Mirela CRISTEA, PhD
simona.cristea@edu.ucv.ro
University of Craiova, Craiova, Romania

Grațiela Georgiana NOJA, PhD (corresponding author)
gratiela.noja@e-uvt.ro
West University of Timisoara, Timisoara, Romania

Radu Ion FILIP, PhD
radu.filip@rei.ase.ro
Bucharest University of Economic Studies, Bucharest, Romania

Elena Iulia GRIGORIE, PhD Candidate
iuliagrigorie99@gmail.com
University of Craiova, Doctoral School of Economics, Craiova, Romania
"Constantin Brâncuși" University of Târgu-Jiu, Târgu-Jiu, Romania

Silviu Valentin CÂRSTINA, PhD
silviu.carstina@yahoo.com
University of Craiova, Craiova, Romania

Digital Transformation and Innovation in the European Insurance Market: Life vs. Non-Life Sectors

Abstract. *Digitalisation and innovation have transformed the insurance industry, improving customer experience, operational efficiency, and risk management practices across both life and non-life insurance sectors. The purpose of this study is to evaluate, during the 2007–2023 period, the specific and overall effects of digital transformation and innovation on the performance of the European Union's insurance market, with a focus on both life and non-life segments. The research methodology consists of applying two econometric models: robust regression models to assess the direct implications of digital transformation and innovation on each sector of the insurance market, and Bayesian Network Analysis, utilising Gaussian Graphical Models, to evaluate global interlinkages among these sectors. Our findings reveal the specific impact of digitalisation and innovation on the insurance market, reflected in insurance-to-GDP penetration and density levels. Based on these insights, we propose measures for EU insurance institutions and markets, differentiated between life and non-life sectors, to adapt to the inevitable changes brought by digitalisation.*

Keywords: *digital transformation, innovation, insurance dimensions, life insurance, non-life insurance, standard of living, European Union, econometric modelling.*

JEL Classification: C1, G22, O33.

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1. Introduction

The rapid pace at which technologies, innovations, and digital devices are evolving, coupled with their immediate absorption into society and the economy, has created a pressing need to comprehend their impact and effects in all areas of activity. This is particularly important for the insurance sector, which is a crucial pillar of the financial market. Given the pivotal role of the insurance sector in the economy, stakeholders must remain informed and up-to-date on the latest trends and developments. By adopting a proactive and well-informed approach, the insurance sector could harness the power of technology in an effort to extend its services, increase overall efficiency, and better address emerging consumer needs. Nowadays, digital technologies are also changing quickly the dimensions of the labour market (Ciarli et al., 2021; Vasilescu et al., 2020). Therefore, some skills and jobs have become morally obsolete, facing the risk of disappearing, while new ones are being encountered due to technology, which is constantly expanding (Van Laar et al., 2020). Thus, digital transformation becomes essential for the insurance sector, encompassing both life and non-life insurance components (Cappiello, 2020).

Digital transformation is a phenomenon that offers opportunities for the development of the insurance market. Still, this opportunity can also be seen as a challenge for insurance companies, which must keep pace with the changes imposed. The emergence and rapid development of the online environment, with all that it implies, have influenced consumer behaviour, as they seek comfort, speed, and transparency, and thus turn to online services (Braun & Jia, 2025; Peña-García et al., 2020). Based on this, insurers help people with personalised offers and services according to their requirements and expectations.

Moreover, insurance plays a more important and useful role in society than individual protection; it influences economic development and changes people's living standards profoundly. According to Cristea et al. (2014), Poontirakul et al. (2022), Pradhan et al. (2016), and Radermacher & Brinkmann (2011), insurance provides societal welfare by transferring risk, assisting entrepreneurship, offering financial security, and reducing poverty.

Given the above framework and information, the central purpose of this research is to study the direct and combined effects of digitalisation, innovation, living standards, and labour market performance on insurance market indicators. With this in mind, a dual-layered approach is adopted that addresses both life and non-life insurance within the European Union's member states.

The methodological approach involves the utilisation of two econometric models, namely: *(i)* robust regression models to appraise direct implications of digital transformation and innovation and the standard of living in the insurance market; and *(ii)* Bayesian Network Analysis, using Gaussian Graphical Models, to assess global interlinkages between these coordinates. Data for a period ranging from 2007 to 2023 were extracted and compared with the data available for the insurance market to ensure completeness of the analysis.

The novelty of our research, concerning the interplays between digital transformation, innovation, and the insurance market, involves the investigation of the complex impacts, challenges, and opportunities stemming from these convergences, developed through a two-fold analytical approach, respectively, for life insurance and non-life insurance dimensions, with the further inclusion of standard of living credentials measured by a composite indicator, namely HDI, and dimensions of labour market performance. Examining the socioeconomic impact of digital transformation on insurance markets will reveal the implications for inclusivity and accessibility, including how digitalisation affects insurance affordability, access to disadvantaged populations, and digital exclusion.

The structure of the research paper is as follows: after contextualising our endeavour in the introduction, we proceed to survey the relevant literature related to the interplay between digitalisation, innovation, and insurance in order to highlight the main theoretical underpinnings of these issues. The data used in our research are presented next, along with an explanation of the methodology applied. The research objectives and hypotheses proposed for assessment are also outlined in the third section. Further, the findings are described, the significance and implications for insurance theory, practice, and policymakers are highlighted, and concluding remarks are made. Additional analyses of the methodology applied are given in the Appendix.

2. Literature review

The interrelationships between digitalisation, innovation, and insurance are a highly debated topic, clearly indicating that technology and its various innovations are having a significant impact on the field of insurance. Significant changes have been observed in recent years in insurance, affecting diverse aspects, including a range of services tailored to meet the evolving needs of both individuals and enterprises. Digital technologies have been extensively discussed in the academic literature regarding their impacts on various aspects of the insurance process, customer interactions, and entrepreneurship.

Insurance domain research requires an in-depth understanding of how this sector operates and is performing. Market development, measured by specific indicators, determines the level of penetration and density that signals the protection level against risks and the provided financial security to the households and businesses (Borovcová & Špačková, 2019).

Insurance penetration is considered a core measure representing the size of an insurance market in a country, relating to the country's GDP by the share of insurance premiums (Cristea et al., 2021). Higher insurance penetration reflects that more insurance is purchased in an economy, and, therefore, a higher share of the population and businesses has protection through insurance policies. Generally, people in developed countries are more aware, have higher disposable incomes, and have easier access to a greater availability of insurance products. Insurance density is a fundamental measure of how much an average citizen of a particular country

spends on buying insurance premiums (Lee et al., 2022). As opposed to insurance penetration, which relates premiums to GDP, this provides a more complicated view, further segmenting the premiums into a country's total population. It also depicts the living standards that affect the form of insurance products requested by the citizens (Sanjeewa et al., 2019).

The insurance dimension indicators are an important tool in the work of policyholders, insurers, and researchers in assessing the performance and potential of insurance markets. Analyses of these indicators show that areas for improvement can be pinpointed by implementing interventions that improve financial protection. Understanding the indications within the insurance market will continue to be of great importance in developing economic stability and resilience in a changing economy.

Research has focused on how digitalisation and innovation force product innovation and customisation within the insurance market. The literature has continually made it known that nearly all insurers embrace digital technologies. For example, insurers are developing new insurance products, adopting digital tools such as online portals, mobile applications, artificial intelligence, big data analytics, and cloud computing to rationalise and simplify their operations (Klapkiv and Klapkiv, 2017). The consequences of the great fluctuations in customers' behaviour and expectations within the insurance sector are apparent. Customers want personalised, easy, and smooth experiences across digital touchpoints. They become better educated, and there is a need for relevant insurance products with rapid claims processing.

Research indicates that in order to promote better customer experience and involvement, insurance companies should integrate digital innovation into their core activities (Eckert et al., 2022). As technologies continue to evolve, digitalisation will become increasingly vital for the future of the insurance industry. The fact that more people are using the Internet gives insurers access to an unprecedented amount of information about them (Xu et al., 2022). At higher levels of Internet access among households, awareness among them regarding insurance is likely to emerge; therefore, greater insurance penetration may be expected in both life and non-life insurance markets (Benlagha and Hemrit, 2020). Using fingerprint analysis along with online behaviour analysis, insurance products could be personalised based on the individual risk profile. Moreover, personalised quotes could be provided due to this data-driven underwriting process, which is beneficial to both customers and insurers. AI-powered virtual assistants ease the insurance process by which insurers can respond instantly to customers' needs (Eling et al., 2022). This AI-based tool can facilitate qualified support for customers throughout the assurance process and therefore could enhance overall customer engagement.

The share of the total ICT sector in GDP indicates several decisive factors, including a well-developed digital infrastructure and the emphasis on technology. This, in insurance, implies advanced data analytics, artificial intelligence, and automation and positively influences the development of insurance (Eling et al., 2022). Technological advancements have smoothened the processes of insurance,

raised efficiency, and enabled insurers to provide innovative products and services. High-speed Internet coverage helps insurers exchange data in real time (Garven, 2002). Again, it allows the IoT to be integrated into insurance. IoT devices and sensors can show real-time data on the insured assets.

While data analytics and innovation have gained significant attention in literature for underwriting processes, Stanković & Stanković (2022) note that advanced analytics, such as machine learning and predictive models, assist insurers in analysing large volumes of data to determine risk more precisely, offer personalised pricing and coverage, and enhance the efficiency of underwriting workflows. Such innovations make underwriting more efficient, thus allowing insurers to manage their portfolio of risks much more effectively. Automation expedites policy issuance, removes errors due to manual processing, and allows insurers to issue policies immediately, thus improving operational efficiency and creating a seamless customer experience.

According to the literature on innovations, measured by GII scores, countries with higher GII scores are likely to develop the insurance dimension by adopting InsurTech solutions. By doing so, InsurTech solutions can enhance customer engagement and improve claims management, thus helping life and non-life insurance segments.

In economics, finance, and development studies, research has been conducted on the impact of living standards, measured by the Human Development Index, and poverty on the insurance market. Many papers have analysed the influence of insurance penetration on economic development, usually measured using variables like GDP per capita or the HDI (Cristea et al., 2014; Cristea et al., 2021; Lee et al., 2022; Pradhan et al., 2016; Mohy Ul Din et al., 2017; Ward and Zurbruegg, 2000). All of these generally indicate that there is a positive relationship between insurance penetration rates and higher economic development, where insurance in the most developed economies plays a vital role in risk management and financial stability.

The living standards, expressed through the HDI, have a strong impact on the insurance market of a country. From here, higher HDI values are associated with higher insurance penetration (Pradhan et al., 2016), preference for life insurance, and higher diversification of non-life products, but also with increased levels of education, awareness, and financial literacy (Herrero et al., 2012). Thus, with the improvement in the standard of living, people become more conscious about the management of risk and financial protection. Because of this reason, it results in increasing demand for insurance products, increasing the insurance penetration rates of countries having high HDI scores.

Other studies have also explored access to insurance and its consequences on poverty alleviation and social welfare (Apostolakis et al., 2015; Poontirakul et al., 2022; Radermacher and Brinkmann, 2011). In countries where the population experiences higher poverty rates, life insurance is out of many people's reach because it is perceived to be unaffordable (Singh, 2012). The incidence of poverty tends to significantly affect the vulnerability of the population to a number of non-life risks (Poontirakul et al., 2022), such as those experienced in natural catastrophes and

accidents. Low-income communities often lack the capacity to handle such situations financially.

The literature underlines that there are complex interdependencies between the labour market performance and the insurance market, and that macroeconomic conditions, level of income, and social protection mechanisms will therefore be of crucial importance when shaping the insurance demand, affordability, and the risk management strategies at the individual, company, and societal levels.

Studies also show that during periods of economic boom and low unemployment, households and businesses alike exhibit higher disposable incomes and a heightened tolerance for risk (Panzaru et al., 2025; Pirtea et al., 2019). Thus, the demand for greater life insurance cover to afford protection and income replacement in the case of early death is often higher, as is the demand for a range of other non-life insurance covers to protect against property loss, liability, and other potential perils (Outreville, 2014).

It has, therefore, devised ways in which changes to employment and unemployment rates influence the competitive dynamics in the insurance market. A worsening or improvement in the labour market could be a determinant of changes that an insurer may seek to make to their pricing strategy, its range of products, or underwriting criteria in an effort to be more competitive or appealing to its clients (Eling and Schaper, 2017).

Taken together, the available literature highlights that, for both life and non-life insurance, digitalisation, innovation, and living standards are drivers for the insurance market in terms of enhanced customer experience, more products and services, operational efficiency, and improved attitudes toward better risk management. These implications also help policymakers and insurers develop policies that improve the availability, affordability, and coverage of insurance. Moreover, insurance has a very significant role in financial resilience and protection for individuals and societies if it addresses the special needs and challenges linked to different living standards and poverty levels.

3. Data and Methodology

The data used in our research (Table 1) are extracted at the level of EU countries for the 2007-2023 time period. The variables employed in our models were grouped into three categories:

- *Insurance data:* insurance penetration degree for life insurance (IPLF) and non-life insurance (IPNLF) market; insurance density for life insurance (IDLF) and non-life insurance (IDNLF) market;
- *Digital and innovation dimensions:* households - level of Internet access (IA_H); individuals - Internet use, for last Internet use over the previous 12 months (IU_IND); Information and Communication Technology (ICT) in the total sector on GDP (ICT); high-speed Internet coverage (ICHS); Global Innovation Index (GII);
- *Standard of living and labour market dimensions (control variables):* Human Development Index (HDI); at-risk-of-poverty rate by poverty line (POV); employment rate, 20-64 years (ER).

Table 1. Variables used in the empirical analysis at the EU-27 level, period 2007-2023

No.	Groups of variables	Variables explanation	Unit of measure (UM)	Acronym	Source
1.	Insurance dimensions – life and non-life segments	Life insurance penetration degree	% of GDP	IPLF	Swiss Re Institute (2024)
2.		Non-life insurance penetration degree	% of GDP	IPNLF	
3.		Life insurance density	USD/capita	IDLF	
4.		Non-life insurance density	USD/capita	IDNLF	
5.	Digital and innovation dimensions	Households - level of Internet access	% of households	IA_H	European Commission (2025)
6.		Individuals - Internet use, Last Internet use in the last 12 months	% of individuals	IU_IND	
7.		Percentage of the ICT total sector on GDP	% of GDP	ICT	
8.		High-speed Internet coverage	% of households	ICHS	
9.		Global Innovation Index	Score (scale from 0 - 100)	GII	World Organisation of Intellectual Property (2023)
10.	Standard of living and labour market dimensions (control variables)	Human Development Index	Score (scale from 0 - 1)	HDI	United Nations Development Programme (2023)
11.		At-risk-of-poverty rate by poverty line	% of the total population	POV	European Commission (2025)
12.		Employment rate, 20-64 years	% of the total population	ER	

Source: Authors' contribution.

Regarding *life insurance penetration* (IPLF), there are significant differences among EU countries in the share of life insurance in GDP (Appendix, Figure A1). The highest contribution to GDP in 2023 was obtained in Denmark (8.2%) and Finland (8.1%), and the lowest in Romania (0.2%), Bulgaria (0.3%), Poland (0.4%), Croatia (0.6%), and the Slovak Republic (0.6%). Estonia, Latvia, and Lithuania have no reported data for the whole period. Concerning non-life insurance contribution to GDP (IPNLF), in the period 2007-2023 (Appendix, Figure A2), steady growth was registered in all EU countries, with the highest value in the Netherlands (7.2%).

In terms of amount paid by inhabitants to buy insurance – namely, *insurance density* - countries with the highest allocations for purchasing life insurance (IDLF) (Appendix, Figure A3) in 2023 were Denmark (over 5,500 USD/capita) and Finland (over 4,360 USD/capita), while the lowest amount spent per capita for insurance

premiums were in Romania (27 USD/inhabitant) and Bulgaria (43 USD/inhabitant). The positioning of the extreme countries for non-life insurance density (IDNLF) (Appendix, Figure A4) was in favour of the Netherlands (over 4.450 USD/capita) and Luxembourg (over 2.600 USD/capita), on the one hand, and Romania (over 160 USD/capita) and the Slovak Republic (over 220 USD/capita), on the other hand.

The Human Development Index (HDI) is a composite measure introduced by the United Nations Development Programme (UNDP) to evaluate and compare the well-being levels of different countries. This composite index acknowledges that development is not only about economic growth, but also about improvements in health and education, which are essential for human flourishing. Therefore, HDI considers factors such as life expectancy, education, and per capita income, allowing for time comparisons between countries and regions. Thus, in Figure A5 from the Appendix, it is shown the evolution of HDI in the period 2007-2023, with the highest scores in Denmark (0.962), Sweden, Germany (0.959 for each country) and the Netherlands (0.955) and the lowest in CEE countries, with the lowest level in Bulgaria and Romania (0.845 for each country).

The Global Innovation Index (GII), published annually by the World Intellectual Property Organisation (WIPO) together with partners such as Cornell University and INSEAD, assesses and ranks countries worldwide according to their innovation capacity and performance. Aggregating scores across various indicators and sub-indices calculate this ranking. Figure A6 from the Appendix illustrates the evolution of GII from 2007 to 2023, where Sweden recorded the highest GII in 2023 (64.2), while Romania scored the lowest (34.7).

Table 2 shows the summary statistics of the crude variables used in the econometric analysis. We note that there is missing data (i.e., no reported data) for some variables, which may represent a limitation of our research. The EU average life insurance contribution to GDP for 2007-2023 was 3.05%, and for non-life insurance, 2.47%. These averages were positioned closer to the lower bound of their respective indicators, with the effect being more evident in the non-life insurance segment. On average, expenditures amounted to 1344.90 USD per capita for life insurance and 955.64 USD per capita for non-life insurance. Regarding human development, the average was 0.88, with a maximum score of 0.962 achieved by Denmark in 2023 and a minimum score of 0.773 recorded for Bulgaria in 2007. The average of the Global Innovation Index (GII) was 48.55 for the period 2007-2023, with a maximum score of 64.2, achieved by Sweden in 2023, and a minimum score of 34.7, registered by Romania in 2023.

Table 2. Summary statistics of variables used in the econometric analysis, 2007-2023

Variables	N	Mean	Standard deviation	Minimum	Maximum
IPLF	406	3.051182	2.364863	0.1	9.68
IPNLF	406	2.465764	1.440964	0.87	9.5
IDLF	405	1344.895	1374.633	17.7	5803
IDNLF	405	955.6358	888.6579	85	4777
HDI	453	0.8833488	0.0413532	0.773	0.962
POV	450	23.17133	7.169302	10.8	49.3

Variables	N	Mean	Standard deviation	Minimum	Maximum
ER	453	71.16336	6.157288	52.9	83.5
IA_H	457	77.51558	16.31221	18.96	99.18
IU_IND	457	78.37175	14.90577	28.3	99.35
ICT	280	4.347107	1.262013	1.99	10.14
ICHS	297	49.04411	29.81437	0	100
GII	294	48.54728	7.420788	34.7	64.2
N total	459				

Source: Authors' contribution in Stata 17.

The *research methodology* employed in this study is designed to provide in-depth insights into the impacts of digital transformation and innovation on the standard of living in the insurance market. To achieve this, two econometric models have been utilised: the robust regression model (RREG) and Bayesian Network Analysis, using Gaussian Graphical Models (GGMs).

The first model, RREG, is a statistical technique used to estimate the relationship between variables - the direct effects - when there is evidence of heteroscedasticity or outliers. Robust regression is a powerful statistical technique designed to provide more accurate estimates by reducing the impact of outliers. Rather than relying on traditional methods that extreme values can heavily influence, robust regression is based on Huber and biweight iterations, which help ensure that the results are more reliable and trustworthy. This is particularly important when analysing data from a diverse sample, such as the EU-27 countries, which can have significant differences in terms of their culture, population, and economic conditions.

The second model, Bayesian Network Analysis, using GGMs, is a tool for analysing the interconnections between variables in a complex system. This study uses Bayesian Network Analysis to evaluate the global interdependencies among digital transformation, innovation, the standard of living, and the insurance market. By doing so, the study aims to provide a comprehensive understanding of the dynamics between these variables and their mutual influence. Gaussian Graphical Models (GGMs) are undirected networks constructed from partial correlation coefficients, which can take on either positive or negative values. The intensity of direct links between nodes is illustrated by the edges' width and colour saturation. GGMs enable the modelling of conditional associations, reducing the risk of spurious correlations. Their purpose is to uncover the relationships among variables, including direct, indirect, and overall effects.

Based on our methodology, we assess the following research hypotheses:

- *H1: Digital transformation directly and favourably shaped the insurance dimensions, both for life and non-life insurance sectors;*
- *H2: Innovation degree directly and favourably influenced the insurance dimensions, both for life and non-life insurance sectors;*
- *H3: Socio-economic credentials directly and favourably influenced the insurance dimensions, both for life and non-life insurance sectors;*
- *H4: There are overall interconnections between digital transformation,*

innovation, socio-economic credentials and the insurance dimensions, both for life and non-life insurance sectors.

4. Results and Discussions

4.1 Results of robust regression models

To capture the impact of digital transformation/innovation and living standards on the insurance market, as formulated in *hypotheses H1-H3*, robust regression models (RREG) were applied. Separate models were generated for each dependent variable - insurance penetration and insurance density - namely model (1) for the life insurance sector and model (2) for the non-life sector.

The empirical evidence confirmed that *human development* (HDI) acted as a driving force in insurance expansion, seen in its effect on GDP contribution (Table 3), for both life (coefficient is 19.74, statistically significant, $p<0.001$, model 1) and non-life insurance (coefficient is 6.834, statistically significant, $p<0.05$, model 2). Favourable implications were also induced on insurance density (Table 4), for both life (coefficient is 8.914, statistically significant, $p<0.001$, model 1) and non-life insurance (coefficient is 5.136, statistically significant, $p<0.001$, model 2).

However, *life insurance contribution to GDP* (IPLF - model (1) in Table 3) was affected by poverty (POV) – since the increase in poverty has determined the rise in insurance penetration to GDP (coefficient is 0.0319, statistically significant, $p<0.05$). Therefore, as Singh (2012) highlighted, access to life insurance may be limited due to the financial limitations of the population. To mitigate these limitations, microinsurance can provide affordable life insurance coverage to low-income individuals and countries, helping vulnerable populations manage financial risks associated with illness and other adverse life events, as proposed by Radermacher and Brinkmann (2011) and Apostolakis et al. (2015). Unfavourable implications were also determined by the employment rate (ER) (the coefficient is -0.0277, $p<0.05$), which is opposite to the findings of Eling and Schaper (2017) and Outreville (2014), which highlighted that a developed labour market may sustain insurance market development. The favourable implications on life insurance penetration (IPLF) were induced by the innovation degree (GII) and ICT contribution to GDP (ICT) (coefficients are 0.0604, respectively, 0.249, $p<0.001$), which may sustain the adoption of advanced data analytics, artificial intelligence, and automation, with a favourable impact on insurance development, as Eling et al. (2022) proved.

Table 3. RREG, dependent variable Insurance penetration degree – life, non-life

Variables	Model (1)	Model (2)
	IPLF	IPNLF
HDI	19.74***	6.834*
	(3.459)	(2.961)
POV	0.0319*	-0.0218*
	(0.0126)	(0.0108)
ER	-0.0277*	0.0555***
	(0.0113)	(0.00968)

Variables	Model (1)	Model (2)
	IPLF	IPNLF
IA_H	-0.0223	-0.0194
	(0.0203)	(0.0174)
IU_IND	0.0199	-0.00757
	(0.0196)	(0.0168)
ICT	0.249***	-0.226***
	(0.0575)	(0.0492)
ICHS	0.000315	-0.000254
	(0.00277)	(0.00237)
GII	0.0604***	0.0335*
	(0.0169)	(0.0145)
_cons	-18.21***	-5.764**
	(2.532)	(2.167)
R^2	0.726	0.588

Note: Standard errors in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$.
Source: Authors' research in Stata 17.

Regarding the *insurance density* (Table 4), the first step was to apply the logarithmic procedure to the data.

The results indicate that, other than human development, *life insurance density* (IDLF_lg - model (1) in Table 4) was shaped by the Internet use of the population during the last year (IU_IND) (coefficient is -0.0201, $p<0.05$) and innovation degree (GII) (coefficient is 0.0301, $p<0.001$). Household access to the Internet (IA_H) and the employment rate (ER) acted as negative factors (coefficients of -0.0158 and -0.00992, respectively, $p < 0.05$) in buying life insurance products (IDLF_lg).

Concerning *non-life insurance dimensions*, the contribution to GDP (IPNLF_lg - model (2) in Table 3) and the non-life insurance density (IDNLF_lg - model (2) in Table 4), besides human development, favourable were influenced by the employment rate (ER) (coefficients are 0.0555, respectively, 0.00914, $p<0.001$), being in line with the findings of Outreville (2014), Eling and Schaper (2017), but also Cristea and Danciulescu (2016). Unfavourable implications were induced by poverty (POV), as increasing poverty has led to a decrease in insurance penetration into GDP (coefficient is -0.0218, $p < 0.05$). This is opposite to the life insurance field, where non-life insurance is often mandated, such as motor third-party liability insurance. To address this problem, microinsurance was also introduced to help poor populations manage financial risks associated with natural disasters and other adverse events, thereby reducing the burden on vulnerable communities (Herrero et al., 2012; Poontirakul et al., 2022; Radermacher and Brinkmann, 2011).

Table 4. RREG results, dependent variable Insurance density – life, non-life

Variables	Model (1)	Model (2)
	IDLF_lg	IDNLF_lg
HDI	8.914***	5.136***
	(1.312)	(0.799)
POV	-0.00313	-0.00524
	(0.00477)	(0.00291)
ER	-0.00992*	0.00914***

Variables	Model (1)	Model (2)
	IDLF_lg	IDNLF_lg
	(0.00429)	(0.00261)
IA_H	-0.0158*	0.000157
	(0.00770)	(0.00469)
IU_IND	0.0201**	-0.00273
	(0.00744)	(0.00453)
ICT	0.0307	-0.0627***
	(0.0218)	(0.0133)
ICHS	-0.00115	0.000228
	(0.00105)	(0.000641)
GII	0.0301***	0.0186***
	(0.00641)	(0.00390)
_cons	-6.405***	-2.795***
	(0.961)	(0.585)
R^2	0.860	0.854

Note: Standard errors in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$.
Source: Authors' research in Stata 17.

Regarding digital credentials, non-life insurance penetration to GDP (model 2, Table 3) and non-life insurance density (model 2, Table 4) were adversely affected by the share of ICT in GDP (coefficients are -0.226, respectively, -0.0627, $p<0.001$), contrary to the findings of Eling et al. (2022). In addition, non-life insurance penetration to GDP (model 2, Table 3) was negatively influenced by household Internet access (IA_H), contrary to Benlagha and Hemrit (2020). By comparison, non-life insurance penetration to GDP (model 2, Table 3) and non-life insurance density (model 2, Table 4) were positively associated with the Global Innovation Index (GII) (coefficients are 0.0335, respectively, 0.0186, statistically significant).

Based on these findings, the following were demonstrated:

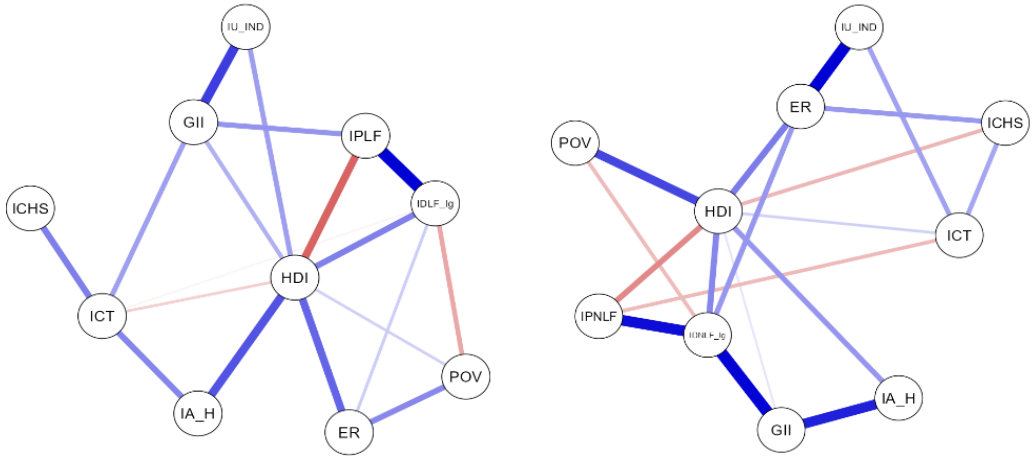
- *H1: Digital transformation directly and favourable shaped the insurance dimensions, both for life and non-life insurance sectors,* is partially supported, as some adverse effects emerged from household Internet access and ICT share in GDP;
- *H2: Innovation degree directly and favourably influenced the insurance dimensions, both for life and non-life insurance sectors,* is fully validated for both life and non-life insurance;
- *H3: Socio-economic credentials directly and favourably influenced the insurance dimensions, both for life and non-life insurance sectors,* and this is supported only in the case of non-life insurance, while for life insurance, negative influences were observed from poverty and employment rates.

4.2 Results of Bayesian Network Analysis using Gaussian Graphical Models

To assess the 4th hypothesis, *H4: There are overall interconnections between digital transformation, innovation, socio-economic credentials, and the insurance dimensions, both for life and non-life insurance sectors, we applied Bayesian Network Analysis using Gaussian Graphical Models (GGMs)* for each class, life and non-life insurance.

The results proved that, when all credentials acted together, as regards *life insurance market* (Figure 1(a) and Appendix, Table A1 and Figure A7a), insurance dimensions were favourable interconnected with human development index (HDI), employment rate (ER) and poverty (POV) (poverty decreases, life insurance density increases) - for the insurance density credential (IDLF_lg) - and innovation index (GII) – for life insurance penetration (IPLF). Moreover, for life insurance penetration (IPLF), there was an established unfavourable interconnection with the human development index (HDI). The level of innovation (GII) showed a positive and strong association with both Internet usage among the population (IU_IND) and the Human Development Index (HDI), as well as the ICT share of GDP. Digital determinants acted only as indirect factors in the life insurance market.

As regards the *non-life insurance component* (Figure 1(b) and Appendix, Table A2, and Figure A7b), the results revealed adverse connections with both the Human Development Index (HDI) and ICT's share of GDP, in case of insurance penetration to GDP (IPNLF). By contrast, non-life insurance density (IDNLF_lg) was favourably related to innovation index (GII), employment rate (ER), and Human Development Index (HDI) and poverty (POV) (poverty decreases, non-life insurance density increases). Innovation, as reflected in the Global Innovation Index (GII), displayed strong positive associations with household Internet access (IA_H) and the lowest with HDI. As in the case of life insurance, digital coordinates acted as indirect factors for the non-life insurance market.



(a) (b)

Figure 1. Bayesian Network Analysis, using Gaussian Graphical Models (GGMs), life insurance (a) and non-life insurance market (b)

Source: Authors' contribution in JASP.

Therefore, the 4th hypothesis, *H4: There are overall interconnections between digital transformation, innovation, socio-economic credentials and the insurance dimensions, both for life and non-life insurance sectors,* is partially fulfilled.

5. Conclusions

Our research on the interplays among digital transformation, innovation, and the insurance market offers a rich and diverse landscape of topics that contribute to understanding how digitalisation reshapes each sector of the insurance industry. The socioeconomic framework also plays a fundamental role in shaping the direction of the sector, with policymakers and regulators working to create a conducive environment for growth and innovation.

Therefore, according to the main results of this research, the life insurance market benefited from greater human development, greater contribution of ICT to GDP, widespread use of the Internet, and innovation. It suffered, however, from the high level of poverty, limited employment, and household access to the Internet. Thus, we suggest the *following life insurance market strategies*: enhancing human development through investing in financial education starting at school and promoting health and prevention programmes; accelerating ICT contribution to the economy or creating partnerships between insurers and technology providers, offering tax incentives for ICT investments; more population using the Internet by expanding broadband infrastructure in rural areas or digital literacy campaigns for adults and the elderly; supporting innovation in life insurance, providing support for InsurTech and promoting innovative products.

In addition, the European non-life insurance market is positively influenced by different factors such as the standard of living, labour market conditions, and level of innovation. However, the share of ICT in GDP has a negative impact on the market. To improve this sector, based on our findings, we suggest the following policies: the standard of living could be improved by increasing real incomes thanks to sustainable wage policies that reduce regional inequalities; labour market conditions could be strengthened, enabling stable employment, reducing precarious work, occupational security programmes, and benefits offered by employers; innovation in the non-life insurance market can be supported through the development of Insurtech or the launch of telematics products; the creation of specific insurance policies for the digital economy; the possibility of reducing the gap between growth in the ICT sector and the adaptation of the insurance industry could be realised through training for actuaries and underwriters in digital risk assessment, along with company collaborations.

In essence, taking advantage of various recommendations for insurance companies will enable them to become more competitive by using digital transformation and innovation, as well as socioeconomic credentials, catering to constantly changing customer needs and contributing to sustainable socioeconomic development. Nowadays, as developments in digital technology have transformed the way insurance companies carry out operations, customer relationships, risk management processes, and business strategy formulation, understanding digitalisation and using it positively will be the key to success for insurers in modern society.

The primary limitation of our study is incomplete data for certain variables, combined with the various levels of living standards and technological advancement among EU member states. Therefore, the results should be interpreted with caution. Future research directions will consider analyses by different groups of EU countries, including both developed and developing ones, and will also incorporate more credentials on digitalisation, such as the *Digital Economy and Society Index* (*DESI*).

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Appendix

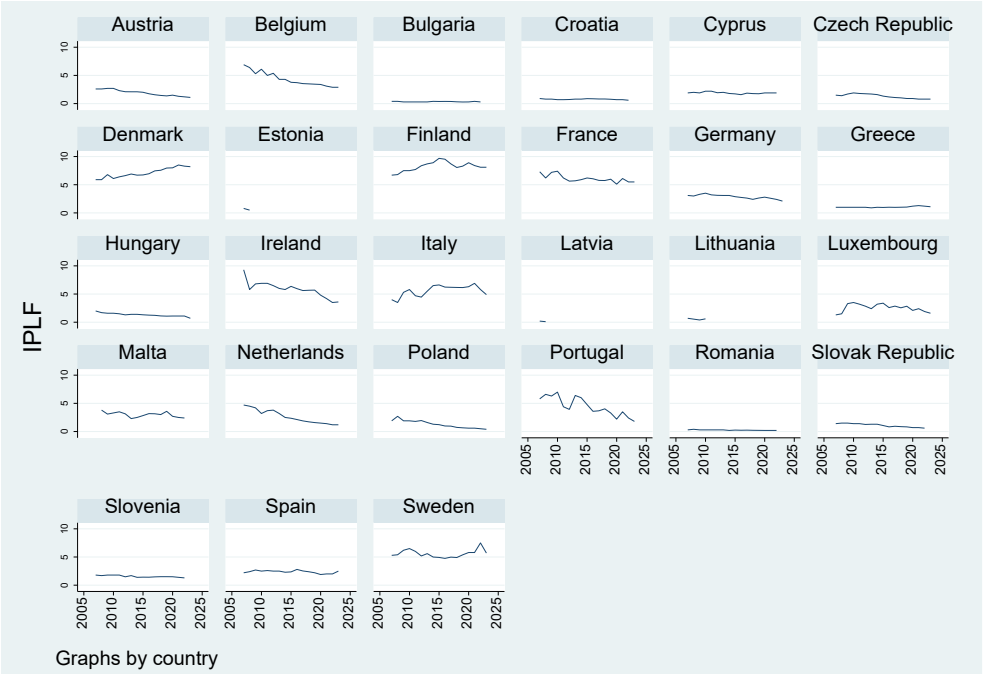


Figure A1. Evolution of life insurance penetration in GDP, EU MS, 2007-2023
Source: Authors' contribution in Stata 17.

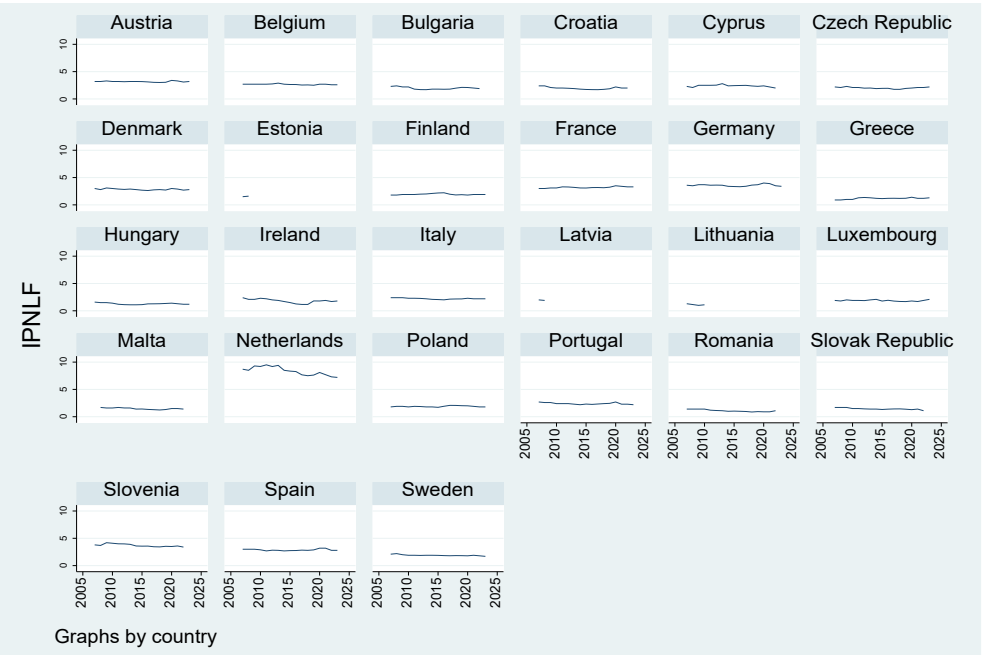


Figure A2. Evolution of non-life insurance penetration in GDP, EU MS, 2007-2023
Source: Authors' contribution in Stata 17.

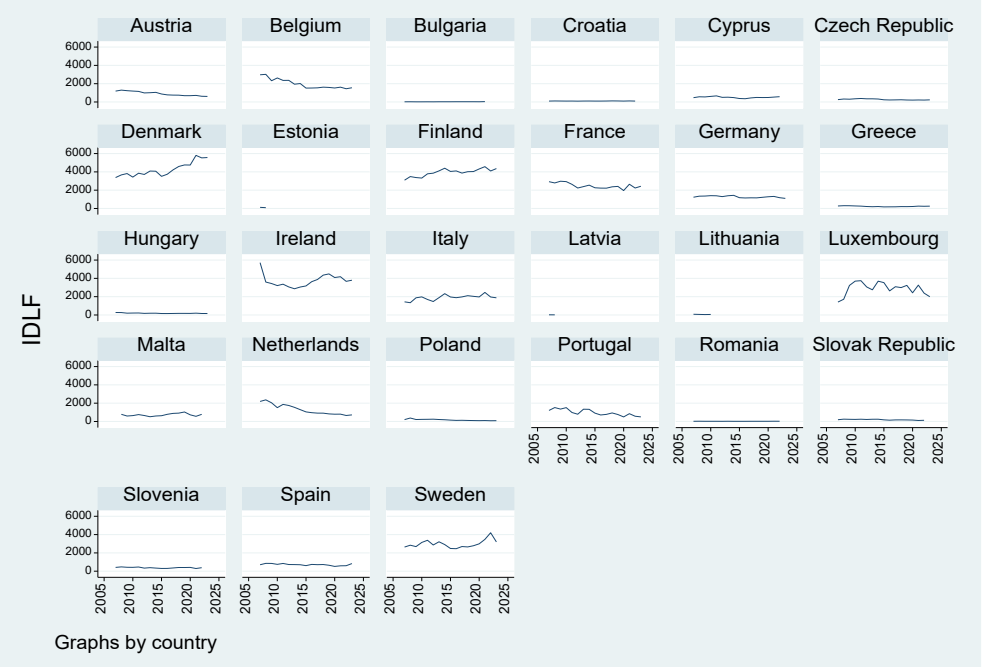


Figure A3. Evolution of life insurance density, EU MS, 2007-2023
Source: Authors' contribution in Stata 17.

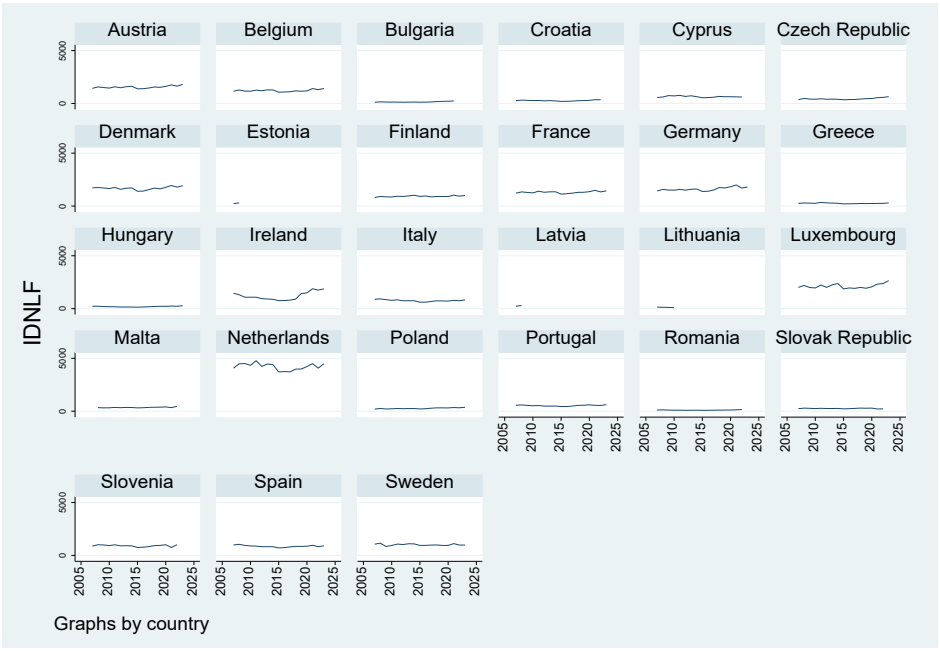


Figure A4. Evolution of non-life insurance density, EU MS, 2007-2023
Source: Authors' contribution in Stata 17.

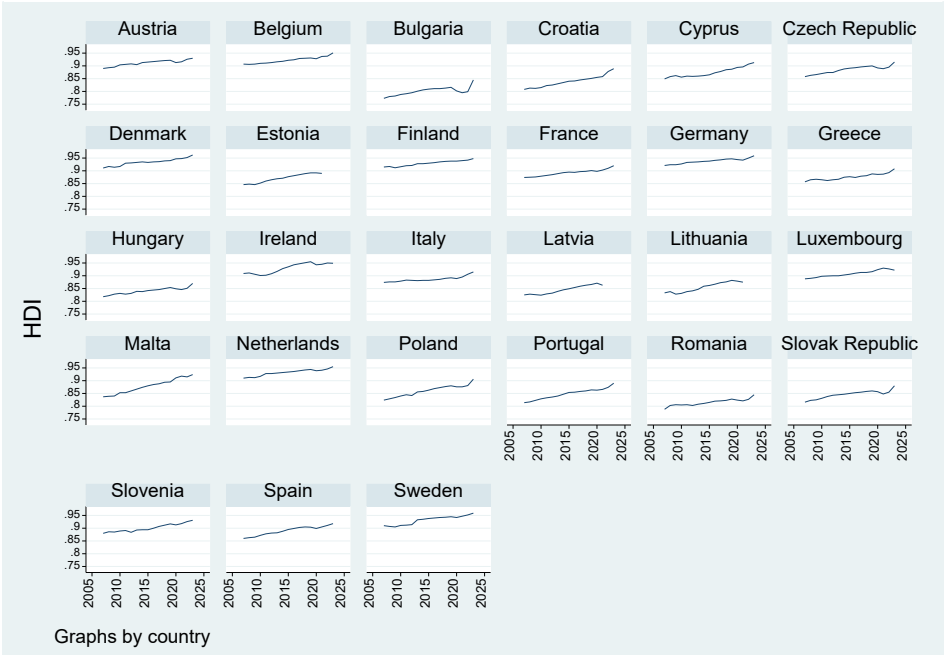


Figure A5. Evolution of HDI, EU MS, 2007-2023
Source: Authors' contribution in Stata 17.

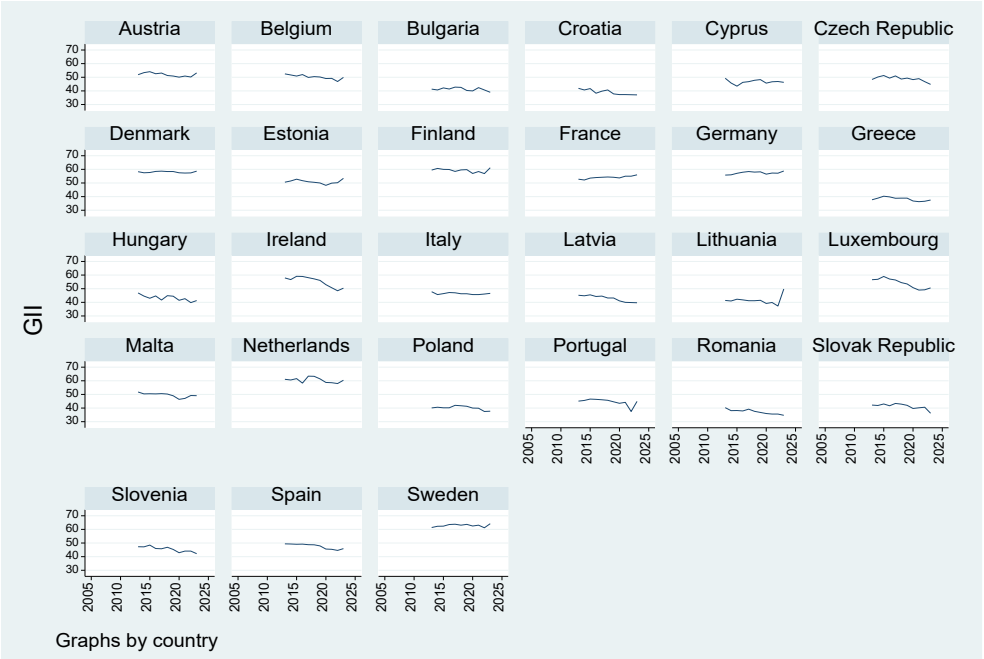


Figure A6. Evolution of Global Innovation Index, EU MS, 2007-2023
Source: Authors' contribution in Stata 17.

Table A1. Summary of Network, GGM, life insurance

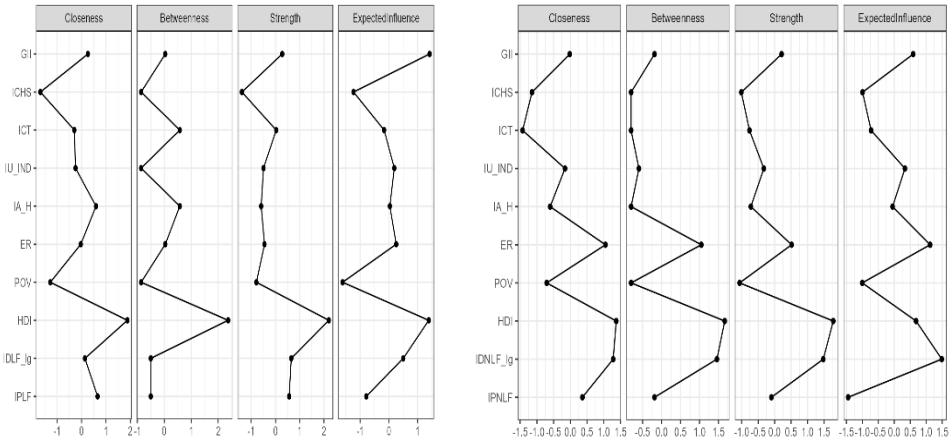
Number of nodes	Number of non-zero edges	Sparsity
10	18 / 45	0.600

Source: Authors' contribution to JASP.

Table A2. Summary of Network, GGM, non-life insurance

Number of nodes	Number of non-zero edges	Sparsity
10	18 / 45	0.600

Source: Authors' contribution in JASP.



(a) **(b)**

Figure A7. GGM, Centrality Plot, life insurance (a), and non-life insurance (b)

Source: Authors' contribution in JASP.