth has been neither the "victim" nor the "beneficiary" of random worldwide exogenous shocks but the result of certain choices that reflect the characteristics and needs of participants. Overall, it would be really difficult and potentially misleading to try and draw conclusions based solely on the above diagram; hence, a more rigorous quantitative approach is needed to disentangle the determinants of SWIFT diffusion worldwide.

4. Determinants of cross-country SWIFT diffusion

As already discussed, adoption decisions from individual firms are commonly based on their perceived costs and benefits from the use of the relevant technology. According to the relevant economic theory, an entity would only adopt an innovation

[16] That was the first year since the founding of SWIFT that the total amount of users decreased even slightly.

when the expected profits from its use are equal or exceed the adoption costs. For different firms this point may come at different times according to their attributes. Yet, the diffusion of innovations literature has also highlighted the importance of the economic, social and technological environments within which firms function. These measures are primarily reported on an economy-wide basis and often predict the rate of innovation adoption since they act as proxies for some of the firm-level characteristics that influence the firms' decisions. DOI scholars have looked at such determinants of diffusion and have identified a set of variables that best explain the adoption patterns among countries.

First of all, there is considerable evidence that the size of real GDP per capita as well as country population have been influential factors for the adoption of various innovations (Grajek and Kretschmer 2009, Bech and Hobijn 2007, Lee and Brown 2008, Zhu and Kraemer 2005, Caselli and Coleman 2001). Statistical analysis of cross-country technology adoption patterns has shown that there is a positive relationship between the size of the economy and innovative activity, which is broadly in line with the Schumpeterian hypothesis[17]. This outcome is also expected in the case of SWIFT diffusion mainly because countries with larger population and bigger economies will potentially have a higher demand for interbank communication and thus it is more likely that SWIFT will install its service[18].

In parallel, a number of works have pointed to the role of industry factors as potential influences for the diffusion of innovations (Lee and Brown 2008, Caselli and Coleman 2001). These factors mostly depend on the sector under study and are often measures that account for the developments and intensity or size of the business under study. In order to take the magnitude of the finance sector into account, the current research employs two variables that capture financial activity: the total value of traded stocks and the value of current transfers for each country annually. These are

[17] The size of the population is usually a proxy for the size of the market in each country. GDP per capita can also represent the values of other omitted variables (for more information see section on modelling strategy and results). Both of these variables are included in the analysis.

[18] While the uptake of SWIFT from a single firm is somewhat an easy task, the introduction of a country onto the network is a long process that involves a lot of effort and costs. In most of the cases SWIFT needed to install regional processors and also negotiate with national PTTs the connectivity arrangements. It was common that SWIFT would not often set up its service unless there was a certain level of volume (or number of firms showing genuine interest) that could justify the installation costs (Garsson 1983).

expected to have a positive influence on the adoption and use of SWIFT since such financial transactions usually depend on secure payment systems with high resilience and consistency.

Complementarily, goods and inputs like telecommunication infrastructures or technologically skilled workers have also proved to be important factors influencing technology adoption (Brynjolfsson and Hitt 2000, Caselli and Coleman 2001, Hall and Khan 2002). In the case of the former, various studies have shown that improvements and increased use of supplementary ICTs were positively correlated with the diffusion of technological innovations (Gruber and Verboven 2001). To capture the effects of relevant technological advancements and changes on the capacity of the telecommunication channels in each country this paper considers a measure of telephone connections. In addition, the imports and exports of computers, communications and other services are used to account for the significance of these goods in the economy. It is expected that economies which are technologically advanced (both in terms of technology and skills) and are able to manufacture computers and offer telecommunications services will have a higher (positive) influence on the diffusion of SWIFT than economies that produce less and rely mainly on ICT imports.

Furthermore, recent studies on the effect of the installed base of previous generations of innovation suggest that moving to a new technology becomes harder the larger the base of the old innovations (Grajek and Kretschmer 2009). However, such an outcome can be overturned if the new technology has "backward compatibility"[19] where new users can communicate with old users of the previous generation innovations (Stoneman and Toivanen 1997). As we can see from the historical narrative, SWIFT belongs to the second category because older generations of technology such as Telex were compatible with SWIFT terminals and could operate onto the SWIFT network. This compatibility feature balances out the lack of data on Telex subscribers in the financial services industry for each country.

[19] In (Grajek and Kretschmer 2009, p.10).

In addition to the size of the economy, the intensity of the financial sector and the underlying technological infrastructures, the literature has identified the openness of the economy as another important factor that affects innovation diffusion. Imports and exports of insurance and financial services are also expected to influence SWIFT adoption and use. Exporting economies are expected to have a positive relationship with the spread and use of SWIFT within their country, whereas, importing economies would have less users adopting over time.

Geographic effects are widely regarded as critical factors for the spread and use of technologies from one country to another. This is well documented in the trade literature where international technology diffusion decreases as geographic distance increases (Leamer and Levinsohn 1995). As a result, innovation diffusion can sometimes follow a geographically localized process (Keller 2004). An advantage of these geographic effects is that variables like distance between countries are definitely exogenous when trying to estimate their influence on ICT adoption. In this research, distance from Belgium is used to account for these geographic effects and investigate how cross-country technology diffusion is affected. It is therefore expected that there would be a negative relationship between the distance of countries from the birthplace of SWIFT and their adoption patterns.

Whilst these factors are considered to be the most influential on innovation diffusion between countries, additional unobserved economic or non-economic parameters may exist that have an effect on the adoption of SWIFT. An example is the effect SWIFT prices may have had on the decision to adopt or not the service, or the effect of complementary technologies (like certain innovations and standards) that were diffused simultaneously. Unfortunately, the impact of these variables cannot be recovered in this paper due to data limitations, however, the effect of variables like SWIFT standards and prices, which vary for all adopters, are controlled for in the subsequent analysis[20].

[20] SWIFT prices were deployed for all members and users worldwide at the same time. The same goes for new standards developments and new products (as well as changes in governance and user acceptance), where slight variations in implementation among countries usually did not exceed the twelve months. As a result, time dummies in the econometric specifications will capture these effects that do not vary between countries and are year-specific.

5. Empirical Data

Sources and definitions

The data used in this study were drawn from several sources. First of all, the SWIFT adoption and usage data were either provided by SWIFT or collected from annual reports and online records[21]. Both sources provided information on the complete number of adopters per country from 1977 (the year SWIFT started its operation) until 2006 where the data end. In addition, usage figures record the number of messages that were sent from each country[22]. Both variables are reported annually and include more than 200 countries and territories around the world.

Country-level economic variables were also acquired from multiple sources based on the availability and duration of the data. Population statistics were obtained from the International Monetary Fund (IMF) World Economic Outlook 2008 and largely cover from 1980 (for well-developed economies) to 2005. In addition, GDP figures were drawn from the World Bank and OECD national accounts and exist for most of the countries between 1977 and 2006. Information on the imports and exports of financial and ICT services, as well as current transfers were acquired from the IMF Balance of payments statistics Yearbook. These are also reported annually beginning in 1977 through 2006.

To complement the main datasets, the total values of stocks traded were drawn from the Standard and Poor's emerging stock markets Factbook. Furthermore, two additional measures on the distance from Belgium and the national telephone infrastructure were introduced from the French Research Centre for International Economics (CEPII) and the International Telecommunication Union (ITU) respectively.

Table 1 presents a detailed list of all the variables used in the analysis along with a brief description and the source from which they were acquired.

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[21] Most of the annual reports were made available by SWIFT employees. However, additional information were acquired from the company's website (www.swift.com) which maintains a large number of recent reports (post-2000) and figures on the number of adopters and usage by country.

[22] Usage data are also broken down according to the different types of transactions that were facilitated by SWIFT: payments, treasury, trade, and securities messages.

Table 1. Variable definitions and descriptions

Variables	Definition	Description	Source
DISTBel	Distance from Belgium (km)	Measures the distance between capitals of Belgium (Brussels) and the respective country in kilometres.	French Research Centre in International Economics (CEPII)
POP	Population (millions)	Country population in millions.	IMF World Economic Outlook 2008
GDPpc	GDP per capita (constant 2000 US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant U.S. dollars.	World Bank national accounts data, and OECD National Accounts data files.
TELE	Telephone lines (per 100 people)	Telephone lines are fixed telephone lines that connect a subscriber's terminal equipment to the public switched telephone network and that have a port on a telephone exchange. Integrated services digital network channels and fixed wireless subscribers are included.	International Telecommunication Union, World Telecommunication/ICT Development Report and database, and World Bank estimates.
TRANSF	Current transfers, receipts (BoP, current US$)	Current transfers (receipts) are recorded in the balance of payments whenever an economy receives goods, services, income, or financial items without a quid pro quo. All transfers not considered to be capital are current. Data are in current U.S. dollars.	International Monetary Fund, Balance of Payments Statistics Yearbook and data files.
STOCKS	Stocks traded, total value (current US$)	Stocks traded refers to the total value of shares traded during the period.	Standard & Poor's, Emerging Stock Markets Factbook and supplemental S&P data.
ICTimp	Computer, communications and other services	Computer, communications and other services (% of commercial service imports) include such activities as international telecommunications, and postal and courier services; computer data; news-related service transactions between	International Monetary Fund, Balance of Payments Statistics Yearbook and data files.

Variables	Definition	Description	Source
	(% of commercial service imports)	residents and non-residents; construction services; royalties and license fees; miscellaneous business, professional, and technical services; and personal, cultural, and recreational services.	
ICTexp	Computer, communications and other services (% of commercial service exports)	Computer, communications and other services (% of commercial service exports) include such activities as international telecommunications, and postal and courier services; computer data; news-related service transactions between residents and non-residents; construction services; royalties and license fees; miscellaneous business, professional, and technical services; and personal, cultural, and recreational services.	International Monetary Fund, Balance of Payments Statistics Yearbook and data files.
FINimp	Insurance and financial services (% of commercial service imports)	Insurance and financial services cover freight insurance on goods imported and other direct insurance such as life insurance; financial intermediation services such as commissions, foreign exchange transactions, and brokerage services; and auxiliary services such as financial market operational and regulatory services.	International Monetary Fund, Balance of Payments Statistics Yearbook and data files.
FINexp	Insurance and financial services (% of commercial service exports)	Insurance and financial services cover freight insurance on goods exported and other direct insurance such as life insurance; financial intermediation services such as commissions, foreign exchange transactions, and brokerage services; and auxiliary services such as financial market operational and regulatory services.	International Monetary Fund, Balance of Payments Statistics Yearbook and data files.

Descriptive Statistics

Table 2 provides some descriptive statistics on the variables of interest. As mentioned earlier, the period and the number of countries the data cover depend on the particular variables, but in general the sample covers more than 200 countries from 1977 to 2006. Nevertheless, coverage for most of the empirical work will decrease due to limitations in the covariates that are being used. The table below also reports summary statistics of the OECD countries included in the sample.

Table 2. Summary statistics

Variables	Obs.	Countries	Mean	St. dev.	Min	Max
	Pooled sample					
DISTBel	6240	207	6279.21	3935.03	68.44	19011.83
POP	4257	179	23.42	67.14	0.04	987.05
GDPpc	4925	187	6869.68	11197.23	62.24	93165.1
TELE	5469	194	14.90	18.05	0.01	94.43
TRANSF	4383	179	$1.4\cdot10^{9}$	$3.42\cdot10^{9}$	0	$4.79\cdot10^{10}$
STOCKS	1666	114	$2.64\cdot10^{11}$	$1.83\cdot10^{12}$	0	$3.33\cdot10^{13}$
ICTimp	4339	179	26.64	16.37	$-3.27\cdot10^{-13}$	100
ICTexp	4330	179	27.24	20.49	$-4.83\cdot10^{-13}$	100
FINimp	4234	179	6.23	5.24	-28.61	61.93
FINexp	4153	179	3.45	6.12	-5.18	70.45
	OECD sample					
DISTBel	990	33	3476.32	4776.14	68.44	19011.83
POP	833	33	33.68	50.40	0.23	296.26
GDPpc	944	33	17143.51	9791.82	2063.98	54009.34
TELE	976	33	37.92	17.51	1.97	74.46
TRANSF	891	33	$4.57\cdot10^{9}$	$5.76\cdot10^{9}$	600000	$4.79\cdot10^{10}$
STOCKS	586	33	$7.04\cdot10^{11}$	$3.04\cdot10^{12}$	$1.90\cdot10^{7}$	$3.33\cdot10^{13}$
ICTimp	889	33	32.61	13.68	$-1.85\cdot10^{-13}$	100
ICTexp	889	33	31.97	15.11	0.17	100
FINimp	857	33	5.94	7.98	-0.48	61.93
FINexp	857	33	5.21	9.42	-2.28	70.45

Notes: This table presents summary statistics of the regressors used throughout the analysis in this study. The values reported here represent levels of the measured variables, whereas, their log values are used in some of the specifications in later tables. Columns provide information on the number of observations and countries, variable mean, standard deviation, the minimum and the maximum values.

In addition, Table 3 provides measures on the number of adopters and countries as well as SWIFT usage from 1977 to 2006.

Table 3. Growth of SWIFT connections, countries, and annual traffic: 1977-2006

Year	Firms			Countries			Annual traffic (Thousands of messages)
	Accumulated Adopters	Change in Adopters	Change (%)	Accumulated Countries	Change in Countries	Change (%)	
1977	518	518		15	15		3400
1978	586	68	13.13	17	2	13.33	21600
1979	683	97	16.55	17	0	0.00	34500
1980	768	85	12.45	23	6	35.29	46900
1981	900	132	17.19	27	4	17.39	62500
1982	1017	117	13.00	33	6	22.22	79900
1983	1046	29	2.85	38	5	15.15	104100
1984	1188	142	13.58	40	2	5.26	129900
1985	1946	758	63.80	47	7	17.50	157220
1986	2161	215	11.05	51	4	8.51	192010
1987	2360	199	9.21	54	3	5.88	222300
1988	2537	177	7.50	59	5	9.26	255111
1989	2814	277	10.92	66	7	11.86	296070
1990	3049	235	8.35	77	11	16.67	332895
1991	3243	194	6.36	81	4	5.19	365159
1992	3582	339	10.45	91	10	12.35	405541
1993	3986	404	11.28	102	11	12.09	457000
1994	4625	639	16.03	124	22	21.57	518000
1995	5229	604	13.06	142	18	14.52	603000
1996	5632	403	7.71	159	17	11.97	688000
1997	6176	544	9.66	172	13	8.18	812000
1998	6557	381	6.17	188	16	9.30	937000
1999	6797	240	3.66	197	9	4.79	1059000
2000	7125	328	4.83	199	2	1.02	1274000
2001	7457	332	4.66	204	5	2.51	1534000
2002	7601	144	1.93	207	3	1.47	1817000
2003	7527	-74	-0.97	210	3	1.45	2047000
2004	7667	140	1.86	212	2	0.95	2299000
2005	7863	196	2.56	215	3	1.42	2518000
2006	8105	242	3.08	219	4	1.86	2865000
		8105			219		

Notes: The data contain the population of SWIFT adopters, which includes 8105 firms from 219 countries and territories. Adoption information is from 1977 to 2006. The second, third, and fourth columns above include data on the number of adopters and their change over time, and columns five, six, and seven the number of countries SWIFT was introduced. The last column reports the annual number of SWIFT messages that were sent in the first 30 years of SWIFT operation.

Source: S.W.I.F.T. sc.

Even though aggregate usage data (traffic of SWIFT messages) are provided for all the years since SWIFT operations began, traffic data per country in the sample cover a span of 8 years from 1999 to 2006. Drawing from the prior historical analysis of SWIFT, it can be seen that the majority of the initial 15 countries that implemented SWIFT in 1977 were European: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Luxembourg, Netherlands, Norway, Sweden, Switzerland, UK, and US. These countries can be considered as “innovators” due to the fact that their member banks contributed to the founding of SWIFT in 1973.

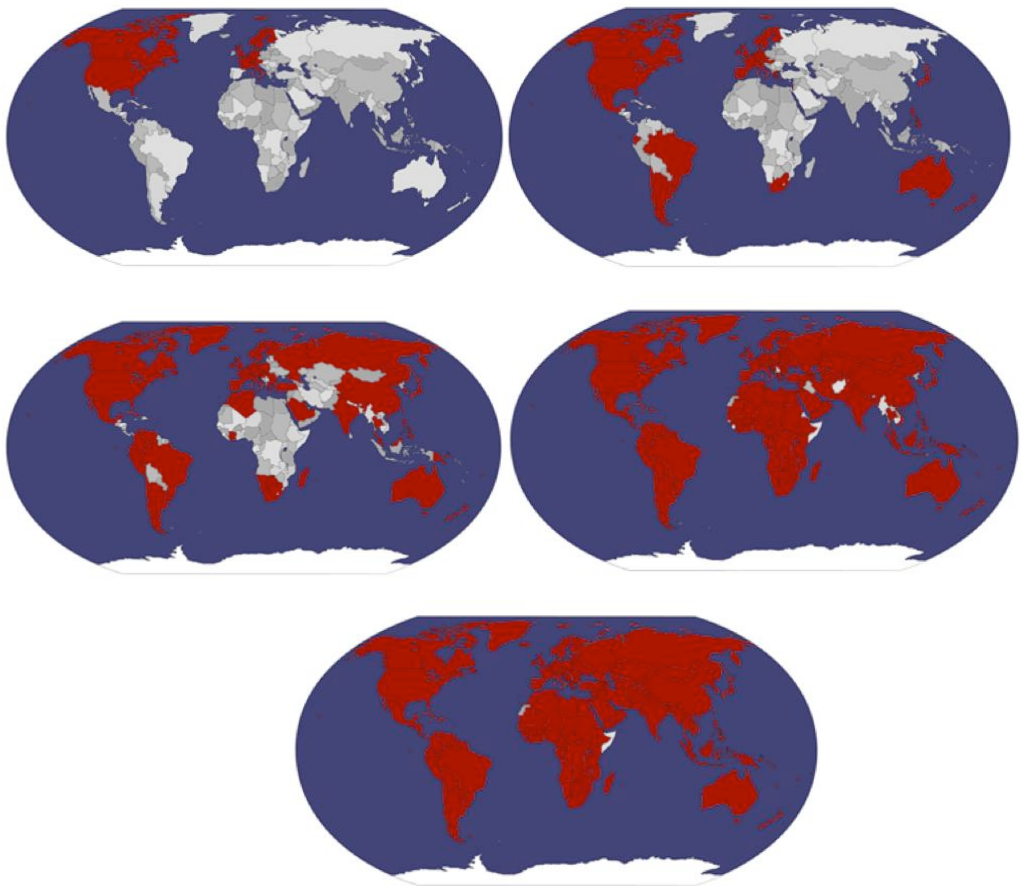


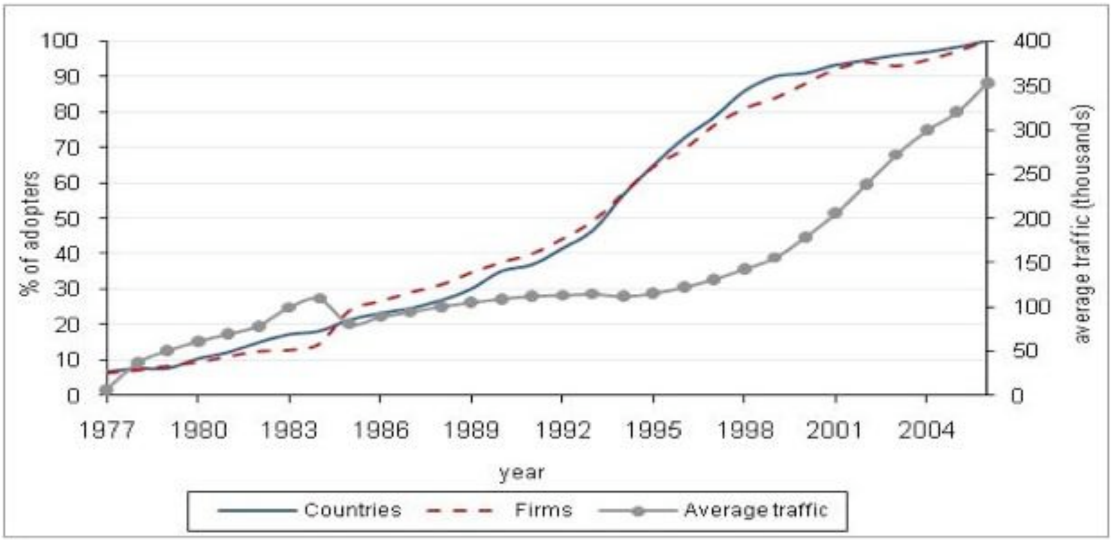
Figure 2. Diffusion of SWIFT in 1977, 1984, 1992, 2000, and 2007

As cross-country payment systems were becoming more popular during the 1980s, the number of adopter countries increased slowly from 15 in 1977 to 51 within a decade (end of 1986). By 1990 member countries went up to 77 and were doubled by 1996 to a total of 159 countries and territories around the world. Figure 2 illustrates the spread of SWIFT throughout the world in 5 different years: 1977, 1984, 1992, 2000, and 2007. Also apparent in the figure is the fact that SWIFT was first adopted in Europe and the US and covered most of the countries by 2000.

Apart from the rate of adoption, this paper also seeks to link usage data to the different adoption patterns characterizing the diffusion process. Figure 3 plots SWIFT adoption among all countries and firms (left axis, % of total adopters), and average usage (right axis, number of messages per firm in 000's). By looking at the graph (as well as Table 3) it becomes apparent that the number of firms and country adopters increase at approximately the same pace. Nonetheless, it is important to note that country adopters have almost reached saturation with very few countries and territories not yet part of SWIFT. On the contrary, firm adopters increase substantially as the eligibility criteria for new joins change over time.

In spite of the fact that the overall diffusion is S-shaped, the above descriptive statistics imply that usage trends differ significantly from the patterns of adoption. As can be seen from the figure below, the average traffic per user was proportionally higher between 1978 and 1984 compared to post 1985 figures. This is broadly in line with the historical evidence according to which SWIFT founders were sizeable European and US banks that created the network in order to satisfy their needs for interbank telecommunication. As a result, the average usage intensity during the first years was relatively higher and later decreased when smaller banks and less intense users joined the network. It is notable that after a significant drop between 1984 and 1985, the average usage started to increase again and accelerated significantly around 1999-2000. This later change in average traffic could either signify that users of the network started to use the service more by migrating their existing operations to SWIFT[23] or that post-2000 adopters were more intense users of the infrastructure. In any case, these statistics are only indicative and should be interpreted cautiously as there are no controls for key firm and country-level characteristics.

[23] This effect could be explained by the constant falling prices of SWIFT messages and the series of new products that SWIFT introduced over time to its customers (Scott and Zachariadis 2010). Both of these could have had an effect on the usage intensity of current and future adopters.



Notes: The blue (regular) line represents the rate of country adoption as a percentage of the country population in 2006, and the red (dashed) line the rate of firm adoption as a percentage of the firm adopters population in 2006 (left axis). The grey (bulleted) line describes the average traffic in thousands of messages or else the number of messages per firm (right axis). The data are for 219 countries and territories in the sample and cover the period from 1977 to 2006.

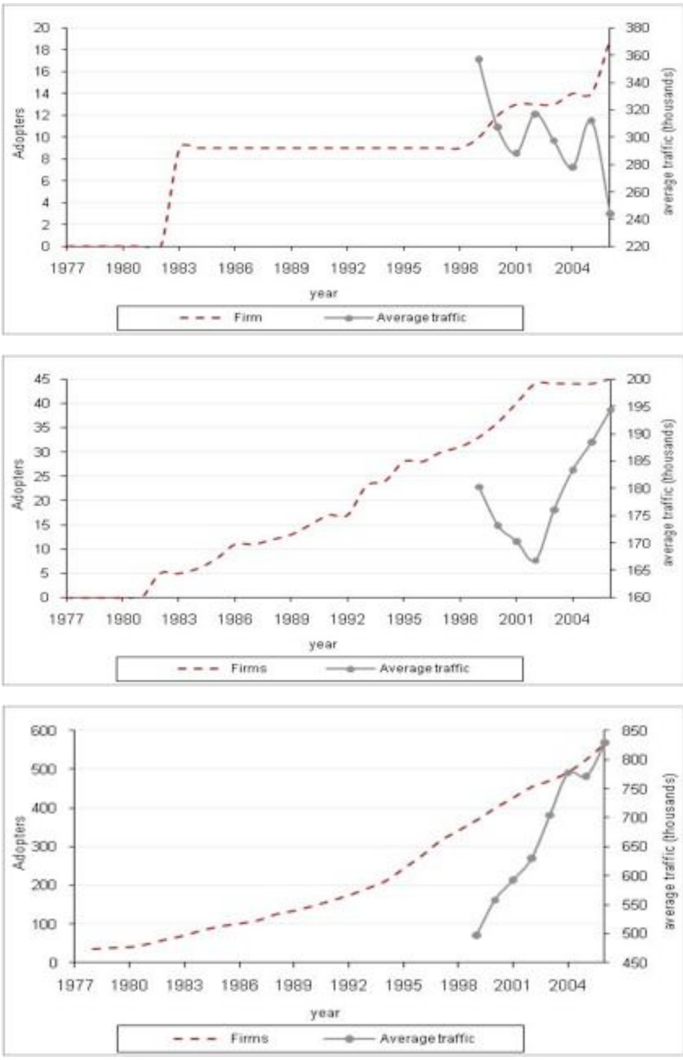
Figure 3. Global diffusion and usage intensity of SWIFT

To demonstrate the differences between usage intensity and diffusion patterns further, additional examples are drawn from three countries in the sample. The following figures (grouped in Figure 4) illustrate the rate of SWIFT adoption and average usage in Israel, Portugal and the US respectively. Even though global usage data is available for all the years since 1977, country-level data were not accessible so usage intensity is truncated from 1999 through to 2006. As it can be seen, there is substantial variation between these countries regarding SWIFT diffusion and usage. Israel displays a pattern of decreasing average use over time, while Portugal at first decreases and then steadily increases. The correlation coefficient for Israel (assuming a linear relationship between average usage and diffusion) is negative (–0.89) while for Portugal it is positive but low (0.29). On the other hand, the US poses a rather different picture since both SWIFT diffusion and usage intensity gradually increase and are highly correlated (0.97)[24]. Clearly, the results vary as different countries were introduced to SWIFT in different years resulting in a range of penetration ratios[25]. These results provide further motivation to study the determinants of SWIFT adoption

[24] All the results are highly significant at 1% level.

[25] The results vary even more between developed and emerging economics. In the particular example, all three countries are considered to be well-developed with sound technological and communicational infrastructures as well as solid financial sectors.

more closely to investigate average usage in the large panel of countries that is available.



Notes: As in Figure 3, the red (dashed) line represents the rate of firm adoption from 1977 to 2006 (30 years in total), however, this time the line reports the increase in the number of adopters (left axis). The grey (bulleted) line describes the average traffic in thousands of messages (right axis), or else the number of messages sent per firm from 1999 to 2006 (8 years in total). The data are for Israel (top diagram), Portugal (middle diagram), and the US (bottom diagram) respectively.

Figure 4. Diffusion and average usage in Israel, Portugal and United States

6. Multivariate analysis of SWIFT adoption and use

Empirical specifications

As mentioned before, the purpose of this study is to try and explain the number of adopters and usage intensity of SWIFT as a function of certain country characteristics. In order to achieve this, the analysis looks at a variety of regression results based on a set of different specifications of the form:

$$S_{it} = \alpha + \beta X_{it} + T_t + \eta_i + \varepsilon_{it}$$

where, S_{it} is a measure of SWIFT adoption or usage intensity in country i and year t, X_{it} is a set of country-level explanatory variables, T_t is a set of year dummies that control for aggregate time-specific shocks (economic and non-economic), η_i is a country-specific effect, and ε_{it} is an idiosyncratic error term which is assumed to be independently and identically distributed (i.i.d.) among i and t. In general, there is significant debate among researchers who use cross-country panel data sets, as to what is the most suitable estimation method for such studies. More specifically, the controversy is focused onto the assumptions that are made about the country-specific term η_i. The two obvious alternatives are the fixed-effects (FE) models that treat the term as unobserved heterogeneity and assume that is stable (or fixed) over time, versus the random-effects (RE) type of estimation which assumes that η_i is a group-specific random element.

The main difference between the two estimators is that RE imposes an additional (more strict) assumption which treats η_i as if it was uncorrelated with all the explanatory variables in the model. This assumption is not necessary in the case of the FE estimator which allows for unobserved individual heterogeneity to correlate with X_{it}[26]. Having acknowledged this, it should be noted there is a trade-off between the use of FE and RE. While FE estimators increase the possibility of more consistent results, RE models produce more efficient estimates[27]. Naturally this occurs because the RE estimator will use all the variation in the independent variable data, in contrast to the FE estimator that uses just the within-group variation of the regressors. A

[26] In other words, in addition to $E[\varepsilon_{it} \mid X_{it}] = 0$ that is assumed under the fixed effects estimation, random effects estimation also assumes that $E[\eta_i \mid X_i] = 0$. It is obvious that in the later case the assumptions for the exogeneity of the errors required to produce consistent results are stronger. This can be understood better if we view η_i as part of a composite error term $v_{it} = \eta_i + \varepsilon_{it}$ where both of its components need to satisfy the respective exogeneity assumptions. This method is different from fixed effects where η_i is treated as a parameter to be estimated and we only care that ε_{it} meets the mentioned conditions. For a more detailed discussion between fixed effects and random effects see Greene (2003, pp. 283-303).

[27] The assumptions made in the first place regarding the composite error term need to be satisfied in order for these effects to take place. In that case, standard errors will typically be smaller than the ones in fixed effects. When individual country effect η_i is correlated with the regressors for country i, this would lead to inconsistency. A way to understand this is to think of η_i as omitted variables that are correlated with X_{it}. On the other hand, treating η_i as country fixed-effects it absorbs a significant part of the variation in the data resulting to a relatively inefficient estimator.

benefit from using random effects is that one can estimate the effects of observed variables that do not vary over time for specific countries in the sample. For example, a key variable that is of interest in this research is the distance that adopters have from Belgium. In addition, fixed effects estimator has the disadvantage of intensifying classical measurement error, which can be common in large aggregate country-level datasets like the one used here.

To deal with this "efficiency-consistency" trade-off, this research adopts the approach of Caselli and Coleman (2001) who model the country-specific term η_i based on a composite solution in which random-effects and fixed-effects are considered together[28]. This is done by introducing a full set of regional dummies to control for regional fixed-effects[29] while treating the residual as random country effect. The estimator will be consistent if the country-specific effect that is uncorrelated to the region-specific effect is also uncorrelated to the remaining elements of X_{it} (Caselli and Coleman 2001, p.5). By assuming that η_i is uncorrelated with X_{it} (while having controlled for region-specific effects), the estimator is also more efficient than the FE estimator which treats η_i as "fixed"[30].

Based on the above assumptions, the baseline specification for SWIFT adoption reads as follows:

$$SWIFTad_{it} = \beta_1 DISTBel_i + \beta_2 POP_{it} + \beta_3 GDPpc_{it} + \beta_4 TELE_{it} + \beta_5 TRANSF_{it} + \beta_6 STOCKS_{it} + \beta_7 ICTimp_{it} + \beta_8 ICTexp_{it} + \beta_9 FINimp_{it} + \beta_{10} FINexp_{it} + \sum Year\ Controls_t + \sum Regional\ Fixed\ Effects_j + \eta_i + \varepsilon_{it}$$

Here, $SWIFTad_{it}$ denotes the cumulative number of adopters for country i and year t, where t=1977, 1978, …, 2006. However, additional dependent variables are also

[28] Caselli and Coleman (2001) use this type of identification to estimate the cross-country diffusion of computers in a panel of 89 countries between 1970 and 1990.

[29] Regional dummies represent all 219 countries in the sample and are for: Eastern Asia, Eastern Europe, Latin America and Caribbean, North America, Northern Africa, Northern Europe, Oceania, OECD, Rest of Asia, Southern Europe, Sub-Saharan Africa, and Western Europe. The composition of the geographical areas and regions were drawn from United Nations data that were found at http://unstats.un.org. The countries that were included in the OECD grouping were excluded from their original region.

[30] The term "fixed" here is not to be confused with a non-stochastic term (which is not necessarily the case), but it signifies an individual effect that does not vary over time.

examined ($SWIFTtraf_{it}$ and $SWIFTavtraf_{it}$) that describe traffic and average traffic of SWIFT over time[31]. In the above specification, independent variables are mostly treated as exogenous for SWIFT adoption (SWIFTad_{it}). Reverse causality is not a considerable concern here as it is quite implausible that the increasing number of SWIFT adopters would have influenced POP_{it} and $GDPpc_{it}$ or have a direct effect on imports and exports of ICT, especially since our sample contains a large number of less advanced economies (non-OECD countries)[32].

Results

Table 4 reports the core results from the regressions based on the above specification using SWIFTad_{it} as a dependent variable and including all countries and years in the sample. The specification in column (1) includes only the basic variables that are used in all of the regressions in this study. Columns (2) and (3) expand the model by adding more variables that explain further the variation of the number of adopters in each country. In contrast to Columns (1)-(3) which use RE, column (4) reports the results from the pooled OLS specification without controlling for any individual country characteristics but including regional and year dummies (hence, regional fixed effects). Finally, column (5) provides results using a fixed-country effect specification in order to prove that when the FE technique is applied there are no significant explanatory variables whatsoever apart from the population variable which also seems to have a negative sign. In addition, one can notice that R-squared dropped to 0.15 as opposed to 0.6 in the two previous columns. Standard errors are also clustered at the country level (reported in brackets in all columns) in order to account for autocorrelation and correct for possible heteroskedasticity. Thus, the calculated standard errors are robust to heteroskedasticity and to cross-country error correlation.

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[31] $SWIFTtraf_{it}$ and $SWIFTavtraf_{it}$ variables are restricted between 1999 to 2006, thus covering only 8 years. In contrast to $SWIFTad_{it}$ covers the full history of SWIFT adoption between 1977 and 2006 (up to where the data were available).

[32] Even among the OECD countries reverse causation is rather unlike especially during the 80s where SWIFT adopters were very few.

Table 4. Cross-country SWIFT adoption: Full sample

	(1)	(2)	(3)	(4)	(5)
Estimation method	RE	RE	RE	Pooled OLS	FE
Dependent variable		$SWIFTad_{it}$		$SWIFTad_{it}$	$SWIFTad_{it}$
Log($DISTBel$)$_i$	–2.47	–8.657	–6.208	–4.355	–
	(5.04)	(6.54)	(6.385)	(6.009)	
Log(POP)$_{it}$	6.38***	14.41***	13.519***	23.963***	–129.086***
	(1.407)	(4.588)	(4.524)	(5.582)	(51.361)
Log($GDPpc$)$_{it}$	–0.744	10.566*	8.621	24.33***	–30.634
	(2.821)	(6.406)	(6.301)	(7.25)	(19.102)
$TELE_{it}$	1.533***	0.887*	0.936**	1.024*	0.451
	(0.374)	(0.491)	(0.48)	(0.611)	(0.504)
Log($TRANSF$)$_{it}$	–	–0.949	–0.628	2.627	–3.548
		(2.826)	(3.327)	(2.609)	(3.857)
Log($STOCKS$)$_{it}$	–	1.835	2.163	–0.967	1.75
		(1.544)	(1.598)	(1.627)	(1.612)
$ICTimp_{it}$	–	–	–0.12	–0.241	–0.032
			(0.19)	(0.204)	(0.17)
$ICTexp_{it}$	–	–	0.289*	0.13	0.231
			(0.166)	(0.155)	(0.16)
$FINimp_{it}$	–	–	–0.105	–0.644	0.127
			(0.531)	(0.666)	(0.567)
$FINexp_{it}$	–	–	0.75	1.857***	0.729
			(0.549)	(0.623)	(0.532)
Regional dummies	Yes	Yes	Yes	Yes	Abs.†
Year dummies	Yes	Yes	Yes	Yes	Yes
Country dummies	No	No	No	No	Yes
Number of countries	173	104	102	102	102
Number of obs.	3934	1386	1340	1340	1340
R^2	0.4517	0.5459	0.5818	0.6153	0.1510

Notes: *significant at 10%, **significant at 5%, ***significant at 1%. Robust standard errors are reported in brackets (clustered by country). All columns include a full set of year dummies. Regional dummies and country dummies are included as described in the empirical specification section. The dependent variable is $SWIFTad_{it}$ and represents the number of firms that have adopted SWIFT in each country each year. All the independent variables are described in Tables 1 and 2. The time period of the sample is 1977-2006 (thirty years).
† = Regional dummies are absorbed from country dummies.

Based on the discussion in the previous section and the current analysis, GDP per capita and population variables have the expected signs (both positive) and are mostly significant. This result is welcome as richer countries with larger populations will have an increasing demand for financial telecommunication services and would therefore adopt SWIFT faster. The number of telephone lines per 100 people ($TELE_{it}$) also seems to be correlated with the number of SWIFT adopters over time. It is possible that this variable is a proxy for the telecommunications infrastructure thus capturing ICT advances and connectedness between organisations within and among countries. Reverse causation would also be a rare case here since the number of SWIFT adopters (even in the extreme cases) is far too small to impact the total number of telephone connections per country. Exports of computer, communications and financial services are also positively correlated (and statistically significant) with SWIFT adoption[33]. All the rest of the variables seem to be largely insignificant based onto the current specifications.

In Table 5 regressions were performed using the samples of OECD and non-OECD countries separately to identify differences between the less developed regions and more advanced OECD economies. As it can be noticed, there is variation in the results when the observations change from the full sample to OECD countries. Population, GDP per capita, and $TELE_{it}$ variables have kept their positive signs and significance in most columns. More specifically, changes in POP_{it} appear to have a larger effect on SWIFT diffusion: for every 1% increase in population there is an average increase of 35 adopters in OECD countries (columns 1-3) versus approximately 6 adopters in non-OECD ones (columns 4-6). In the contrary, $GDPpc_{it}$ matters more in non-OECD countries (with 1% increase leading to an average increase of 7 adopters) and is insignificant when restricting to OECD economies. Moreover, distance from Belgium now appears to have a negative effect on the number of SWIFT adopters, which means that the closer a country is to Belgium, the more adopters it will have on average. This result is consistent with prior hypothesis according to which ICT diffusion decreases as geographic distance increases (Leamer and Levinsohn 1995). However, this effect can only be found among the OECD countries and wears off as we move to the non-OECD sample[34].

[33] Exports coefficient of financial and insurance services seems to be positive and significant in the Pooled OLS regression when using the full sample, whereas ICT exports are only in the random-effects specification. These support the argument that exporting countries are more likely to adopt SWIFT in a larger scale since they produce and potentially adopt more ICTs and can provide financial services abroad more efficiently. A similar effect was also included in the findings of Caselli and Coleman (2001), where technology investment was positively correlated to a country's openness and trade.

[34] In column (4) the effect even appears to be positive. This is most likely because non-OECD countries in the sample, especially those that adopt SWIFT extensively, are distant emerging economies, therefore, this can change the results when OECD countries are excluded.

Table 5. Cross-country SWIFT adoption: OECD and non-OECD samples

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	OECD			Non-OECD		
Est. method	RE	RE	RE	RE	RE	RE
Dep.variable	$SWIFTad_{it}$			$SWIFTad_{it}$		
Log($DISTBel$)$_i$	–9.334*	–14.317**	–8.484	8.563**	8.353	6.98
	(5.029)	(7.245)	(6.801)	(3.561)	(6.399)	(6.46)
Log(POP)$_{it}$	23.516***	37.872***	43.792***	4.531***	6.742**	6.193*
	(7.143)	(14.87)	(13.411)	(0.79)	(2.754)	(3.217)
Log($GDPpc$)$_{it}$	11.784	10.13	1.508	2.674**	9.047*	10.302*
	(22.977)	(19.924)	(15.369)	(1.059)	(5.487)	(5.367)
$TELE_{it}$	0.741	1.062	1.08*	0.765***	0.454	0.388
	(0.912)	(0.724)	(0.642)	(0.283)	(0.511)	(0.534)
Log($TRANSF$)$_{it}$	–	–3.146	–6.551	–	0.31	1.084
		(6.44)	(7.269)		(2.402)	(3.278)
Log($STOCKS$)$_{it}$	–	–3.344	–3.783	–	2.661	2.833
		(3.074)	(2.838)		(1.88)	(1.997)
$ICTimp_{it}$	–	–	–0.461	–	–	–0.024
			(0.425)			(0.093)
$ICTexp_{it}$	–	–	0.669	–	–	0.126
			(0.587)			(0.105)
$FINimp_{it}$	–	–	–1.593**	–	–	0.466
			(0.659)			(0.494)
$FINexp_{it}$	–	–	3.207**	–	–	–0.081
			(1.42)			(0.236)
Regional dummies	Yes†	Yes†	Yes†	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	33	33	33	140	71	69
Number of obs.	813	530	509	3121	856	831
R^2	0.5358	0.5634	0.6813	0.4285	0.5446	0.5510

Notes: *significant at 10%, **significant at 5%, ***significant at 1%. Robust standard errors are reported in brackets (clustered by country). All columns include a full set of year dummies. Regional dummies and country dummies are included as described in the empirical specification section. The dependent variable is $SWIFTad_{it}$ and represents the number of firms that have adopted SWIFT in each country each year. All the independent variables are described in Tables 1 and 2. The time period of the sample is 1977-2006 (thirty years).
† = Regional dummies are dropped because sample is restricted to OECD countries.

$FINexp_{it}$ has also kept its positive effect, while the respective financial services imports hold the opposite sign on the total of SWIFT adopters. This is perhaps because insurance and financial services imports are a proxy for less developed financial markets and relevant services[35].

Table 6 uses average usage intensity per firm as the dependent variable[36].

[35] The same hypothesis can be said for ICT imports, whereas, ICT exports should be expected to have a positive correlation with SWIFT diffusion.
[36] An additional specification using message traffic as the dependent variable ($TRANSF_{it}$) is also being reported in the Appendix (Table A.1) and the results are among the same lines with the ones discussed earlier.

Table 6. Cross-country SWIFT traffic per firm: Full and OECD samples

	(1)	(2)	(3)	(4)
Sample	Full	Full	OECD	OECD
Estimation method	RE	RE	RE	RE
Dependent variable	Log(*SWIFTtrafirm*)$_{it}$			
Log(*DISTBel*)$_i$	–0.132*	–0.136*	–0.203**	–0.186**
	(0.08)	(0.08)	(0.082)	(0.082)
Log(*POP*)$_{it}$	0.168***	0.157***	0.119	0.127
	(0.048)	(0.049)	(0.1)	(0.1)
Log(*GDPpc*)$_{it}$	0.669***	0.674***	0.554***	0.518**
	(0.082)	(0.088)	(0.185)	(0.242)
$TELE_{it}$	–0.008*	–0.009*	–0.001	–0.001
	(0.005)	(0.005)	(0.007)	(0.007)
Log(*TRANSF*)$_{it}$	0.074*	0.082*	–0.002	–0.004
	(0.042)	(0.044)	(0.038)	(0.065)
Log(*STOCKS*)$_{it}$	0.031*	0.029*M	0.022	0.02
	(0.017)	(0.018)	(0.029)	(0.028)
$ICTimp_{it}$	–	–0.002	–	0.002
		(0.002)		(0.004)
$ICTexp_{it}$	–	–0.002	–	–0.001
		(0.001)		(0.005)
$FINimp_{it}$	–	–0.014**	–	–0.009
		(0.007)		(0.007)
$FINexp_{it}$	–	0.004	–	0.008
		(0.003)		(0.007)
Regional dummies	Yes	Yes	Yes†	Yes†
Year dummies	Yes	Yes	Yes	Yes
Number of countries	101	98	33	32
Number of obs.	656	637	227	220
R^2	0.8612	0.8579	0.5614	0.5483

Notes: *significant at 10%, **significant at 5%, ***significant at 1%. Robust standard errors are reported in brackets (clustered by country). All columns include a full set of year dummies and regional dummies as described in the empirical specification section. The dependent variable is Log(*SWIFTtrafirm*)$_{it}$ and represents the average traffic per firm that has adopted SWIFT in each country each year. All the independent variables are described in Tables 1 and 2. The time period of the sample is 1999-2006 (eight years).

† = Regional dummies are dropped because sample is restricted to OECD countries.

*M = Marginally significant close to 10%.

Once again there is strong evidence that distance from Belgium, population, and GDP per capita explain much of the variation of SWIFT diffusion among countries. The value of traded shares and current transfers also influence positively usage intensity, however, the effect is constrained in the full sample. Finally, $FINimp_{it}$ is negatively correlated with average usage as in the case of SWIFT traffic and number of adopters earlier. What is striking here is that for the first time the number of telephone connections (per 100 people) is negatively correlated with the average usage of SWIFT (even though marginally). A possible explanation for this is that the size of the telecommunications infrastructure is somehow correlated with the number of SWIFT adopters which by itself might have a negative effect on usage intensity as the number of additional adopters increases. This can be better understood by looking at Table 7.

The last set of results (Tables 7 and 8), explores how the average message traffic by firm varies in relation to the number of SWIFT adopters (size of SWIFT network). Here $SWIFTad_{it}$ is the main variable of interest and largely captures the network effects on average usage intensity. As it was seen earlier from Figures 3 and 4, there is substantial heterogeneity among countries (and firms) regarding the diffusion and usage of SWIFT. As the size of the network increases there are two possible effects that may be taking place (Grajek and Kretschmer 2009). Firstly, depending on the perceived usefulness and the different needs and strategies, firms may adopt SWIFT at various points in time and use the network in a lower capacity if for example their preference for financial telecommunication is lower. This will also affect negatively the average usage of SWIFT as new adopters join the network. The mentioned scenario could be presented graphically in the case of Israel (Figure 4), where usage intensity falls as the number of adopters increases[37]. On the contrary, one could argue that as the size of the network increases then new communication opportunities arise among users which lead to an increase in the average usage intensity. This network effect is illustrated again in Figure 4 by the case of the US, where the increase of network size correlates with an even sharper increase of the average use of the network. In any case, while the one effect does not exclude the existence of the other, the sign of the $SWIFTad_{it}$ coefficient will depend on which effect of the two prevails. From columns (1) and (4) we can posit that when using the full sample, adopter-heterogeneity effect dominates by establishing a negative relationship between the variables of interest although there is some indication that among OECD countries the network effect is stronger thereby imposing a positive effect on average usage intensity.

[37] Figures 3 and 4 provide just a simple illustration of correlations between variables and no control variables were included in order to strip off other significant effects.

Table 7. SWIFT network effects: Full and OECD samples

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Full	OECD	Full	OECD	Full	OECD
Est. method	RE	RE	RE	RE	RE	RE
Dep. variable			Log(*SWIFTtrafirm*)$_{it}$			
SWIFTad$_{it}$	–0.002***	0.001	–0.001	0.001*M	–0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log(*DISTBel*)$_i$	–0.139*	–0.178**	–0.142*	–0.181**	–0.143*	–0.168*
	(0.075)	(0.083)	(0.078)	(0.088)	(0.078)	(0.089)
Log(*POP*)$_{it}$	0.388***	0.099	0.186***	0.064	0.17***	0.065
	(0.033)	(0.08)	(0.048)	(0.112)	(0.05)	(0.119)
Log(*GDPpc*)$_{it}$	0.679***	0.538***	0.689***	0.519***	0.687***	0.491**
	(0.071)	(0.191)	(0.085)	(0.191)	(0.091)	(0.245)
TELE$_{it}$	0.005	–0.002	–0.008*	–0.002	–0.009*	–0.003
	(0.004)	(0.006)	(0.004)	(0.006)	(0.005)	(0.006)
Log(*TRANSF*)$_{it}$	–	–	0.075*	–0.002	0.081*	0.001
			(0.042)	(0.036)	(0.043)	(0.066)
Log(*STOCKS*)$_{it}$	–	–	0.033*	0.023	0.03*	0.021
			(0.017)	(0.028)	(0.018)	(0.027)
ICTimp$_{it}$	–	–	–	–	–0.002	0.002
					(0.002)	(0.004)
ICTexp$_{it}$	–	–	–	–	–0.002	–0.001
					(0.001)	(0.005)
FINimp$_{it}$	–	–	–	–	–0.014**	–0.011
					(0.007)	(0.008)
FINexp$_{it}$	–	–	–	–	0.004	0.007
					(0.003)	(0.007)
Regional dummies	Yes	Yes†	Yes	Yes†	Yes	Yes†
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	71	33	101	33	98	32
Number of obs.	1160	231	656	227	637	220
R^2	0.8422	0.5100	0.8669	0.5091	0.8625	0.4987

Notes: *significant at 10%, **significant at 5%, ***significant at 1%. Robust standard errors are reported in brackets (clustered by country). All columns include a full set of year dummies and regional dummies as described in the empirical specification section. The dependent variable is Log(*SWIFTtrafirm*)$_{it}$ and represents the average traffic per firm that has adopted SWIFT in each country each year. In this table *SWIFTad*$_{it}$ is also included as an explanatory variable to examine the network effect of the network size on the average traffic. All the independent variables are described in Tables 6.1 and 6.2. The time period of the sample is 1999-2006 (eight years).
† = Regional dummies are dropped because sample is restricted to OECD countries.
*M = Marginally significant closer to 10%.

Table 8 draws a similar picture. The network effect even gets slightly bigger if we use the lagged population of adopters. The larger and more significant effect can be justified as it can take a while for new adopters to fully use the technology and incorporate the SWIFT standards. In that case, for each additional adopter the average usage intensity will increase by approximately 0.0013-4%.

Table 8. SWIFT network effects: Lagged network size

	(1)	(2)	(3)
Sample	OECD	OECD	OECD
Estimation method	RE	RE	RE
Dependent variable	Log(*SWIFTtrafirm*)$_{it}$		
SWIFTad$_{it-1}$	0.0013*	0.0014*	0.0014*
	(0.000)	(0.000)	(0.000)
Log(*DISTBel*)$_{i}$	–0.175**	–0.179**	–0.166*
	(0.083)	(0.088)	(0.089)
Log(*POP*)$_{it}$	0.092	0.057	0.057
	(0.078)	(0.111)	(0.118)
Log(*GDPpc*)$_{it}$	0.531***	0.513***	0.484**
	(0.192)	(0.192)	(0.248)
$TELE_{it}$	–0.001	–0.002	–0.002
	(0.006)	(0.006)	(0.006)
Log(*TRANSF*)$_{it}$	–	–0.003	0.001
		(0.036)	(0.066)
Log(*STOCKS*)$_{it}$	–	0.024	0.022
		(0.028)	(0.027)
ICTimp$_{it}$	–	–	0.001
			(0.004)
ICTexp$_{it}$	–	–	–0.001
			(0.005)
FINimp$_{it}$	–	–	–0.011
			(0.008)
FINexp$_{it}$	–	–	0.007
			(0.007)
Regional dummies	Yes†	Yes†	Yes†
Year dummies	Yes	Yes	Yes
Number of countries	33	33	32
Number of obs.	231	227	220
R^2	0.5026	0.5034	0.4930

Notes: *significant at 10%, **significant at 5%, ***significant at 1%. Robust standard errors are reported in brackets (clustered by country). All columns include a full set of year dummies and regional dummies as described in the empirical specification section. The dependent variable is Log(*SWIFTtrafirm*)$_{it}$ and represents the average traffic per firm that has adopted SWIFT in each country each year. In this table *SWIFTad*$_{it-1}$ (lagged) is also included as an explanatory variable to examine the network effect of the network size on the average traffic. All the independent variables are described in Tables 1 and 2. The time period of the sample is 1999-2006 (eight years).
† = Regional dummies are dropped because sample is restricted to OECD countries.

7. Discussion and conclusions

The findings of our analysis support the hypotheses that were made earlier in the paper: firstly, the coefficients of the POP_{it} and $GDPpc_{it}$ indicator variables are positive and significant in most of the specifications used. This is also in line with the findings from previous studies on the determinants of technological innovation diffusion (Caselli and Coleman 2001, Grajek and Kretschmer 2009). Secondly, another very robust result of interest is that the variables of SWIFT adoption and usage respond negatively to the distance from Belgium. When using both the full and OECD samples on SWIFT adoption, the $DISTBel_i$ coefficient is around 8.0 (which signifies a decrease in the number of adopters for every 1% increase in distance), however, its magnitude is reduced between 0.13 and 0.66 when using traffic and average usage on the left-hand side. A likely scenario that could explain this difference is that, once SWIFT is adopted, there is little relationship between its usage and the distance from SWIFT headquarters. This is because traffic becomes more dependent on other factors like population and GDP per capita, which are largely associated with overall demand for financial transaction (see Tables 6-7 and A.1). In parallel to this, the effect weakens when we move from the OECD to the full sample, and eventually becomes positive when taking only non-OECD economies. A possible explanation for this can be deduced by closer examination of Figure 2 which reveals that after the first wave of OECD adopters (from Europe, the Americas and Australia), most of the countries that joined SWIFT were distant emerging economies (e.g. China, India, etc.). This outcome could distort the results when excluding OECD countries from the sample. As mentioned before, a certain advantage of this kind of geographic effect is that $DISTBel_i$ can only be considered as exogenous when trying to estimate its influence on SWIFT diffusion since it cannot be subject to impact from changes in the later. The analysis in this study, finds no consistent evidence for the effect of telephone connections (per 100 people) on SWIFT adoption or usage intensity.

In the full sample and occasionally in the OECD sample there is some confirmation that the total value of traded stocks and of current transfers also affects SWIFT diffusion. More specifically, the log values of $TRANSF_{it}$ and $STOCKS_{it}$ seem to be positively associated with both message traffic and average SWIFT usage in a few instances. The effect of current transfers (between 0.07-0.14%) appears to be larger than that of the value of traded shares, which varies between 0.03% and 0.13%[38]. These effects are justifiable if we consider that financial transfers and transactions of any kind can have an immediate impact on the demand for SWIFT services. As a result, the number of SWIFT adopters and message traffic would be expected to increase.

[38] These figures explain how much the number of messages or average traffic increases when $TRANSF_{it}$ and $STOCKS_{it}$ increase by 1%.

Even though there is not much research that links imports with technology diffusion, imports are sometimes associated with technology spillovers (Keller 2004). In this study, the effect of financial services imports is weakly and negatively related with SWIFT adoption and use after controlling for size. It is possible that economies in which foreign sources of financial services (or ICT for that matter) are of major significance, are less concerned with adopting SWIFT solutions since they are on the receiving end of the transaction and are not motivated to adopt new practices. On the other hand, economies with a substantial percentage of financial product exports (and in some occasions ICT exports) are positively associated with SWIFT adoption and use, even after having controlled for the level of GDP. Extant literature on the economics of technology diffusion also supports this with a number of studies that advance the idea of "learning-by-exporting"[39] (Clerides et al. 1998, Keller 2004). Even though this only applies marginally in the case of SWIFT, one can say that economies with substantial percentages of ICT and financial exports are more likely to extensively adopt ICT and financial solutions.

Overall, network effects of similar network technologies or standards are difficult to capture and estimate since they are often diluted from the heterogeneity of adopters (Grajek and Kretschmer 2009). As we have seen, the effect of "lower-preference users" (Grajek and Kretschmer 2009, p.28) often dominates the outcome of the positive externalities that are created as the size of the network grows. For that reason, a negative sign in front of the $SWIFTad_{it}$ coefficient does not necessarily mean that network effects do not exist but rather that they do not outweigh the heterogeneity effect. Even so, in Tables 7 and 8 we can see that among OECD countries there is a marginal network effect that produces a positive coefficient. This result suggests that as the number of SWIFT adopters increases, this will have a positive effect on the average usage intensity (between 0.001-0.0014%) generated by new opportunities that are being created as the network grows. On the contrary, column (1) of Table 7 reports a negative effect of the number of adopters on average traffic when using the full sample. This suggests that an increase in the size of the SWIFT network will lead

[39] These studies also report that exporting economies are on average more productive than non-exporters (Keller 2004).

to a 0.002% decrease in the average usage per firm. Additional negative effects can be drawn if the non-OECD sample is used instead[40].

In conclusion, this work presented a case study on the determinants of SWIFT diffusion across a panel of around 100 countries and territories in 12 regions between 1977 and 2006. Gaining insight into the diffusion process of SWIFT, a core part of the financial services infrastructure, has important implications for the behaviour of financial institutions and standard setting bodies. Overall, the results show that there is substantial firm heterogeneity based on the decision of firms to adopt and use SWIFT or not. However, despite this multiplicity, the analysis highlights substantial benefits from network effects. Even though it was not possible to disentangle and measure the separate impact of the two, the analysis identified approximately their net effect by using a set of different specifications on different samples. As a result, we can say that there is marginal indication of network effects prevailing over adopter heterogeneity among OECD countries, which is removed when the analysis is restricted onto non-OECD countries or the full sample. This important outcome could be used when designing diffusion policies and strategies based on network products that could entail network effects.

The results also demonstrate that there is a robust relationship between SWIFT diffusion and distance from Belgium (where SWIFT was founded and headquartered since the beginning of its operations). This suggests that the diffusion process reflects "infection of a population" (Stoneman 2002), where the closer one is to the source of knowledge and expertise the more infected one can become. This finding also holds an important consequence when it comes to diffusion strategies as it introduces the geographic effects on knowledge transfer and innovation adoption.

Apart from the main variables of interest, additional variables like the price and the quality of services have had an impact on the underlying diffusion mechanism of SWIFT. By looking at historical studies on SWIFT (Scott and Zachariadis 2010) we realize that the society maintained the same level of prices internationally and provided the same quality of products and services to all its customers. Having said

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[40] These results are included in Table A.2 in the Appendix.

that, we can make the assumption that these two important variables would have varied over time equally for all countries, hence, their effect should be largely captured by the year dummies in the regressions.

This research is one of the few that have attempted to unravel empirically the heterogeneity of adopters and the network externalities on the diffusion of financial telecommunications.

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Appendix

To further investigate the determinants of SWIFT diffusion a set of additional regressands are considered in Table A.1. Reassuringly, a similar picture is drawn as earlier when message traffic is used as a dependent variable instead of the number of SWIFT adopters. In all columns distance from Belgium, population and GDP hold the expected signs (negative, positive, positive) and are significant. In the case of overall traffic – Columns (1) and (2) – current transfers ($TRANSF_{it}$) are also positively correlated and significant in the full sample, nevertheless, the effect becomes more prevalent when payments traffic is used on the left hand side. This is expected since cross-country current transfers are normally rooted through payments traffic and thus the two should be closely linked. A similar outcome can be noticed between the number of stocks traded and the securities traffic through SWIFTNet in OECD countries[41]. Financial imports and exports also remain the same in Columns (2), (3), and (6).

[41] The total value of shares traded also reflects the size of the financial markets which is expected to be higher in OECD economies and virtually absent in smaller regions. As a result, the correlation is only significant in Column (4). On the other hand, current transfers are more common even in smaller countries as they capture generic transactions recorded in the balance of payments (goods, services, income, and other financial items).

Table A.1 Cross-country SWIFT traffic: Full and OECD samples

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Full	OECD	Full	OECD	Full	OECD
Est. method	RE	RE	RE	RE	RE	RE
Dependent variable	Log(*SWIFTtraf*)$_{it}$ (total)		Log(*SWIFTtraf*)$_{it}$ (securities)		Log(*SWIFTtraf*)$_{it}$ (payments)	
Log(*DISTBel*)$_i$	–0.356***	–0.435***	–0.371*	–0.666***	–0.298***	–0.368***
	(0.085)	(0.094)	(0.218)	(0.184)	(0.075)	(0.083)
Log(*POP*)$_{it}$	0.601***	0.626***	1.383***	0.807***	0.558***	0.557***
	(0.07)	(0.111)	(0.186)	(0.171)	(0.072)	(0.103)
Log(*GDPpc*)$_{it}$	1.112***	0.818***	2.349***	1.779***	1.005***	0.641***
	(0.107)	(0.265)	(0.331)	(0.46)	(0.097)	(0.24)
$TELE_{it}$	0.002	0.003	–0.008	–0.009	0.01^{*M}	0.012
	(0.005)	(0.008)	(0.014)	(0.012)	(0.006)	(0.01)
Log(*TRANSF*)$_{it}$	0.129**	0.048	0.166	0.034	0.147**	0.093^{*M}
	(0.066)	(0.063)	(0.119)	(0.122)	(0.067)	(0.058)
Log(*STOCKS*)$_{it}$	0.025	0.018	–0.044	0.139*	0.025	0.026
	(0.019)	(0.031)	(0.062)	(0.072)	(0.02)	(0.022)
$ICTimp_{it}$	–0.004	0.002	–0.01	0.006	–0.004	–0.002
	(0.004)	(0.004)	(0.018)	(0.012)	(0.004)	(0.005)
$ICTexp_{it}$	–0.001	–0.001	–0.01	–0.002	–0.002	–0.002
	(0.002)	(0.006)	(0.009)	(0.012)	(0.002)	(0.005)
$FINimp_{it}$	–0.009	–0.012*	–0.01	0.009	–0.009	–0.014**
	(0.008)	(0.006)	(0.019)	(0.019)	(0.008)	(0.006)
$FINexp_{it}$	0.004	0.02***	0.035***	0.011	0.004	0.02**
	(0.004)	(0.008)	(0.011)	(0.016)	(0.004)	(0.008)
Regional dummies	Yes	Yes†	Yes	Yes†	Yes	Yes†
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	98	32	98	32	98	32
Number of obs.	637	220	620	220	637	220
R^2	0.9209	0.8957	0.8123	0.7942	0.9199	0.8938

Notes: *significant at 10%, **significant at 5%, ***significant at 1%. Robust standard errors are reported in brackets (clustered by country). All columns include a full set of year dummies and regional dummies as described in the empirical specification section. The dependent variable is $SWIFTtraf_{it}$ and represents the number of messages sent through SWIFT from each country each year. Columns (1) and (2) use the total traffic, (3) and (4) the number of messages sent as part of the securities transactions, and (5) and (6) the traffic sent as part of payments transactions. All the independent variables are described in Tables 1 and 2. The time period of the sample is 1999-2006 (eight years).

† = Regional dummies are dropped because sample is restricted to OECD countries.

^{*M} = Marginally significant around 10%.

Table A.2 SWIFT network effects: non-OECD sample

	(1)	(2)	(3)
Sample	Non-OECD	Non-OECD	Non-OECD
Estimation method	RE	RE	RE
Dependent variable	Log(*SWIFTtrafirm*)$_{it}$		
SWIFTad$_{it}$	–0.003**	–0.002***	–0.002**
	(0.001)	(0.000)	(0.000)
Log(*DISTBel*)$_{i}$	0.526***	0.673***	0.717***
	(0.194)	(0.162)	(0.173)
Log(*POP*)$_{it}$	0.418***	0.171***	0.164***
	(0.037)	(0.057)	(0.058)
Log(*GDPpc*)$_{it}$	0.675***	0.702***	0.681***
	(0.074)	(0.083)	(0.09)
TELE$_{it}$	0.011**	–0.007	–0.006
	(0.006)	(0.006)	(0.006)
Log(*TRANSF*)$_{it}$	–	0.12**	0.124**
		(0.051)	(0.052)
Log(*STOCKS*)$_{it}$	–	0.036*	0.034*
		(0.019)	(0.019)
ICTimp$_{it}$	–	–	–0.003
			(0.003)
ICTexp$_{it}$	–	–	–0.002
			(0.002)
FINimp$_{it}$	–	–	–0.012
			(0.009)
FINexp$_{it}$	–	–	0.003
			(0.004)
Regional dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Number of countries	138	68	66
Number of obs.	929	429	417
R^2	0.7193	0.7937	0.7908

Notes: *significant at 10%, **significant at 5%, ***significant at 1%. Robust standard errors are reported in brackets (clustered by country). All columns include a full set of year dummies and regional dummies as described in the empirical specification section. The dependent variable is Log(*SWIFTtrafirm*)$_{it}$ and represents the average traffic per firm that has adopted SWIFT in each country each year. In this table *SWIFTad*$_{it}$ is also included as an explanatory variable to examine the network effect of the network size on the average traffic. All the independent variables are described in Tables 1 and 2. The time period of the sample is 1999-2006 (eight years).