Diffusion of Mobile Technologies in the Area of Financial and Insurance Activities in Poland

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Abstract

The diffusion of innovation in the area of banking and certain financial services is a topic eagerly taken up in empirical research, but in the case of Poland the study of this phenomenon in the area of finance and banking that utilizes the econometric models in question is practically non-existent. This article attempts to fill this research gap to some extent. The main objective of the article is to present a comparative analysis of the rate of mobile technologies diffusion among 3 groups of enterprises in the financial and insurance sectors: banking and lending, insurance and reinsurance, and brokerage and other activities. The occurrence of diffusion of mobile technologies and its rate was studied with the help of a logistic function. Results show that in companies operating in the insurance industry, the phase of rapid growth of mobile innovation diffusion lasted longer than in other groups of enterprises, but the highest dynamics of mobile innovation diffusion in the first phase of this phenomenon was achieved by companies conducting brokerage and other activities.

Keywords	***DOI***	***JEL code***
Innovation diffusion, logistic function, banking, insurance, Poland	*https://doi.org/10.54694/stat.2023.47*	*O30, C01, C22*

INTRODUCTION

In recent years the process of industrial production and the ways of providing services have undergone an enormous transformation, and the scale of these changes is so large that the accompanying ubiquitous progress has the hallmarks of the fourth industrial revolution (Yang and Gu, 2021). Its effects are visible in virtually all spheres of human activity. The essence of the fourth industrial revolution is the full integration of the physical production environment with the Internet, where communication between devices based on mobile technologies plays a fundamental role. Mobile technologies include the production of mobile devices and software dedicated to them, but also products and services that can be created

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and/or provided through these devices. The creation of innovations based on such technologies usually requires a large scientific and technical base, high-class specialists, significant financial resources invested in research and development, as well as providing appropriate conditions by the state to conduct such innovative activity. Most countries do not have an appropriate potential to create mobile innovations, so for countries such as Poland the main channel for the development of these technologies is their diffusion. The diffusion of mobile technologies can be understood as the process of market penetration by new products and services using remote access to the Internet network, GSM network, GPS geolocation technology or NFC proximity technology. The spread of this type of technology is stimulated by social factors (Peres et al., 2010), and whether an innovation is appreciated by the audience depends on their perceived use value of the solution, which is an outcome of the benefits and costs associated with the innovation. Mobile technology should be considered an unprecedented civilizational leap taking place at an express pace and affecting almost every area of human life. But it is also an important factor in giving businesses a competitive advantage. In themselves, these technologies stimulate innovation in enterprises and directly affect the development of many industries and economic sectors, consequently strengthening their economic potential.

The main advantages of mobile technologies include connectivity and immediacy that allow users to utilize them anywhere and at any time, personalization options allowing for the exchange of personal information in the target group of users, wide configuration options enabling system settings in a manner tailored to user needs, as well as data portability allowing for the possibility of storing and managing them (Łysik and Kutera, 2013).

The recipients of mobile technologies are both individual customers, enterprises and organizations. Improving mobile techniques within organizations and companies enables improvements in the production process and strengthens ties between the service provider – producer – consumer. This is visible in the sphere of financial and insurance services, where quick and direct contact with the customer during the provision of the appropriate service may be of key importance (e.g. in brokerage activities). In banking sector, internal mobile applications enable the company employees to easily access customer and account information, as well as supporting transaction processing. It is worth noting that mobile technologies allow for easy, safe and quick verification of customer accounts and data, as well as for carrying out various types of financial operations. The financial and insurance sectors are certainly one of those areas of economic activity where mobile technologies find particularly fertile ground and spread quite quickly. In the area of insurance, mobile technologies equip employees with the ability to quickly access information about customers and policies while away from the office, as well as to report claims of damage, handle them and process compensation claims. As a result, customers can be served faster and more effectively, which translates into increased customer satisfaction and loyalty. Thanks to such benefits, mobile technologies within banking and insurance organizations are becoming a business standard, since they increase work efficiency and flexibility, improve communication, facilitate customer service and increase the level of satisfaction with the use of financial and insurance services.

The diffusion of innovations in the area of banking, insurance and related financial services is the subject of numerous analyses and empirical studies. International literature offers a number of research results on the diffusion of mobile technologies using econometric models, however, the study of this phenomenon in the area of finance and banking with the use of these models is rare in Poland. The existing research gap in this area makes it difficult to reliably assess the diffusion of mobile technologies and the pace of this phenomenon. This article attempts to fill this gap to some extent. The main objective of undertaken analysis is to investigate the extent and rate of diffusion of mobile technologies in the area of financial and insurance services. The occurrence of diffusion of mobile technologies and its rate was studied with the help of a logistic function.

1 LITERATURE REVIEW

Technology diffusion is studied in various contexts, including a geographical perspective (Haynes et al., 1977; Brown, 1981), marketing (Mahajan et al., 1990), economics (Gurbaxani, 1990), and sociology (Rogers, 1995). A leading trend in mobile technology research is the diffusion analysis of mobile telephony innovations, since the mobile phone smartphone is the most recognizable example of the technology in question. Almost every consumer has a smartphone, and its wide functionality allows for using many functions and mobile applications. Hence, research on the diffusion of mobile innovations in this area is very popular. The analyses focus on the rate of innovation diffusion, as well as its determinants. Dekimpe et al. (1998), studying the diffusion of innovation between countries, showed that its determinants include the social system and the adoption ceiling. The research also draws attention to the deregulation of the telecommunications market and the possibilities of competing within it. Gruber and Verboven (2001a) showed, for example, that the regulatory effect upon the market in question, and competition within it, is less than the technological effect. In their research on mobile communications, they found that technological development and market deregulation, when creating the right conditions for competition through licensing, allows for accelerating the spread of mobile telephony in fifteen European countries. Similar conclusions were reached by Petrazzini (1996), Wallsten (2001), and Buys et al. (2009). Perkins and Neumayer (2005) found that the openness of trade significantly positively affected the speed of innovation diffusion, but did not prove the positive effect of FDI on the rate of diffusion of new technologies.

Gruber and Verboven (2001a) have concluded that a country's GDP is not a significant factor in diffusion of innovation, and countries that were the first to grant licenses to operate in the mobile telephony market tend to be slower to implement the *catch-up effect*. Research also identifies the telecommunications infrastructure as a factor in innovation diffusion. Gruber and Verboven (2001b) and Frank (2004) showed, for example, that the number of recipients of new mobile technologies was influenced by the signal coverage of telecommunications networks, and the level of development and availability of fixed-line telephony were not important factors in the diffusion of innovation. Liikanen et al. (2004) provided an interesting analysis of the impact of the first generation (1G) mobile networks on the diffusion of innovations related to the next generation network (2G) and vice versa. They concluded that the development of the first generation (1G) mobile network was an important factor in the diffusion of the second generation cellular network, but not the other way around. The level of economic development, the wealth of the country and cultural conditions as factors in the diffusion of mobile innovations, have been highlighted by authors such as Sundqvist et al. (2005), who conducted their research among 25 countries. Rouvinen (2006) showed that the diffusion rate of mobile innovation did not differ significantly between developed and developing countries. Chu et al. (2009) showed that market competition significantly influenced the diffusion of innovation in this market through downward pressure on the price of telecommunications services. They also proved that, in the case of Taiwan, the level of economic development, the number of mobile network operators did not affect the speed of diffusion of mobile innovations. Comer and Wikle (2008) examined mobile telephony diffusion between 1995 and 2005 and concluded that GDP per capita explained more than 75 percent of the variability of this phenomenon, Another important research strand analyses the spread of innovations by modeling their life cycles (Peres et al., 2010), with results in the form of mathematical models describing innovation growth curves with estimated parameters. The aim of this research is generally to provide accurate images of diffusion processes over time, so that managers can forecast sales, develop appropriate strategies, and act accordingly (Mahajan, Muller and Bass, 1990). When researching the process of diffusion of mobile innovations, the logistic function is most often used (Gruber and Verboven, 2001a, 2001b; Frank, 2004; Liikanen et al., 2004; Lee and Cho, 2007), and less often the Bass model (Dekimpe et al., 1998; Sundqvist, Frank and Puumalainen, 2005) or the Gompertz function (Rouvinen, 2006). It should be noted that in most cases, different countries are studied, characterized by different levels of technological development, GDP, and cultural customs,

so the research results are not always consistent. What in some countries may be an important determinant of the diffusion of mobile innovations, in another country may not have a significant impact on this process. The methods used to study this phenomenon are also an open question. A model that may work well in describing diffusion in one country does not necessarily correctly describe it in another country. For this reason, further study of this phenomenon is still relevant. In Polish literature, studies of the diffusion of innovation can be found in the works of Klincewicz (2011), Firlej and Żmija (2014), Wiśniewska (2004), Gwarda-Gruszczyńska (2017). Apart from a few exceptions (Kolarz, 2006), the use of econometric tools in this type of research in the case of Poland is rare, which makes it difficult to properly identify this process in general. An even greater challenge is the area of financial and insurance services, which, due to their specificity, show great ease in absorbing new mobile technologies.

2 METHODOLOGY

The authors of many studies have shown that the innovation diffusion rate varies according to an S-shaped curve (Sharif and Kabir, 1976; Desiraju et al., 2004; Cyclist, 2006). The process of spreading innovation is generally predictable: it is usually characterized first by a slow growth rate, then in the middle phase this rate increases rapidly, then finally decreases, the S-shaped curve flattens, and the level of innovation stabilizes (the growth dynamics of innovation diffusion fades). Therefore, in research on the dynamics of innovation diffusion, econometric models that reflect this kind of course of the phenomenon are most often used. Popular tools in modeling this type of phenomena include the logistic function, Gompertz model and Bass model. This article centers on the logistics model, whose effectiveness in the study of mobile technologies has been confirmed in other studies (Gruber and Verboven, 2001a, 2001b; Frank, 2004; Cramer, 2004; Liikanen et al., 2004; Lee and Cho, 2007). The logistic curve belongs to a more general family of S-shaped curves, which are represented by the Richards function (Richards, 1959; Lei and Zhang, 2004):

$$y(t) = \delta + \frac{\alpha - \delta}{\left(\theta + \beta exp(-\gamma t)\right)^{1/\nu}}, \tag{1}$$

where: t – time variable, α, β, γ, δ, θ, ν – parameters of the Richards function.

In Formula (1), the parameter γ expresses the growth rate, ν is the growth parameter with the maximum asymptote, and the parameters α and δ represent the upper and lower asymptote of the Richards function, respectively.

If we assume that $\delta = 0$, $\theta = \nu = 1$, then we get the logistic function (2):

$$y(t) = \frac{\alpha}{1 + \beta exp(-\gamma t)}. \tag{2}$$

In order to improve flexibility of the model that will be adapted to the data with limited supply, for the purposes of this study, the model (2) has been supplemented with the free term φ, which allows the modified logistic function to be written as follows:

$$y(t) = \frac{\alpha}{1 + \beta exp(-\gamma t)} + \varphi. \tag{3}$$

In modeling the diffusion of mobile technologies, it is important to determine the rate of change of this process. The growth rate of the logistic function can be calculated from the formula:

$$GR = \frac{dy}{dt}\frac{1}{y}. \tag{4}$$

According to the course of the logistic function, it is possible to distinguish the area in which it has an increasing growth rate, and then the area with decreasing growth dynamics, whereby at infinity the phenomenon tends to the saturation level expressed by the asymptote $y = (\alpha + \varphi)$.

The point separating the area of rapid growth rate from the area with decreasing growth rate is the *inflection point* with coordinates $\left(\frac{ln\beta}{\gamma}, \frac{\alpha}{2} + \varphi\right)$. The logistics function and its properties is used in the empirical part of the article to analyze the process of mobile innovations diffusion in various areas of financial and insurance activity in Poland.

3 EMPIRICAL RESEARCH RESULTS AND DISCUSSION

The study of innovation diffusion was based on statistical data on the number of companies belonging to the following financial industry sectors (according to the Polish Classification of Activities; PKD, 2007): banking and lending, insurance and reinsurance, and brokerage and other activities, which provide their employees with access to mobile devices enabling mobile access to the Internet, such as portable computers and smartphones.[2] Access to this type of equipment among employees in these industries is important because the modern financial sector is increasingly based on the latest technologies and digital solutions. Access to mobile devices, and, through them, to the Internet, is vital for the effective functioning of these industries, since many financial sector employees work remotely or need access to information and systems outside the office, and mobile devices enable them to work in the field, during meetings with clients or on business trips. Use of mobile equipment in the researched industries is necessary for:

- Communication with customers – financial sector employees need to keep in touch with customers in order to obtain additional information, explanations or to sign contracts. Mobile devices enable quick communication via e–mails, text messages or phone calls.
- Viewing customer data – employees need to access customer data, transaction history, or credit information in a variety of places and situations. Mobile devices enable real–time access.
- Analysis, calculations and decisions (credit, insurance premium, etc.) – when evaluating loan applications or determining insurance premiums, employees often have to analyze a variety of data, information and parameters. Mobile devices enable viewing this data in any location, which can speed up the decision–making process.
- Signing electronic documents – increasingly, documents can be signed electronically. Mobile devices allow employees and their customers to sign the necessary documents online.
- Accessing documents – financial sector employees must have access to documents such as policies, contracts and documents related to claims, loan agreements. Mobile devices enable storage and viewing of these documents on–line
- Market and trend monitoring – many financial firms follow markets and trends to make appropriate investment decisions. Mobile devices enable access to current market information and trend analysis.
- Banking and client applications – banks and credit companies often offer their customers mobile applications for account management, loan repayment, etc. Employees must be familiar with these applications to help customers use them.

Data for 2011–2020, obtained from the CSO Local Data Bank, were used to model the phenomenon in question jointly, and separately in each of the highlighted areas. Data includes time series of the number of companies in Poland in mentioned areas. Thanks to the characteristics of the logistics function, it is possible to compare the areas of banking, insurance and insurance and brokerage activities in terms of the rate of diffusion of mobile technologies, their ability to absorb innovations and develop patterns

[2] *<https://bdl.stat.gov.pl/bdl/start>.*

of diffusion of innovation in each of these areas. In the first periods, the number of enterprises in the financial and insurance sectors decreased (this may be due to changes in the way companies are classified), and in subsequent periods it systematically increased. First, using the Gauss-Newton algorithm, the parameters of the logistics function (2) were estimated separately for all enterprises from the financial and insurance sector. The estimation results of parameters are included in Table 1 and the course of the corresponding logistic curve for this type of enterprises is presented in Figure 1.

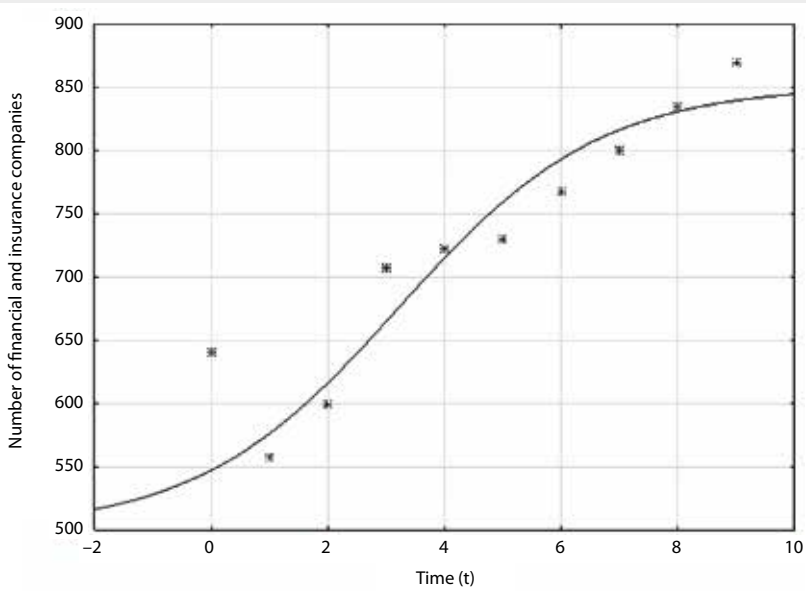
Table 1 Parameters of the logistic regression function among all enterprises operating in all analyzed sectors

Parameter	α	β	γ	φ
Coefficient	351.08476	6.45637	0.47121	501.21220
Standard error	54.61674	2.30892	0.14428	133.25470
t-Stat	6.42815	2.79628	3.26589	3.76131
p	0.00036	0.02667	0.01375	0.00706

Source: Own calculations

As can be seen in Figure 1, it was possible to match the logistic function to empirical data, which is confirmed by the process of diffusion of mobile technology innovations in this group of Polish enterprises. The parameters of the model are statistically significant, and the level of fit measured by the coefficient of determination is satisfactory. The inflection point of this logistic function is 3.96, which means that the phase of rapid diffusion growth in enterprises operating in the financial and insurance sectors lasts approximately 48 months. Also, the growth rate (GR) of the logistic function calculated at this point is 6.11%. The theoretical number of companies in the financial and insurance industry supplying employees with mobile devices with the Internet access will stabilize at around 853 in the long term.

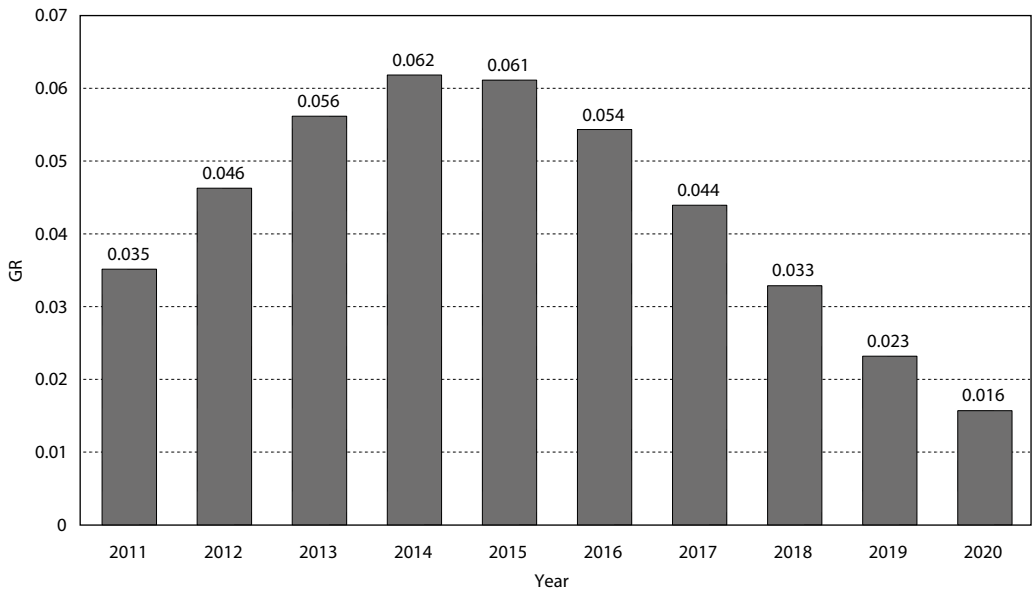
Figure 1 The course of logistic curve for all enterprises operating in all analyzed sectors



Source: Own elaboration

The growth rate in the logistics function in the examined group of companies was also calculated in subsequent periods. The results are illustrated in Figure 2. It can be seen here that the diffusion rate systematically increases in the first 4 periods from 3.5% to 6.2%, and then systematically decreases from 6.1% to 1.6%.

Figure 2 Growth rate of the logistics function for all enterprises operating in the financial and insurance sectors



Source: Own elaboration

Among Polish companies active in the researched sectors, a similar survey was carried out separately for companies engaged in banking and lending activities, insurance and reinsurance, and brokerage and other activities (following the Polish Classification of Activities; PKD, 2007). In each of these three cases, logistic functions were matched with statistically significant parameters (except parameter β in the model for brokerage and other activities sector). Therefore, it can be argued that the diffusion of mobile technologies occurs in each group of companies considered. The inflection points of the logistics curves in each of these 3 groups of companies (banking, insurance and brokerage activities) were respectively: 5.83, 6.94 and 3.94. This means that the insurance sector had the longest phase of rapid growth in the diffusion of innovation, where it lasted about 84 months. On the other hand, the shortest period of dynamic growth of 47 months had the diffusion of mobile innovations in companies conducting brokerage activities.

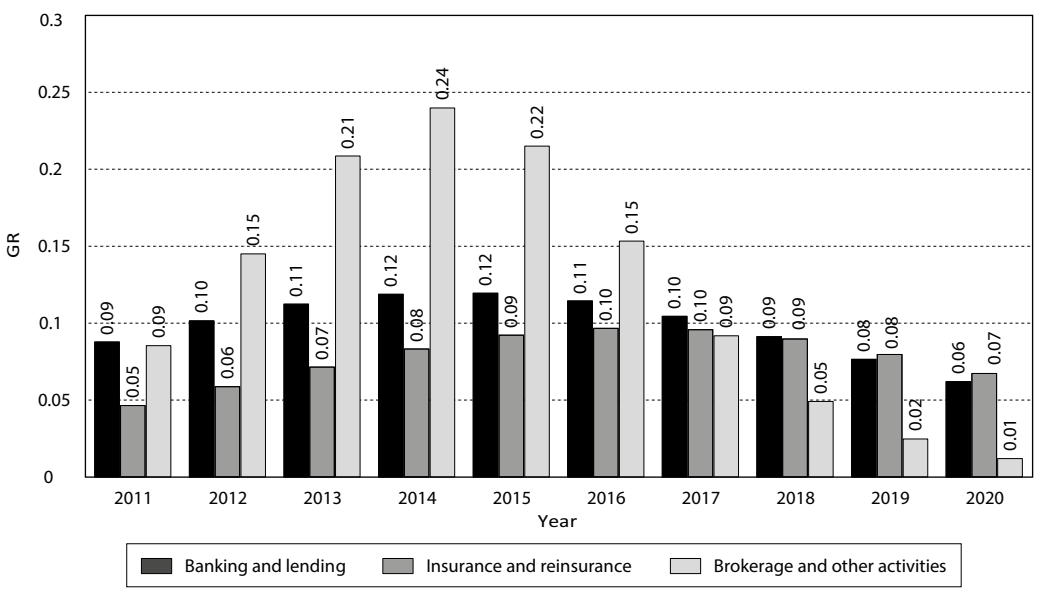
At the same time, in this group of companies, the growth rate at the inflection point was the highest among all groups of companies (the growth rate of the logistics function amounted to approx. 21.77%). On the other hand, the lowest growth dynamics were characterized by companies conducting insurance activities, as evidenced by the growth rate (GR) of the logistics curve of 9.01%. A slightly higher growth rate of the diffusion of mobile innovations was recorded by enterprises conducting banking or lending activities, where the growth rate was 10.64%. The growth rate in the logistics function in each of the 3 groups of companies, was also calculated in 10 consecutive periods. The results are illustrated in Figure 3, which shows that the rate of diffusion systematically increases in all groups of enterprises, and then decreases after passing through the inflection point, which is different in each group of enterprises.

Table 2 Parameters of the logistic regression function for enterprises operating separately in all analyzed sectors

Parameter	α	β	γ	φ
Banking and lending				
Coefficient	360.87530	7.12562	0.33668	105.1247
Standard error	145.91257	2.49353	0.13534	39.3251
t-Stat	2.47323	2.85764	2.48764	2.67322
p	0.04263	0.02442	0.04174	0.03185
Insurance and reinsurance				
Coefficient	45.36380	11.54123	0.35227	21.6361
Standard error	16.83706	3.28445	0.09972	8.8723
t-Stat	2.69428	3.51390	3.53239	2.43861
p	0.03089	0.00981	0.00957	0.04485
Brokerage and other activities				
Coefficient	82.21831	19.33760	0.75109	29.78168
Standard error	7.70495	13.51639	0.20822	7.30219
t-Stat	10.67084	1.43068	3.60717	4.07846
p	0.00001	0.19561	0.00866	0.00470

Source: Own calculations

Figure 3 Growth rate of logistics function of enterprises operating separately in all analyzed sectors



Source: Own elaboration

In the period 2011–2015, the highest growth dynamics of the logistics curve was achieved by companies conducting brokerage and other activities. On the other hand, the dynamics of diffusion of mobile innovations after 2015 in this group of companies clearly weakened and was lower than in other groups of companies. The lowest dynamics of diffusion in the first 6 years was shown by companies conducting insurance activities, while in the last two years for this group of companies the dynamics of diffusion growth was the highest among all enterprises. It may be surprising that, in terms of the analyzed rate of innovation diffusion, companies engaged in banking and lending activities are weaker compared to other groups of enterprises. Banks, in particular, generally have considerable investment capital to implement specific innovation strategies. However, it should be remembered that in this article, the measurement of innovation is limited to portable devices enabling mobile Internet access among employees. Simultaneously, the innovativeness of the banking sphere concerns various processes and product innovations, focused not on equipment but rather on a specific type of service provided by banks, in the form of development work initiated by customer needs, implementation of information processing and security technologies or development of marketing and sales support tools. Depending on the adopted innovation strategy, the aim of a specific innovative activity may include the intent to achieve and/or maintain a leading position on the market, gain new customers, acquire new solutions that are no longer protected by patents. Obtained results suggest that mobile devices may be more important for employees in the insurance industry. Some of them work in the field (e.g. claims liquidation) and such devices are necessary to carry out their tasks, which is reflected in the longest period of rapid increase in the diffusion of innovations in the surveyed groups of enterprises. Equally important is the use of such devices in the work of stack market traders. Modern stock exchange transactions take place mainly electronically, and fast and uninterrupted access to data is crucial for making the correct investment decisions. Hence, the relatively deep diffusion of innovation in brokerage companies can be explained by the nature of the work performed by brokers. Often their work requires making decisions in a fairly short time. Mobile devices such as smartphones and tablets make it easy for them to monitor the market in real time, view up-to-date financial information, analyze charts and indicators, and execute trades anywhere they have access to the Internet.

CONCLUSIONS

Based on the results obtained, it can be concluded that the diffusion of mobile technologies occurs in all analyzed groups of companies in the financial and insurance industries, although the duration and intensity of this phenomenon varies and depends on the specific group of enterprises. Among companies operating in the insurance industry, the phase of rapid growth of mobile innovation diffusion lasts longer than in other groups of enterprises, but the highest dynamics of mobile innovation diffusion in the first phase of this phenomenon was achieved by companies conducting brokerage and other activities. The shortest phase of rapid growth of innovation diffusion was in brokerage companies, but the dynamics of this phenomenon in the period under review was the highest. The varied length of the phase of increase in the diffusion of mobile innovations may result from the specificity of individual industries, and its lower dynamics in the group of companies conducting insurance activity (in the first phase of diffusion) may indicate the presence of certain barriers, factors weakening the phenomenon of diffusion. Their detailed diagnosis requires continued research (e.g. by using a purpose-designed questionnaire). Previous studies of diffusion of innovations in enterprises may indicate that factors differentiating the period and pace of diffusion of innovation include the level of technological advancement of the industry, the level of internationalization, and the ownership structure of enterprises. The analyzed groups of companies belong to the same financial and insurance industry, so the differences in the level of technological advancement may be insignificant, but the impact of this factor on the length and depth of diffusion, as well as other factors, cannot be excluded without additional research. It should also be taken into

account that the research was limited to the analysis of diffusion of product innovations, namely portable equipment enabling access to the Internet, the use of which in different groups of employees may vary, depending on the specifics of work in a given area. Analysis of the length and depth of process innovations among similar groups of companies could provide different results.

References

BUYS P., DASGUPTA S., THOMAS T. S., WHEELER D. (2009). Determinants of a Digital Divide in Sub-Saharan Africa: A Spatial Econometric Analysis of Cell Phone Coverage. *World Development, Elsevier*, 37(9): 1494–1505.

BROWN, L. A. (1981). *Innovation diffusion: A new perspective*. New York: Methuen.

CHU, W., WU F., KAO, K., YEN, D. C. (2009). Diffusion of mobile telephony: An empiricalstudy in Taiwan [online]. *Telecommunications Policy*, 33(9): 506–520, <https://doi.org/10.1016/j.telpol.2009.07.003>.

COMER, J. C., WIKLE, T. A. (2008). Worldwide diffusion of the cellular telephone, 1995–2005 [online]. *The Professional Geographer*, 60(2): 252–269, <https://doi.org/10.1080/00330120701836303>.

COURI, C. L., ARBACHE, J. (2006). *Are Fixed and Cell Phones Substitutes or Compliments? The Case of Brazil* [online]. <http://dx.doi.org/10.2139/ssrn.905125>.

CRAMER, J. S. (2004). The early origins of the logit model [online]. *Studies in History Philosophy of Biological & Biomedical Science*, 35(4): 613–626, <https://doi.org/10.1016/j.shpsc.2004.09.003>.

DEKIMPE, M. G., PARKER, P. M., SARVARY, M. (1998). Staged Estimation of International Diffusion Models: An Application to Global Cellular Telephone Adoption [online]. *Technological Forecasting and Social Change*, 57(1–2): 105–132. <https://doi.org/10.1016/S0040-1625(97)00085-1>.

DESIRAJU, R., NAIR, H., CHINTAGUNTA, P. (2004). Diffusion of new pharmaceutical drugs in developing and developed Nations [online]. *International Journal of Research in Marketing*, 21(4): 341–357, <http://dx.doi.org/10.2139/ssrn.945419>.

FIRLEJ, K., ŻMIJA, D. (2014). *Transfer wiedzy i dyfuzja innowacji jak źrodło konkurencyjności przedsiębiorstw przemysłu spożywczego w Polsce* [*Knowledge transfer and diffusion of innovation as a source of competitiveness of food industry comapnies in Poland*]. Kraków: Fundacja Uniwersytetu Ekonomicznego w Krakowie.

FRANK, L. D. (2004). An analysis of the effect of the economic situation on modeling and forecasting the diffusion of wireless communications in Finland [online]. *Technological Forecasting and Social Change*, 71(4): 391–403, <https://doi.org/10.1016/S0040-1625(02)00392-X>.

GRUBER, H., VERBOVEN, F. (2001a). The diffusion of mobile telecommunications services in the European Union [online]. *European Economic Review*, 45(3): 577–588, <https://doi.org/10.1016/S0014-2921(00)00068-4>.

GRUBER, H., VERBOVEN, F. (2001b). The evolution of markets under entry and standards regulation – the case of global mobile telecommunications [online]. *International Journal of Industrial Organization*, 19(7): 1189–1212, <https://doi.org/10.1016/S0167-7187(01)00069-8>.

GURBAXANI, V. (1990). Diffusion in computing networks: The case of BITNET [online]. *Communications of ACM*, 33(12): 65–75, <https://doi.org/10.1145/96267.96283>.

GWARDA-GRUSZCZYŃSKA, E. (2017). Dyfuzja innowacji – następstwo komercjalizacji nowych technologii [Diffusion of innovation – the consequence of commercialization of new technologies]. *Organizacja i Kierowanie*, 2(176): 383–396.

HAYNES, K. E., MAHAJAN, V., WHITE, G. M. (1977). Innovation diffusion: A deterministic model of space-time integration with physical analog [online]. *Socio-Economic Planning Sciences*, 11(1): 25–29, <https://doi.org/10.1016/0038-0121(77)90043-X>.

KLINCEWICZ, K. (2011), *Dyfuzja innowacji. Jak odnieść sukces w komercjalizacji nowych produktów i usług* [*Diffusion of innovation. How to be successful in commercializing new products and services*]. Warszawa: Wydział Zarządzania UW.

KOLARZ, M. (2006). *Wpływ zagranicznych inwestycji bezpośrednich na innowacyjność przedsiębiorstw w Polsce* [*The influence of foreign direct investments on the innovativeness of companies in Poland*]. Katowice: Wydawnictwo Uniwersytetu Śląskiego.

LEE, M-K, CHO, Y. (2007). The diffusion of mobile telecommunications services in Korea. *Applied Economics Letters*, 14(7): 477–481.

LEI, Y. C., ZHANG, S. Y. (2004). Features and Partial Derivatives of Bertalanffy – Richards Growth Model in Forestry. *Nonlinear Analysis: Modelling and Control*, 9(1): 65–73.

LIIKANEN, J., STONEMAN, P., TOIVANEN, O. (2004). Intergenerational effects in the diffusion of new technology: the case of mobile phones [online]. *International Journal of Industrial Organization*, *Elsevier,* 22(8–9): 1137–1154. <https://doi.org/10.1016/j.ijindorg.2004.05.006>.

ŁYSIK, Ł., KUTERA, R. (2013). Technologie mobilne jako determinanta rozwoju innowacyjnego społeczeństwa informacyjnego [Mobile technologies as a determinant of development of innovative information socjety]. *Zeszyty Naukowe Uniwersytetu Szczecińskiego nr. 763, Ekonomiczne Problemy Usług nr. 105*.

MAHAJAN, V., MULLER, E., BASS, F. M. (1990). New product diffusion models in marketing: A review and directions for research [online]. *Journal of Marketing*, 54(1): 1–26, <https://doi.org/10.2307/1252170>.

PERES, R., MULLER, E., MAHAJAN, V. (2010). Innovation diffusion and new product growth models: A critical review and research directions [online]. *International Journal of Research in Marketing*, 27(2): 91–106, <https://doi.org/10.1016/j.ijresmar.2009.12.012>.

PERKINS, R., NEUMAYER, E. (2005). International technological diffusion, latecomer advantage and economic globalization: A multi-technology analysis [online]. *Annals of the Association of American Geographers*, 95(4), 789–808, <https://www.jstor.org/stable/3694013>.

PETRAZZINI, B. (1996). Competition in telecoms – Implications for universal service and employment. *Public Policy for the Private Sector*, Note 96, Washington, DC: World Bank.

RICHARDS, F. J. (1959). A Flexible Growth Function for Empirical Use [online]. *Journal of Experimental Botany*, 10(2): 290–300, <http://dx.doi.org/10.1093/jxb/10.2.290>.

ROGERS, E. M. (1995). *Diffusion of innovations*. 4th Ed. New York: Free Press.

ROUVINEN, P. (2006). Diffusion of digital mobile telephony: Are developing countries different? [online]. *Telecommunications Policy*, 30(1): 46–63, <https://doi.org/10.1016/j.telpol.2005.06.014>.

SHARIF, M. N., KABIR, C. (1976). System dynamics modelling for forecasting multilevel technological substitution. *Technological Forecasting and Social Change*, 9(1–2): 89–112.

SUNDQVIST, S., FRANK, L., PUUMALAINEN, K. (2005). The effects of country characteristics, cultural similarity and adoption timing on the diffusion of wireless communications [online]. *Journal of Business Research*, 58(1): 107–110, <https://doi.org/10.1016/S0148-2963(02)00480-0>.

WALLSTEN, S. (2001). An empirical analysis of competition, privatization, and regulation in African and Latin America. *Journal of Industrial Economics*, 49(1): 1–19.

WIŚNIEWSKA, J. (2004). *Ekonomiczne determinanty dyfuzji innowacji produktowych i technologicznych w banku komercyjnym* [*Economic determinants of diffusion of product and technological innovations in a commercial bank*]. Szczecin: Wydawnictwo Naukowe Uniwersytetu Szczecińskiego.