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The Digital Remedy: How technology is transforming the health sector.

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Abstract

This paper examines how the use of digital technologies is transforming the health sector, with a particular focus on the role of telemedicine, mobile connectivity, and artificial intelligence in improving healthcare outcomes. The study combines three complementary approaches. First, it presents a literature review on the evolution of digital health from the beginning of the twenty-first century to the present, analyzing the expansion of telemedicine, mobile health, big data, and the emergence of artificial intelligence. Second, it develops a case study about telemedicine implementation at Mutua Universal, a leading Spanish mutual insurance company, based on interviews conducted to two experts on the field. The objective of this section is to examine how telemedicine tools are implemented and how they are perceived by professionals from the healthcare sector. And finally, the paper conducts a cross-country analysis to examine the relationship between Digital Health Maturity and selected health outcomes.

A dataset of 137 countries has been used for this analysis and, applying a descriptive analysis together with regression models, the empirical results show that higher Digital Health Maturity is significantly associated with higher life expectancy and lower infant mortality, controlling the internet usage variable. The relationship with maternal mortality is negative but not statistically significant, while the association with tuberculosis incidence is weaker. The case study findings and the analyzed literature reinforce the idea that digital health tools improve efficiency and accessibility of citizens to better health conditions. However, there are important barriers still present, particularly in terms of change management, digital literacy, and professional adoption. Overall, the paper concludes that digital transformation is becoming an important element of modern healthcare systems and its development is positively linked to health system performance.

Resumen

Este trabajo examina cómo el uso de tecnologías está cambiando el sector de salud, centrándose particularmente en el rol de la telemedicina, la conectividad móvil, y la aparición de la inteligencia artificial para mejorar resultados de salud. Este estudio combina tres enfoques complementarios entre sí. Primero, un análisis de literatura sobre la evolución digital del sector de la salud desde principios del siglo XXI hasta el presente, analizando la expansión de la telemedicina, la salud móvil, los datos masivos, y la inteligencia artificial. A continuación, desarrolla un caso práctico sobre la implementación de telemedicina en Mutua Universal, una empresa mutualista líder en el sector, basándose en entrevistas a dos expertos en el ámbito. El objetivo de esta sección es examinar la implementación de las herramientas de telemedicina y cómo las perciben los profesionales del ámbito sanitario. Y finalmente, se lleva a cabo un análisis entre países para examinar la relación entre la madurez en salud digital y los resultados en salud seleccionados.

Para este análisis se ha utilizado una base de datos de 137 países y, aplicando un análisis descriptivo junto a modelos de regresión, los resultados empíricos muestran que un mayor nivel de madurez en salud digital está asociado significativamente a mayor esperanza de vida y menor mortalidad infantil, controlando la variable de uso de internet. La relación con la

mortalidad maternal es negativa pero no estadísticamente significativa, mientras que la asociación con la incidencia de tuberculosis es más débil. Los hallazgos del caso práctico y la literatura analizada refuerzan la idea de que las herramientas de salud digital mejoran la eficiencia y accesibilidad de los ciudadanos a mejores condiciones de salud. Sin embargo, aún existen barreras importantes en el presente, principalmente en términos de gestión de cambio, alfabetización digital y adopción por parte de los profesionales. En general, este trabajo concluye que la transformación digital se está convirtiendo en un elemento importante del ámbito sanitario moderno y su desarrollo está relacionado positivamente al rendimiento del sistema de salud.

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Chapter 1. Introduction

1.1 Study Context and Justification

Technology has reshaped most industries over the past two decades, and healthcare is one of the sectors that has experienced this change the most. Mobile connectivity, digital platforms, electronic records, telemedicine, big data, and AI have all changed how care gets delivered and who can reach it. At this point, technology isn't a back-office support role, but it has become part of how health systems function.

This is happening in a context where health systems are already under pressure. Ageing populations, rising chronic disease, growing costs, and persistent access gaps have made innovation feel less optional than it once did. Digital health has grown in that gap in different ways: by changing how clinicians and patients communicate, helping stretch limited resources, supporting earlier diagnosis. Furthermore, COVID sharpened all of this, as in-person care became dangerous or impossible. In this context, digital infrastructure held things together on one hand, but on the other it also revealed how thin the system was.

Academically, the field has attracted serious attention. Researchers have studied telemedicine, mobile health, monitoring systems, and AI diagnostics extensively. When analyzing this situation, some studies show real improvements in efficiency and access, while others document stubborn problems regarding uneven digital infrastructure, data privacy gaps, systems that can't communicate with each other, and institutions that resist change even when the technology is functional.

Digital health involves multiple dimensions, such as policy decisions, how institutions restructure, and whether changes in infrastructure translate into better outcomes for patients. Collapsing these dimensions into a single debate tends to obscure more than it reveals.

At the same time, governments and health systems are already spending heavily on this. Telemedicine, AI diagnostics, remote monitoring, or electronic records are no longer experimental tools, but are increasingly established components of contemporary healthcare delivery. However, it is not only important to analyze whether these technologies are being used, but whether their adoption is generating meaningful improvements in practice. The implementation of digital tools does not automatically eliminate the structural barriers to access and quality of care that existed before their introduction.

This paper addresses these topics, examining the development of digital health overtime, analyzing the implementation in the real world at Mutua Universal as a case study and conducting an empirical analysis of how Digital Health Maturity is associated with measurable health outcomes across countries. In conclusion, the objective is to assess and understand how these technologies are transforming healthcare systems in practice, rather than relying only on the expectations associated with them.

1.2 Research Objective

The main objective of this study is to analyze how technology is transforming the health sector, focusing on digital health tools and their implications for healthcare delivery and outcomes.

In order to address these general objectives, the dissertation pursues three specific aims:

- **Conceptual objective:** by examining the evolution of digital health and the growing role of technologies.
- **Institutional objective:** by analyzing the practical implementation of these tools through the Mutua Universal case study.
- **Empirical objective:** by exploring the relationship between Digital Health Maturity and selected health outcomes.

The broader goal is to connect those three levels rather than treat them in isolation. That means looking not just at how technology is being adopted, but whether systems that have invested more in it actually perform better.

Chapter 2. Digital Health: Relevance, Evolution and Global Trends

2.1 Why mobile connectivity/digital health matters

In the past years, technology has drastically evolved, being a fundamental driver of both social and economic change, especially with the rapid expansion of mobile connectivity due to the creation of mobile networks, smartphones and other digital platforms. These evolutions have drastically transformed how societies work, and with it, the way in which individuals interact with each other, work and access different day-to-day services.

This transformation is visible in different fields, but especially in public health. From facilitating access to medical records or online appointments from home to providing medical services in remote areas and real-time epidemic monitoring during global health crises, mobile connectivity is being recognized as a key determinant of health outcomes.

2.2 Evolution of research and technologies

The use of technology has evolved significantly over the past decades, becoming a defining feature not only in the health sector but in almost every industry. Within the healthcare field, this transformation has been particularly remarkable, with its main objective being to improve the efficiency, accessibility, and quality of healthcare systems (World Health Organization, n.d.). Throughout the 21st century, we can identify five phases of digital health evolution that have reshaped the way the health system operates.

2.2.1 Early phase: ICT foundations (2000s-2010)

During the early 2000s, Information and Communication Technologies (ICT) began to be considered an essential infrastructure for both economic and social development, including sectors such as health. According to organizations such as the World Health Organization (WHO) and the World Bank, ICT represented the foundational layer that supported eHealth and other digital innovations. Therefore, it became the backbone that enabled digital communication, data management, and information exchange. The presence and adoption of these technologies was considered an indicator of progress towards a more informed and connected society (World Health Organization, n.d.; World Bank, n.d.; Albarrak et al., 2014).

By the end of the decade, several countries had integrated different technologies into their health strategies. For example, in 2003, Finland was one of the first countries to create a national eHealth strategy by implementing electronic health records (EHRs) across hospitals (Ministry of Social Affairs and Health, 2003; Hyppönen et al., 2019). This initiative was part of the country's national effort to standardize health information systems and ensure interoperability across regions. The government created a nationwide program that included the definition of common standards, data structures, and security protocols to enable the safe exchange of patient information across institutions. Other countries, such as Canada and Brazil, have carried out similar initiatives where telemedicine connected remote areas through digital networks.

However, the distribution of these advancements was unequal, as many countries lacked the necessary infrastructure to implement ICT-based health systems. While high-income countries invested early in the expansion of mobile connectivity, many low and middle-income countries faced many barriers such as limited internet penetration, lack of technical capacity, and high implementation costs. Nevertheless, this period laid the groundwork for subsequent efforts to reduce those gaps, marking the beginning of a global shift towards the digitalization of healthcare delivery. Therefore, the early 2000s established ICT not only as a technological innovation but also as a strategic tool of modernization within evolving health systems.

2.2.2 Telemedicine emergence (2010-2015)

The 2010-2015 period marked the transition from infrastructure to application with the development of ICT foundations. The WHO defined telemedicine as the delivery of health care services using ICT for the exchange of valid information for diagnosis, treatment, and prevention of disease when distance is a critical factor (WHO, 2010). Growing recognition from international organizations and governments led to actions with the objective of reducing the existent inequalities in access to care, mainly in rural regions.

As the use of telemedicine became more common, quantitative evidence showed improved access to care, reduced patient travel time, and better local economic outcomes. Developed countries such as the USA or Brazil expanded hospital-based teleconsultations while developing countries, especially in Asia and Latin America, launched the first pilot telemedicine networks. This expansion of telemedicine was particularly evident as health systems had one main objective: to improve access to care and reduce geographical barriers. According to Bhaskar et al. (2020), telemedicine has been increasingly adopted worldwide as a key tool to enhance healthcare delivery, allowing remote diagnosis, monitoring, and consultation, especially in underserved and rural areas.

In 2011, Whitacre examined the economic effects of telemedicine across 24 rural hospitals in the US Midwest (2011). Through his research, he found out that telemedicine in rural US hospitals generated between \$20,000 and \$1.3 million annually in community benefits. Rather than focusing only on hospital-level cost savings, Whitacre developed a methodology that captured four dimensions of impact: (1) hospital savings from outsourcing services, (2) patient transportation cost, (3) work-time savings from the reduced travel time, and (4) local economic gains. These mechanisms revealed how telemedicine contributes not only to better access to healthcare but also broader economic resilience in rural areas. The author also determined that the greatest share of economic benefit came from increased local pharmacy and laboratory revenues.

Despite its promising results, telemedicine still faced significant barriers that limited its implementation during this period. High initial equipment and maintenance costs, ranging from \$7,000 to \$250,000 (Whitacre, 2011), made adoption particularly difficult especially in rural hospitals. In addition, the lack of infrastructure in rural areas restricted connectivity and the quality of real-time interactions, and the absence of legal frameworks further constrained expansion, as cross-border medical licensing was often impossible. These obstacles revealed

that technological innovation alone was insufficient. Nevertheless, this period proved that digital technologies could effectively deliver medical services across distances.

2.2.3 Mobile health and digital integration (2015-2020)

The WHO defined in 2016 mHealth as the use of mobile and wireless technologies to support the achievement of health objectives (WHO, 2016). This period was characterized by the widespread adoption of smartphones and mobile internet, which transformed healthcare delivery, as the various mobile applications and wearables encouraged a shift towards preventive care. According to the OECD (2019), by 2019 more than 300,000 health-related apps were available globally. These apps covered different areas such as fitness, mental health, or diet monitoring.

Simultaneously, the integration of electronic health records (EHRs) and the use of telemedicine platforms in hospitals enabled continuous data exchange between patients and healthcare professionals. This exchange improved coordination between both parts and treatment adherence, as it allowed professionals to monitor the patients' conditions more consistently.

Policy frameworks such as the European eHealth Action Plan 2012-2020 accelerated digital record adoption, promoting data interoperability. The objective was to overcome the fragmentation of digital health services by promoting cross-border access to EHRs, encouraging the adoption of common standards for data exchange, and supporting the creation of national health information infrastructures. Furthermore, it prioritized patient empowerment, giving individuals access to their own medical information. The Action Plan financed pilot projects such as Smar Open Services for European Parliaments (epSOS), a project that consisted of testing cross-border prescription and patient data exchange among EU members (European Commission, 2012).

Despite, this progress led to the emergence of several challenges regarding privacy and security concerns, unequal access to digitalization, and interoperability gaps were still present. Even so, this period marked the transition from a hospital-centred health care to a patient-centred through mobile and data, redefining how health systems operate.

2.2.4 Big Data and Artificial Intelligence during COVID-19 (2020-2022)

The COVID-19 pandemic was a major catalyst for digital transformation in different sectors, especially healthcare, as it was the most collapsed sector during the catastrophe. Digital tools were adopted with the application of lockdowns and social distancing in order to continue providing care services, public communication about the situation, and epidemiological surveillance. Governments and institutions relied heavily on big data, analytics, AI, and mobile connectivity to access real-time data integration to monitor the spread of the virus, predict outbreaks, and optimize resource allocation.

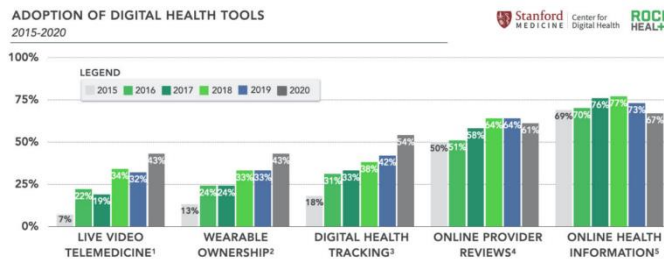


Figure 1. Adoption of Digital Health Tools, 2015–2020. Source: Stanford Medicine and Rock Health (2021).

This graph represents this accelerated adoption of telemedicine tools. The data shows a sharp rise in the use of live video telemedicine, reflecting how virtual consultations became essential as most citizens had to stay at home. Similarly, wearable device ownership and digital health tracking applications grew significantly as individuals

increasingly started to monitor their health and fitness remotely. However, we observe that in 2020 the use of online provider reviews and online health information experienced a decline. This decrease does not imply a reversal of digitalization but rather a shift of user priorities. During the pandemic, patients relied more on direct and institutional digital channels, such as official telemedicine platforms and official apps, as there was a lot of speculation on the internet about the global situation. In this sense, the pandemic transformed digital health engagement from passive information consumption to active and personalized care (Rock Health, 2021; Bhaskar et al., 2020).

As explained in the *Application of Big Data and Artificial Intelligence in COVID-19 Prevention, Diagnosis, Treatment and Management Decisions in China* (Dong et al., 2021) research paper, China integrated big data and AI into its pandemic response with the creation of the Health QR Code system, which classified citizens into red, yellow, or green categories based on health status, travel history, and contact with confirmed COVID-19 cases. This tool determined individual risk levels, guiding mobility restrictions, contact tracing, and decision-making regarding public health and security.

Moreover, machine learning also played a crucial role during the pandemic, especially in vaccine development and pharmacological research. Deep-learning and generative models identified small molecules through which vaccine candidates were designed in a fraction of the time traditionally required, as time was something that the healthcare system lacked in this moment of history. This breakthrough did not replace laboratory trials, but it shortened the discovery phases, allowing drug research and vaccines to transition from years to months. In particular, deep learning systems were able to detect protein structures that were associated with COVID-19, providing insights that were beneficial for vaccine formulation and drug discovery to face the worldwide pandemic (Naseem et al., 2019).

This rapid digitalization was also reflected in an unmatched financial expansion within the health technology sector.

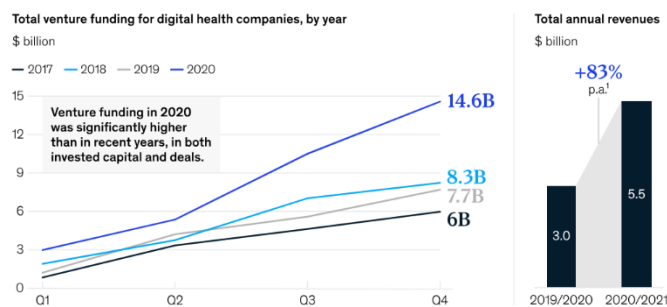


Figure 2. Investment in digital health and the revenues of telehealth players (2017–2020). Source: McKinsey & Company (2021).

As shown in the graph, venture capital funding for digital health companies reached \$14.6 billion in 2020, more than doubling the figures from previous years. Moreover, according to Rock Health’s H1 2021 digital health funding report, investment in the first half of 2021 alone totaled \$14.7 billion, surpassing the total recorded for the whole of 2020 and almost doubling

the 2019 figure of \$7.7 billion. Investors perceived digital health as a strategic and resilient field during the pandemic.

Similarly, the total annual revenues also increased, from \$3 billion in 2019/2020 to \$5.5 billion in 2020/2021, representing an 83% growth in the sector. These figures demonstrate how the pandemic not only accelerated the adoption of health technologies but also redefined the sector’s economic landscape. This situation transformed digital health into one of the fastest growing, and most promising industries of the post-COVID-19 era (McKinsey & Company, 2021).

However, these advances also exposed challenges related to data privacy, algorithmic bias and distrust from some citizens. The rapid collection and use of sensitive information through digital platforms raised concerns about the protection of personal data. This, together with the limited public understanding of how these new technologies operated, contributed to a degree of distrust among citizens from every country (Fahey & Hino, 2020). Addressing these issues became a priority for international health organizations to ensure that innovation in healthcare remained both effective and socially responsible.

2.2.5 Post-pandemic consolidation and future trends (2023-present)

After COVID-19, digital health tools such as telemedicine, mHealth and AI platforms transformed from being emergency instruments to long-term components of healthcare systems. This transformation has made governments and institutions recognize digitalization as requisite for healthcare resilience and accessibility. Countries have formalized this transition by launching national health strategies, which address not only the implementation of telemedicine but also the challenges that may arise with the transformation of the sector. In 2023, the European Union proposed the European Health Data Space (EHDS) as the first framework for health data governance, entering into force in May 2025. The objective of this strategy is to enable secure data exchange and use, support research and innovation, and provide citizens access to their electronic health data across borders (European Commission, n.d)

Furthermore, many governments have increased infrastructure investment to support digital healthcare delivery. In the case of the European Union, the institution allocated 250 million euros through the Digital Europe Program (2021-2027) specifically to support digital health projects. Spain used part of these funds to modernize hospital data centres and improve

telehealth platforms, experiencing a radical transformation in healthcare. The country has become one of the leading digital health hubs in the continent. According to the ONE, in 2024, over 2,100 startups are currently active in the Spanish digital health ecosystem, which together have attracted nearly 114 million euros in 61 investment deals (ONE, 2024). This growth has been characterised by the adoption of telemedicine, AI diagnostics, wearable technologies, and electronic health records (EHRs). To this adds the promotion of interoperability, cybersecurity, and data-driven healthcare management. Spain's strong digital infrastructure has positioned the country as a benchmark for digital health innovation within the EU.

The use and rapid growth of AI have also enabled predictive and preventive care. Machine learning models help forecast disease risk based on genetic, lifestyle, and environmental data. Cancer genomics platforms where AI-driven systems are used to identify genetic mutations and predict how patients will respond to treatments is a clear example of this AI evolution. These machine learning models process genomic datasets to design personalized therapies, improving outcomes from treatments and reducing unnecessary interventions. Initiatives such as the NGS Genomic Medicine Service in the United Kingdom demonstrate how AI algorithms can analyse tumour profiles to guide oncologists when choosing optimal drug combinations or other therapies (Kourou et al., 2015). This integration of AI in treatments represents a fundamental shift to preventive medicine, enabling systems to anticipate diseases rather than just treat them.

Overall, the post-pandemic period marks a decisive shift from reactive innovation to long-term integration of digital health within national and supranational.

According to Grand View Research (2024), this consolidation is expected to generate extraordinary global growth in the following years. In 2024, the digital health market was valued at approximately \$285 billion and is expected to triple in size within six years, reaching nearly \$937 billion by 2030.

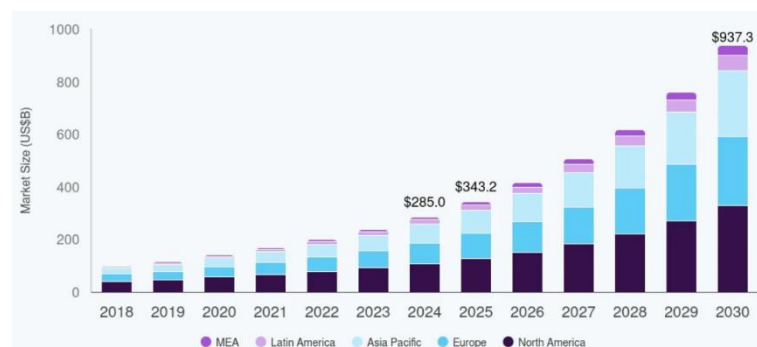


Figure 2. Digital Health Market, Size by Region (2018–2030). Source: Grand View Research (2024).

As illustrated in the graph, North America will continue to dominate the market, benefiting from private investment and a robust digital infrastructure (Grand View Research, 2024).

Europe is expected to keep a steady growth through the institutionalization of initiatives such as EHDS. These types of

initiatives foster interoperability and data sharing across borders (Council of the European Union, 2025).

On the other hand, the Asia-Pacific region is expected to register the fastest expansion, mainly supported by the rapid digital growth that the region has been experiencing in the past years. This growth is expected to be supported by national programs in China and India to digitalize healthcare and integrate AI-based solutions. In particular, China's Healthy China

2030 strategy has become a cornerstone of this transformation. The objective is to build a digital and intelligent healthy system by promoting telemedicine, EHRs and AI-assisted diagnostics in hospitals and public health institutions. China is therefore developing an integrated national health information infrastructure through extensive investment in big data platforms and policies such as Internet Plus Healthcare. This initiative both enhances healthcare in the country and strengthens China's position as a major actor in digital health innovation (Wang et al., 2025).

Although Latin America currently represents a smaller share, the region shows promising growth prospects due to the improvements in connectivity, the expansion of telemedicine and the foreign investments that the region is receiving.

Together, these trends suggest that digital health will shape a new global health ecosystem defined by data-driven care and cross-border cooperation.

Chapter 3. Telemedicine in Mutua Universal – Case Study

3.1 Introduction to the case study

This case study explores the integration and perception of telemedicine within Mutua Universal, one of Spain's leading mutual insurance companies that is specialized in occupational health. The aim is to analyze how digital health tools have transformed healthcare and to understand how professionals from the sector perceive the benefits, challenges and future of telemedicine.

Mutua Universal is a non-profit organization that collaborates with the national health and social security system to provide occupational healthcare, accident insurance, and preventive health services for employees and companies. As a mutual insurance company, the company manages healthcare related to workplace accidents, occupational diseases and temporary disability while offering other services such as rehabilitation, preventive medicine and digital health services.

The primary qualitative materials used in this case study are included in the appendices. Appendix A contains the interview with Concepción López Lera, Appendix B includes the questionnaire answered by Oriol Puig Palau, and Appendix C presents the questionnaire completed by Concepción López Lera. Appendix D provides supporting documentation on Proyecto LINCE.

3.2 Mutua Universal and its telemedicine tools

In recent years, Mutua Universal has undergone a transformation from a predominantly in-person care model to a hybrid system that combines face-to-face visits with a range of telemedicine-based services. This migration was done with two objectives: to provide patients with more personalized and higher-quality healthcare and to optimize the organization's resources.

Dr. Concepción López Lera is part of the Department of Continuous Improvement, Project Detection and Development at Mutua Universal. As she explains, among the mutual insurance organizations in the sector, Mutua Universal has been the one most committed to telemedicine, developing new ways of interacting with the patients.

Mutua Universal has essentially four telemedicine tools. These tools available across the 132 healthcare centres operated by the organization. However, as Dr. López Lera notes, they are not a “one-size-fits-all” solution; professionals must always consider each patient's individual needs and determine when it is appropriate to use them.

3.2.1 Online Clinic

The Online Clinic is the company's core telemedicine platform and main telemedicine tool that has been active for over fifteen years. This system enables both real-time and asynchronous consultations, connecting primary care professionals with specialists. In this

way, the Online Clinic brings specialized medicine closer to primary care, offering a more agile and accessible service.

This tool is fully integrated with the patient's medical record, allowing specialists to have all the information needed to assess each case the best and most accurate way possible. Furthermore, it is available to all specialities, including internal medicine, dermatology, psychiatry, social work, and medical coordination, among others.

According to Dr. López Lera, who oversees the management and use of this tool, approximately 1,000 consultations per month (both synchronous and asynchronous) are conducted through the Online Clinic.

But how does this system work and what is it exactly about?

Each centre has a dedicated consultation room known as the "Online Clinic Box". This room is equipped with a specialized equipment to carry out the best treatment possible: a remotely controlled camera, speakerphone, ambient audio system, and other devices that enable the capture of medical images. To ensure that everything works perfectly, a healthcare professional is always present to accompany the patient. All professionals are authorised to use this tool, with one exception: in cases involving mental illnesses or conditions, the consultation takes place without the presence of the centre's staff.

It is important to mention that all consults must be done under an informed consent and through a secure network, ensuring maximum data protection, especially as they are using sensitive medical data.

On the other hand, Dr. López Lera explained that in certain occasions patient's physical presence is not necessary, and asynchronous consultations are carried out instead. In these situations, a professional from the medical centre can request validation or support from another specialist asynchronously, avoiding the necessity of real-time connexion. This modality is typically used for tasks such as the revision of clinical images, assessing joint recovery or monitoring wound healing, always taking into account the professional's criteria and judgement.

3.2.2 Mobile Telemedicine Visits

The telemedicine mobile visits is a form of digital healthcare that enables remote medical consultations between doctors based at the centre and patients using technological devices. Its main objective is to expand access to healthcare, offering greater flexibility in medical services and ensuring the continuity of clinical follow-ups without requiring patients to travel.

Dr. López Lera specifies that the patient's characteristics are always considered, ranging from their level of digital literacy to the specific nature of their treatment.

The implementation of this tool was carried out progressively and was fully deployed by mid-2024. Mutua Universal opted to carry out the implementation through phases so each centre and professional could get used to the new system and ensure the patient's clinic history integration.

3.2.3 E-consult

The e-consult is an asynchronous and not urgent modality of medical assistance. Through this platform patients can send questions or medical consultations to the professionals who are treating them.

This tool is designed primarily for routine consultations, clarifications or follow-up communications, and therefore is not intended for emergency situations.

3.2.4 Tele-Rehabilitation

Tele-rehabilitation is an advanced form of digital healthcare that Mutua Universal has incorporated most recently. This is the latest telemedicine tool implemented in the company; therefore, it has not yet been completely integrated with the patient's electronic health record.

This platform is only used by physiotherapists, allowing them to create a series of personalized protocols for the patient to complete from home. This is a hybrid model that combines physical sessions together with at-home exercises.

This tele-rehabilitation online platform uses AI, which provides real-time feedback to patients on how to improve their exercises. This interactive system enhance adherence to treatment plans and supports continuous monitoring of rehabilitation progress.

3.2.5 Adoption and ongoing challenges

Regarding the adoption and use of these telemedicine tools, Dr. López Lera highlights that, even though there has been a constant evolution and solutions have gotten better as years have gone by, there is still progress to be made before both patients and professionals become fully accustomed to them. She acknowledges that the COVID-19 pandemic represented a turning point in the adoption of telemedicine but insists that the key factor for long-term success remains in effective change management. This process must involve both patients and healthcare staff, as some professionals still resist the use of these tools, often claiming that they “don't have time”, as she notes. However, the true purpose of telemedicine is to optimize time and enhance healthcare efficiency.

Dr. López Lera also highlights the importance of the continuous training and user engagement from early stages of each project, accompanied by consistent follow-up. These projects must be accompanied by motivational actions, activity's follow-ups and active listening to feedback to identify potential improvements or new developments not considered at the outset. Only this way, she adds, it is possible to evolve these tools and adapt them to the real needs for both professionals and patients.

3.3 Project LINCE: Artificial Intelligence for predictive healthcare management

Beyond telemedicine tools, Mutua Universal has also developed the project LINCE, an initiative that applies machine learning techniques to healthcare management. The project analyses historical data to predict the expected duration of each new sick leave, generating individualized forecasts that help optimize medical and organizational planning.

Oriol Puig Palau, Director of Healthcare Projects at Mutua Universal and Head of the LINCE project, states that the main goal of the project is twofold: first, to organize and prioritize healthcare activities more effectively, and the second, to adapt the patient follow-up model according to the system's predictive outcomes. By doing so, the project allows medical teams to focus their attention and resources on the cases that require the most immediate or intensive intervention.

LINCE currently integrates around 60 variables per case, enabling the model to identify patterns and anticipate recovery times. In the context of occupational accidents and medical leave management, the system also supports the incorporation of clinical process optimization. This helps professionals decide actions that are most appropriate according to the model's insights.

There are several challenges when implementing a project such as LINCE, Mr. Puig mentions. On one hand, there are challenges regarding technology. It is important to spend time and resources to create a good dataset that is useful to develop predictive models with the maximum guarantees. Furthermore, and still within the technical sector, the project also faces challenges regarding the integration of the different informational systems that participate in the process.

However, Mr. Puig states that the biggest challenge is the change management process, which is essential in order to convince those who will ultimately be the beneficiaries of the project. It is crucial that they believe in the project, the changes it will bring to their daily work, the benefits this transformation will entail so it can truly reshape their activity as intended.

Designed as a dynamic and evolving system, LINCE undergoes periodic audits to guarantee the reliability and validity of its algorithms. Overall, the project represents a major step in Mutua Universal's digital transformation, as it complements its telemedicine initiatives by enabling data-driven decision-making, resource optimization, and a more proactive and preventive approach to patient care.

3.4 Results and discussion

This section analyses the main findings obtained from two interviews with Dr. Concepción López Lera, Head of Online Clinic and Continuous Care Improvement, and Mr. Oriol Puig Palau, Director of Healthcare Projects at Mutua Universal. Their insights provide a professional perspective on how telemedicine has been implemented, perceived and developed within the organization.

The analysis is structured around four key themes: (1) perceived benefits, (2) barriers and challenges, (3) institutional strategies for improvement, and (4) future perspectives on telemedicine.

3.4.1 Perceived benefits of telemedicine

When asked about the impact of telemedicine, both interviewees assessed this as highly positive. Dr. López Lera rated its contribution to healthcare quality 8 out of 10, explaining that telemedicine has made patients see healthcare as a more personalized, efficient and continuous

service. According to her, patients highly value avoiding unnecessary travel and being able to access care when needed while maintaining a close follow-up with professionals.

Mr. Puig also highlighted the potential of these new tools to universalize access to specialized care across Mutua Universal's 132 centres. As he stated, "we do not have specialists in every location, but through telemedicine we can reach them anywhere, ensuring that all patients receive the same level of care". It is also important to highlight that the system not only helps patients, but also professionals to optimize time and reduce congestion in rehabilitation facilities, as well as improving both efficiency and the working environment.

These insights are consistent with other existing researches that identify telemedicine as a key driver of accessibility, efficiency and patient-centred care (OECD, 2019; WHO, 2021). Mutua Universal's hybrid model is contributing to the broader digitalization of healthcare in Spain.

3.4.2 Barriers and challenges

Despite the benefits mentioned before, both interviewees identified persistent challenges that hinder the full integration of telemedicine. Dr. López Lera pointed that one of the main problems is the resistance to change among some healthcare professionals and the need for more training. Some professionals still perceive digital tools as time-consuming, she mentions, even though their primary purpose is to increase efficiency and optimize working time. Furthermore, there is another relevant issue particularly for older patients or those with limited digital literacy which is digital divide. Therefore, this is another important issue to overcome when implementing telemedicine.

Similarly, Mr. Puig stressed the importance of convincing professionals from the health sector that they will ultimately benefit from these tools to understand their usefulness and to believe in the transformation that technology brings to their daily work. Without strong institutional support, digital solutions may face low adoption rates regardless of the technical quality.

3.4.3 Institutional strategies for improvement

Both professionals agreed on the importance of change management, continuous training and user involvement. Digital health projects must involve users from early stages and be accompanied by motivational initiatives, ongoing monitoring and active feedback mechanisms. Dr. López Lera explained that only through continuous evaluation and dialogue with workers and patients can telemedicine tools be adapted to real needs and be improved over time.

On the other hand, Oriol Puig similarly highlighted that the human factor is essential for the success of telemedicine. Technology should support rather than replace professional expertise, which we tend to think with the development of AI. He emphasized the need for periodic evaluation of digital systems and regular updates to maintain reliability and be up to date.

These insights show that an institutional culture that prioritizes participatory innovation and organizational learning is a Mutua Universal key aspect that aligns with current research that views digital transformation as a socio-technical process.

3.5.4 Future perspectives on telemedicine

Looking ahead, Concepción López Lera envisions a fully hybrid healthcare model within the next five years at Mutua Universal, where telemedicine will become a standard component of healthcare delivery across all centres. She anticipates continuous technological development and stronger interoperability between digital platforms, ensuring better communication and coordination between patients and doctors.

Oriol Puig Palau also expressed optimism about telemedicine's growing importance in the coming years. He expects that telemedicine will play a relevant role in improving efficiency and accessibility as technology evolves while contributing to preventive and personalized healthcare.

Nevertheless, both professionals emphasized the need for ethical oversight, data security and human supervision. These aspects must remain the core of digital healthcare systems. But most importantly, they think that technology should always function as a supportive complement to professional judgment, not a replacement of it.

The interview and questionnaire materials are included in the appendices in their original language (Spanish). Translated excerpts are provided in the main text where relevant.

Chapter 4. Empirical Analysis: Digital Health Maturity and Health Outcomes

4.1 Data and variables

The following analysis relies on a cross-country dataset that combines information on Digital Health Maturity and selected variables that may be influenced by this variable. The unit of analysis is the country, and the sample includes countries classified into different stages of digital health development according to the World Health Organization (WHO) Global Digital Health Monitor (GDHM).

The Python code used to clean the dataset, run the regression models, and generate the figures is provided in Appendix E.

4.1.1 Digital Health Maturity

The Digital Health Maturity indicator measures countries' progress in developing and institutionalizing digital health systems across different dimensions, including governance structures, regulatory frameworks, infrastructure, interoperability, standards, financing mechanisms and service delivery capacity.

In this variable, countries are classified into maturity stages that reflect the development of each digital health system. These maturity stages are:

- **Phase 2 – Developing:** Digital health components, such as policy frameworks and pilot initiatives, are in place but their implementation remains partial and systems are not fully integrated yet.
- **Phase 3 – Established:** Governance mechanisms are clearly defined, and digital health strategies are formalized while implementation is expanding across the health system.
- **Phase 4 – Advanced:** Digital systems are more interoperable and integrated at national level, regulatory frameworks are stronger and there is more institutional coordination.
- **Phase 5 – Optimized:** Digital health is completely institutionalized, embedded within national health strategies and continuously monitored to make necessary improvements.

In the dataset used on this analysis, most countries are observed between Phase 2 and Phase 5, which reflects that most of them have at least foundational digital health structures in place.

4.1.2 Health Outcomes

To evaluate the relationship between digital health development and population health, the analysis considers several health indicators that capture different dimensions of system's performance:

- **Life expectancy at birth**, as a measure of overall population health and long-term system effectiveness.
- **Infant mortality ratio (per 1,000 births)** reflects child health and access to essential healthcare services.

- **Maternal mortality ratio**, capturing the quality, accessibility, and effectiveness of maternal healthcare.
- **Tuberculosis incidence**, representing communicable disease control capacity and epidemiological monitoring.

These indicators allow for a multidimensional assessment of the association between digital health maturity and health outcomes. The data has been extracted from The World Bank Group.

4.1.3 Data characteristics

The dataset is cross-sectional and includes 137 country observations to which this data is available.

Digital Health Maturity is modeled as an ordered explanatory variable. Given the cross-sectional structure of data, the empirical analysis focuses on identifying associations rather than establishing causal relationships.

4.2 Methodology

In order to determine the relationship between Digital Health Maturity and health outcomes across countries, an empirical approach will be used.

The analysis follows two steps. First, a descriptive analysis, conducted using graphical tools to observe how health indicators vary across maturity states. The objective is to identify patterns in the data and detect possible relationships between development in health systems and health performance.

Second, a regression analysis whose objective is to test if the relationships observed in the previous analysis remain statistically important. The regression models estimate the association between Digital Health Maturity and selected outcomes. In this context, health outcomes such as life expectancy, infant mortality, maternal mortality, and tuberculosis incidence are treated as dependent variables.

Digital Health Maturity is the main explanatory variable. With the objective of reducing potential bias, internet usage (measured as the percentage of individuals using the internet) is included as a control variable. This control helps account for general digital development and ensures that the estimated relationship reflects digital health maturity specifically, rather than overall technological advancement.

The general regression specification can be expressed as:

$$HealthOutcome = \beta_0 + \beta_1 DigitalHealthMaturity + \beta_2 InternetUsage + \epsilon_i$$

The coefficient associated with Digital Health Maturity captures how changes in maturity levels are related to changes in the selected health outcome, holding internet usage constant.

All regressions are estimated using Python in the Google Collab environment. Since the dataset is cross-sectional, the results are interpreted as associations rather than causal effects.

4.3 Descriptive analysis

This section carries out a descriptive analysis of the relationship between Digital Health Maturity and health outcomes across countries. The objective is to examine how key health indicators vary across different levels of digital health development, identifying observable patterns in the data before moving to regression analysis.

4.3.1 Distribution of Digital Health Maturity

This subsection examines the distribution of countries according to their level of Digital Health Maturity. To contextualize the following descriptive analysis, it is essential to understand the countries' distribution across maturity phases, as it provides information about the composition and balance of the sample.

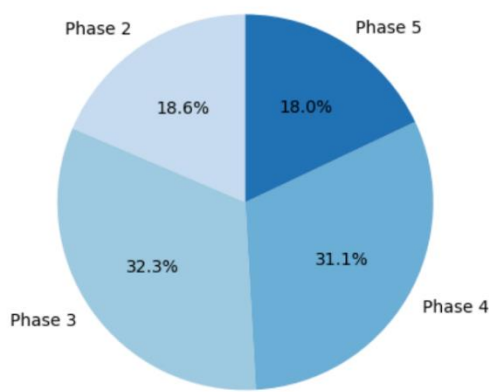


Figure 4. Distribution of Countries by Digital Health Maturity Level. Source: Own elaboration based on data from the World Bank Group.

Figure 4 represents this distribution across maturity levels that range from Phase 2 to Phase 5. Most countries are concentrated in intermediate stages of digital health development, particularly Phases 3 and 4. Furthermore, it is also interesting to observe that the number of countries that have reached the highest level of digital health maturity (Phase 5) is lower than the number of countries on the least digitally advanced group.

This distribution suggests that, although digital health initiatives have grown in the past years, only a limited number of states have reached the highest levels of development. Most countries remain in the intermediate phases which symbolizes ongoing digital transformation rather than fully consolidated systems. This context is important when interpreting the differences in health outcomes in the following analysis.

4.3.2 Relationship between Digital Health Maturity and health outcomes

This subsection analyzes the relationship between Digital Health Maturity and key health outcomes across countries using graphical tools. The objective is to explore if countries with higher levels of digital health development tend to different health outcomes in comparison to countries with lower maturity stages. Therefore, this analysis focuses on identifying patterns without establishing causal relationships.

Overall population health

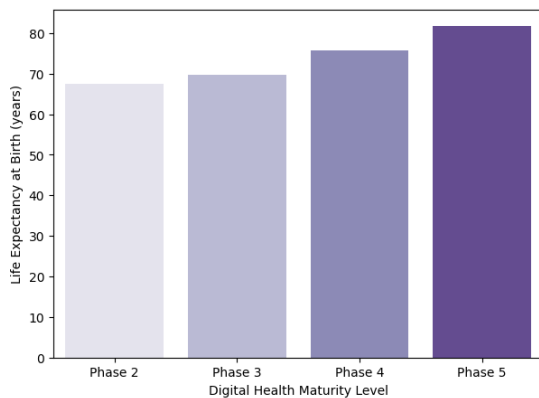


Figure 5. Life Expectancy by Digital Health Maturity Level. Source: Author's own elaboration based on data from the World Bank Group.

An indicator of overall population health and long-term health system performance is life expectancy. As shown in figure 5, it is observed that average life expectancy increases across digital health maturity phases. Therefore, countries in Phase 5 of health digitalization exhibit the highest values regarding life expectancy.

This suggests a positive association between digital health maturity and overall health conditions, highlighting the improvement of citizens' health as digital health systems become more advanced.

Maternal and child health

Outcomes related to maternity and child health have a strong relationship, although it is not linear. In Figure 6, infant mortality rates decrease as countries move from lower to higher maturity phases. This indicates substantial improvements in child health in countries that have more digitally developed health systems.

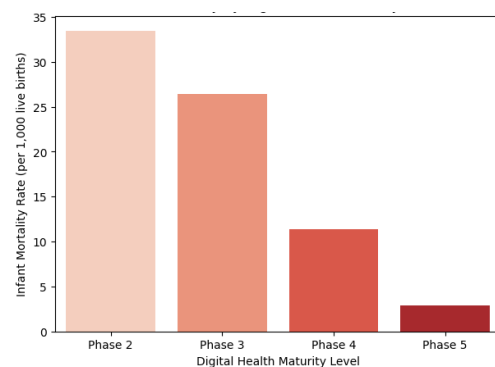


Figure 6. Infant Mortality by Digital Health Maturity Level. Source: Author's own elaboration based on data from the World Bank Group.

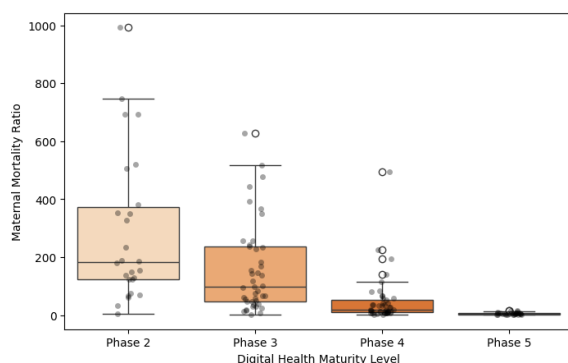


Figure 7. Maternal Mortality and Digital Health Maturity. Source: Author's own elaboration based on data from the World Bank Group.

A clear pattern is also observed for maternal mortality. In Figure 7 we observe that maternal mortality ratios decrease as digital health maturity is in higher phases. States that are in Phase 2 exhibit the highest levels of mortality and the greatest dispersion, reflecting significant heterogeneity in maternal health outcomes. In contrast, countries in Phases 4 and 5 cluster around substantially lower values, suggesting more consolidated and effective maternal healthcare systems.

The downward trend across maturity phases highlights the potential role of digital health development in improving access to maternal care, strengthening monitoring and follow-up, and supporting timely medical interventions. Overall, the descriptive evidence

indicates that higher digital health maturity is closely associated with better maternal and child health outcomes.

Communicable diseases

To examine the relationship between Digital Health Maturity and communicable diseases, tuberculosis incidence is used as a representative indicator. As shown in Figure 8 below, there is a clear downward pattern that emerges across maturity levels. Countries in Phase 2 and Phase 3 display the highest tuberculosis incidence rates, with substantial dispersion and several extreme values.

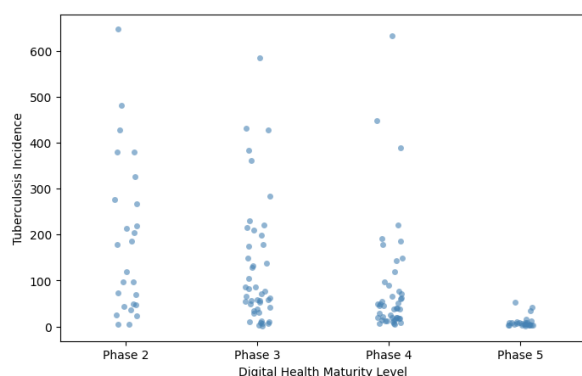


Figure 8. Tuberculosis Incidence across Digital Health Maturity Levels. Source: Author's own elaboration based on data from the World Bank Group.

As digital maturity increases, tuberculosis incidence tends to decline. Countries in phase 4 show noticeably lower and more concentrated incidence levels compared to earlier stages. And Phase 5 countries cluster around very low values with limited variability. This pattern suggests that higher levels of digital health development are associated with improved disease control and monitoring capacity.

Although some heterogeneity remains, particularly in intermediate phases, the overall distribution indicates that more digitally mature health systems tend to exhibit lower tuberculosis incidence rates. This finding is consistent with the role of digital tools in supporting epidemiological surveillance, early detection, and coordinated public health responses.

4.3.3 Synthesis of descriptive findings

The descriptive evidence presented above reveals a consistent pattern across multiple dimensions of health. Countries with higher levels of Digital Health Maturity tend to display better health outcomes, which is reflected in higher life expectancy and lower mortality and disease incident rates.

It is important to emphasize that these findings are based on descriptive comparisons and do not take into account other structural or socioeconomic factors that may influence health outcomes. Nevertheless, the coherence of these results across different health indicators provides a strong motivation for conducting a regression analysis in the following section, where additional variables are introduced to better isolate the relationship between Digital Health Maturity and health outcomes. Furthermore, since descriptive data reflects correlation but not necessarily causality, this regression analysis is needed.

Based on the previous descriptive analysis, we will analyze the following hypothesis in the regression analysis:

- H1: Higher levels of Digital Health Maturity are associated with higher life expectancy.

- H2: Higher levels of Digital Health Maturity are associated with lower infant mortality rates.
- H3: Higher levels of Digital Health Maturity are associated with lower maternal mortality ratios.
- H4: Higher levels of Digital Health Maturity are associated with lower tuberculosis incidence rates.

The next section evaluates whether the associations observed descriptively remain statistically significant once additional controls are introduced.

4.4 Regression analysis

4.4.1 Baseline specification

Following the empirical strategy outlined in the methodology section, this subsection formally defines the baseline regression model used in the following analysis.

The relationship between Digital Health Maturity and health outcomes is estimated using the following ordinary least squares (OLS) specification:

$$Y_i = \beta_0 + \beta_1 \text{Digital Health Maturity} + \beta_2 \text{Internet Usage} + \varepsilon_i$$

where Y_i represents each of the health outcomes analyzed (life expectancy at birth, infant mortality rate, maternal mortality ratio, and tuberculosis incidence).

Digital Health Maturity is introduced as an ordered numeric variable, reflecting the progression from Phase 2 to Phase 5 as defined by the WHO Global Digital Health Monitor. This transformation allows the model to capture how incremental improvements in digital health development are associated with changes in health outcomes.

The specification includes internet usage as a control variable, as previously discussed, to account for broader levels of digital development across countries.

Each model is estimated separately for the different health outcomes. Due to data availability constraints, the number of observations varies slightly across regressions, as only complete cases are included in each estimation.

4.4.2 Results: Life Expectancy

After carrying out a regression analysis on the life expectancy variable, the results confirm the descriptive evidence presented in the previous section.

Table 1. Regression Analysis: Life Expectancy at Birth. Source: Author's own elaboration based on data from the World Bank Group.

OLS Regression Results						
Dep. Variable:	life_exp_birth	R-squared:	0.734			
Model:	OLS	Adj. R-squared:	0.730			
Method:	Least Squares	F-statistic:	184.8			
Date:	Thu, 19 Feb 2026	Prob (F-statistic):	2.99e-39			
Time:	15:47:53	Log-Likelihood:	-372.30			
No. Observations:	137	AIC:	750.6			
Df Residuals:	134	BIC:	759.4			
Df Model:	2					
Covariance Type:	nonrobust					
	coef	std err	t	P> t	[0.025	0.975]
const	53.8460	1.210	44.514	0.000	51.454	56.239
Digital_Maturity_num	1.7493	0.406	4.308	0.000	0.946	2.552
individuals_using_internet	0.1925	0.016	12.256	0.000	0.161	0.224
Omnibus:	2.266	Durbin-Watson:	2.017			
Prob(Omnibus):	0.322	Jarque-Bera (JB):	1.960			
Skew:	-0.291	Prob(JB):	0.375			
Kurtosis:	3.075	Cond. No.	298.			

As observed in Table 1, the estimated coefficient for Digital Health Maturity indicates that moving up one maturity phase is associated with an increase of 1.75 years in life expectancy, holding internet usage constant. This coefficient is statistically significant at the 1% level, as we observe a p value lower than 0.001 while the confidence interval remains strictly positive, reinforcing the robustness of the association.

This finding is consistent with previous literature that highlights the impact of digital health systems on population health outcomes. The OECD (2019) finds that digitally advanced health systems are associated with stronger performance in preventive care and disease management, both of which are key determinants of life expectancy. In this context, the magnitude of the coefficient (1.75 additional years per maturity level) is economically meaningful and aligns with the idea that structural improvements in healthcare delivery, supported by digitalization, can generate substantial gains in population health.

The control variable, internet usage, is also positive and significantly important to life expectancy, explaining that an increase of 1% in internet usage increases life expectancy in approximately 0.19 years.

However, even after accounting for general digital development, the maturity of digital health systems retains a strong and independent association with better health outcomes. Furthermore, the model explains approximately 73% of the cross-country variation in life expectancy, indicating a strong overall fit.

4.4.3 Results: Infant Mortality

Regarding infant mortality, the regression results show a strong and significant negative association with Digital Health Maturity. In Table 2, the estimated coefficient suggests that an increase of one phase is associated with a reduction of 2.71 infant deaths per 1,000 live births, holding internet usage constant. This is statistically significant at 1% with a confidence level negative, which reinforces the robustness of the result. This coefficient is also economically

meaningful, as it indicates that improvements in digital health systems may be associated with substantial gains in child survival.

Table 2. Regression Analysis: Infant Mortality. Source: Author's own elaboration based on data from the World Bank Group.

OLS Regression Results						
=====						
Dep. Variable:	mortality_infant_rate	R-squared:	0.732			
Model:	OLS	Adj. R-squared:	0.728			
Method:	Least Squares	F-statistic:	183.2			
Date:	Thu, 19 Feb 2026	Prob (F-statistic):	4.62e-39			
Time:	15:47:53	Log-Likelihood:	-486.51			
No. Observations:	137	AIC:	979.0			
Df Residuals:	134	BIC:	987.8			
Df Model:	2					
Covariance Type:	nonrobust					
=====						
	coef	std err	t	P> t	[0.025	0.975]

const	61.4652	2.784	22.076	0.000	55.959	66.972
Digital_Maturity_num	-2.7094	0.934	-2.899	0.004	-4.558	-0.861
individuals_using_internet	-0.4792	0.036	-13.258	0.000	-0.551	-0.408
=====						
Omnibus:	11.397	Durbin-Watson:	1.987			
Prob(Omnibus):	0.003	Jarque-Bera (JB):	17.982			
Skew:	0.405	Prob(JB):	0.000125			
Kurtosis:	4.579	Cond. No.	298.			

Regarding internet usage, its coefficient is also negative and significantly associated with infant mortality. However, Digital Health Maturity retains an independent relationship with lower infant mortality even after controlling general digital development.

The model has an R-squared of 0.732, which means that approximately 73% of the cross-country variation in infant mortality is explained by the model and the variables included. This suggests that digital maturity and internet usage together capture a substantial share of the structural differences across countries in terms of child health.

This finding is consistent with previous empirical evidence. In particular, Dutta et al. (2019) show that ICT development is significantly associated with improvements in health outcomes, including reductions in infant mortality, in a sample of Asian countries. Their results highlight the existence of a long-run relationship between digital development and health indicators, suggesting that increased ICT access enhances healthcare delivery by improving information flows and reducing barriers to access.

Similarly, the World Health Organization (2016, 2021) emphasizes that digital health tools such as telemedicine, mobile health (mHealth), and data systems contribute to reducing infant mortality by enabling early detection of complications, improving prenatal and postnatal monitoring, and facilitating faster medical interventions.

Therefore, the descriptive findings are therefore backed up by this regression analysis and strengthen the evidence that higher levels of digital health development are related to child health outcomes.

4.4.4 Results: Maternal Mortality

The results from this regression analysis differ from the patterns and ideas gotten from the descriptive findings. We observe that the coefficient of Digital Maturity is negative, which indicates greater digital maturity with lower maternal mortality. However, the p value is 0.211, which means that this coefficient is not statistically significant. This suggests that, once internet usage is controlled for, there is no strong statistical evidence of an independent association between digital health maturity and maternal mortality rates.

Table 3. Regression Analysis: Maternal Mortality at Birth. Source: Author's own elaboration based on data from the World Bank Group.

Regression Results for maternal_mortality_ratio						
OLS Regression Results						
Dep. Variable:	maternal_mortality_ratio	R-squared:	0.584			
Model:	OLS	Adj. R-squared:	0.578			
Method:	Least Squares	F-statistic:	92.12			
Date:	Thu, 26 Feb 2026	Prob (F-statistic):	1.05e-25			
Time:	16:22:55	Log-Likelihood:	-814.59			
No. Observations:	134	AIC:	1635.			
Df Residuals:	131	BIC:	1644.			
Df Model:	2					
Covariance Type:	nonrobust					
	coef	std err	t	P> t	[0.025	0.975]
const	491.6373	35.192	13.970	0.000	422.019	561.256
Digital_Maturity_num	-14.7474	11.732	-1.257	0.211	-37.957	8.462
individuals_using_internet	-4.5854	0.460	-9.978	0.000	-5.495	-3.676
Omnibus:	104.669	Durbin-Watson:	1.837			
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1389.312			
Skew:	2.519	Prob(JB):	2.06e-302			
Kurtosis:	17.948	Cond. No.	299.			

Nevertheless, the control variable is significant at the 1% level, which means that an increase of 1% in the use of internet is associated with the decrease of 4.6 deaths per 100.000 births. This indicates that broader digital development may play a more relevant role when explaining differences between countries regarding maternal mortality.

The model presents an R-squared of 0.584, meaning that approximately 58% of the variation in maternal mortality across countries is explained by the variables included in the model. While this indicates a moderate explanatory power, it is lower than the values observed for life expectancy and infant mortality, suggesting that maternal mortality may be influenced by a wider range of structural, institutional, and socioeconomic factors beyond digital health maturity alone.

These findings suggest that maternal mortality depends on other structural factors such as income, infrastructure or medical capacity. While the descriptive patterns indicated a downward trend, the regression results highlight the importance of controlling for additional variables.

4.4.5 Results: Tuberculosis Incidence

The regression results for tuberculosis incidence reveal a negative association with Digital Health Maturity, as the estimated coefficient indicates that an increase of one phase

regarding Digital Health is associated with a reduction of 22 tuberculosis cases per 100,000 citizens, holding internet usage constant. However, the p value is 8.9%, which means that it is significant at 10% level, weaker than the previous health outcomes. This suggests moderate rather than strong statistical evidence. While the direction of the relationship is consistent with the descriptive analysis, the weaker significance indicates that other structural factors may also play an important role in explaining cross-country differences in tuberculosis incidence.

Table 4. Regression Analysis: Tuberculosis Incidence. Source: Author's own elaboration based on data from the World Bank Group.

OLS Regression Results						
=====						
Dep. Variable:	incidence_tuberc	R-squared:	0.233			
Model:	OLS	Adj. R-squared:	0.222			
Method:	Least Squares	F-statistic:	20.40			
Date:	Thu, 12 Mar 2026	Prob (F-statistic):	1.84e-08			
Time:	16:12:33	Log-Likelihood:	-847.63			
No. Observations:	137	AIC:	1701.			
Df Residuals:	134	BIC:	1710.			
Df Model:	2					
Covariance Type:	nonrobust					
=====						
	coef	std err	t	P> t	[0.025	0.975]

const	316.5203	38.858	8.145	0.000	239.665	393.375
Digital_Maturity_num	-22.3402	13.042	-1.713	0.089	-48.136	3.455
individuals_using_internet	-1.9393	0.504	-3.844	0.000	-2.937	-0.941
=====						
Omnibus:	81.667	Durbin-Watson:	1.796			
Prob(Omnibus):	0.000	Jarque-Bera (JB):	338.421			
Skew:	2.270	Prob(JB):	3.26e-74			
Kurtosis:	9.219	Cond. No.	298.			

Internet usage remains negative and significantly associated with tuberculosis incidence, reinforcing the role of broader digital development in improving disease monitoring and control capacity.

The model presents an R-squared of 0.233, meaning that approximately 23% of the variation in tuberculosis incidence across countries is explained by the variables included in the model. This relatively lower explanatory power is expected, as communicable diseases are influenced by a wider set of socioeconomic, environmental, and epidemiological factors beyond digital health development alone.

Overall, the results provide some support for the hypothesis that more digitally mature health systems are associated with improved disease control, although the strength of the relationship appears weaker than for other health outcomes analyzed in this study.

4.5 Discussion and summary of findings

The regression analysis offers further insights into the relationship between Digital Health Maturity and health outcomes across different countries. Overall, the results gotten align with those found through the descriptive analysis; however, the strength of this relationship depends upon the health indicators under consideration.

Firstly, considering life expectancy as a health outcome, there is a strong and positive relationship between life expectancy and Digital Health Maturity. Countries that have achieved a higher level of digital health development tend to have a significantly higher life expectancy rate, even after accounting for other factors related to digital development through internet usage. It is possible that a more developed digital health system could be a contributing factor to a better health outcome for a country as a whole.

Secondly, considering infant mortality as a health outcome, it can be seen that there is a strong relationship between Digital Health Maturity and reduced infant mortality. Countries that have achieved a higher level of digital health maturity tend to have a lower rate of infant mortality.

However, the results are less conclusive when it comes to maternal mortality. Although Digital Health Maturity has a negative sign as expected, it is not statistically significant once internet usage is introduced as a control variable. This could indicate that maternal health is a function of a larger range of structural and institutional factors than those captured by digital health maturity.

Lastly, the regression results for tuberculosis incidence show a negative relationship with Digital Health Maturity; however, it is only statistically significant at a 10% level. This could indicate that while digital health maturity is likely to have a positive effect on the quality of disease surveillance and control mechanisms, communicable diseases are a function of a larger range of socioeconomic determinants.

Overall, it is evident from the regression results that a positive relationship exists between health outcomes and digital health maturity; however, it is more pronounced for life expectancy at birth and infant mortality.

It is important to note that while a positive relationship is evident from the regression results, it is important to note that it is a correlation effect rather than a causal effect. While internet usage is introduced as a control variable to account for a range of other determinants of digital development, it is important to note that other structural, institutional, and socioeconomic factors could also be at play.

Chapter 5. Limitations and Future Research

The empirical analysis relies on cross-sectional data, which means the findings capture associations between Digital Health Maturity and health outcomes rather than causal relationships. The regression models include internet usage as a control variable, but other factors likely influence health outcomes across countries, such as income levels, public health expenditure, education, institutional quality, demographic structure, and healthcare capacity. Omitting these variables affects the estimated coefficients and limits how far the conclusions can be taken.

The Digital Health Maturity indicator is also an imperfect measure. It is useful for cross-country comparisons, but countries in the same maturity phase can differ considerably in infrastructure, implementation capacity, governance, and actual use of digital tools in clinical practice. The indicator should therefore be read as a general proxy rather than a precise measure of digital health performance.

The qualitative component is limited to a single case study. Mutua Universal provides valuable evidence on how telemedicine is implemented in the Spanish context, but the findings cannot be generalized to other organizations or national settings. One institution's experience will not fully reflect the range of challenges and opportunities that characterize digital health adoption elsewhere.

These limitations point to several directions for future research. Extending the quantitative analysis with panel data and additional control variables would allow for comparisons over time and more robust conclusions about whether gains in digital maturity translate into measurable improvements in health outcomes. A more disaggregated approach broken down by region, income group, or health system type could also sharpen the analysis, given that the effects of digitalization likely vary depending on development level, institutional capacity, and access to infrastructure. On the qualitative side, future work could compare multiple healthcare institutions and incorporate patient perspective alongside that of clinicians, offering a fuller account of how digital tools affect accessibility, quality of care, and satisfaction in practice.

This dissertation offers evidence that digital health is playing a growing role in the transformation of healthcare systems. Understanding the mechanisms, conditions, and long-term effects of that transformation remains an open and worthwhile research agenda.

Chapter 6. Bibliography

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Chapter 7. Appendix

Note: The interview and questionnaire materials are included in the appendices in their original language (Spanish). Translated excerpts are provided in the main text where relevant.

Appendix A. Interview with Concepción López Lera

La doctora Concepción López Lera forma parte del departamento de mejora continua, detección y desarrollo de proyectos para Mutua Universal. Mutua Universal es, de entre las mutuas del sector, la que más ha apostado por temas de telemedicina, creando otras formas de relación con los pacientes.

La migración a este modelo se ha producido hace poco menos de 2 años, evolucionando de un modelo fundamentalmente presencial a un modelo híbrido que incluye tanto visitas presenciales como otras visitas con diferentes herramientas del mundo de la telemedicina. Esta migración se realizó con dos objetivos: proporcionar a los pacientes una medicina más personalizada y de más calidad además de racionalizar los recursos de la empresa.

Mutua Universal cuenta esencialmente con 4 herramientas de telemedicina. Estas herramientas están a disposición de los 132 centros propios de la mutua. Sin embargo, y según comenta la Doctora López Lera, estas herramientas no son “café para todos”, si no que hay que tener en cuentas las necesidades de cada paciente y en qué momento es adecuado hacer uso de ellas o no.

1. Clínica Online

La herramienta de telemedicina principal de Mutua Universal es la Clínica Online, una plataforma propia de Mutua Universal que lleva en funcionamiento más de 15 años.

Este sistema permite hacer visitas médicas tanto con conexión en tiempo real como asíncronas, facilitando la comunicación entre el profesional del centro y el especialista. De este modo, Clínica Online aproxima la medicina especializada a la atención primaria, ofreciendo un servicio más ágil y accesible.

La herramienta está completamente integrada con el historial clínico del paciente, lo que permite que el especialista disponga de toda la información necesaria para poder valorar su situación de la mejor manera posible. Además, está abierta a todas las especialidades, entre las que podemos encontrar medicina interna, dermatología, psiquiatría, trabajo social y coordinación médica, entre otras.

Según la doctora Concepción López Lera, encargada de la gestión y uso de esta herramienta, se realizan aproximadamente 1.000 visitas al mes con conexión y sin conexión a través de la Clínica Online.

Pero ¿cómo funciona y en qué consiste exactamente este sistema?

En cada centro de Mutua Universal existe una consulta específica, denominada “Box de la Clínica Online”. Esta sala cuenta con un equipo especializado con periféricos para realizar el mejor tratamiento posible: cámara con control remoto, micro altavoz, audio ambiental y otros dispositivos que permiten la captura de imágenes. Además, siempre existe un profesional acompañando al paciente. En este caso, todos los profesionales pueden hacer uso de esta

herramienta. Sin embargo, la doctora López Lera nos comenta que existe una excepción y es el caso de patologías mentales, donde en la sala consulta no hay profesionales del centro y solo interviene el especialista que trata al paciente.

Es importante mencionar que todas las consultas se realizan bajo un consentimiento informado específico y a través de una red segura, garantizando la máxima protección de los datos, especialmente al tratarse de información sanitaria sensible.

Por otra parte, la profesional de Mutua Universal nos explica que en determinadas ocasiones no es necesaria la presencia del paciente, por lo que se llevan a cabo las consultas asíncronas. En estos casos, un profesional del centro puede solicitar la valoración o el apoyo de otro especialista de manera asíncrona, sin necesidad de conexión en tiempo real. Esta modalidad se utiliza, por ejemplo, para la revisión de imágenes clínicas, la evaluación de una recuperación articular o el seguimiento de una cura, siempre a criterio de los profesionales implicados.

2. Visita de telemedicina en movilidad

La visita de telemedicina móvil es una modalidad de atención sanitaria digital que permite realizar consultas médicas a distancia entre el médico desde el centro y el paciente mediante dispositivos móviles. Su objetivo es ampliar el acceso a la atención médica, ofreciendo mayor flexibilidad asistencial y garantizando la continuidad del seguimiento clínico sin necesidad de desplazamientos. Doctora López Lera especifica que siempre se tienen que tener en cuenta las características del paciente, desde la brecha digital hasta el propio tratamiento que este necesite.

La implantación de esta herramienta se llevó a cabo de manera progresiva, terminando de implantarla a mediados del 2024. Mutua Univesal apostó por un despliegue por fases para que cada centro y profesional pudieran adaptarse al nuevo sistema y garantizar la integración con la historia clínica del paciente.

3. E-consulta

La e-consulta es una modalidad de atención médica asíncrona y no urgente. Mediante esta plataforma el paciente puede enviar preguntas o consultar médicas a los profesionales que le están tratando.

Es una herramienta pensada para consultas rutinarias, aclaraciones o seguimiento, por lo que no está diseñada para situaciones de urgencia.

4. Tele-rehabilitación

La tele-rehabilitación es una modalidad avanzada de asistencia sanitaria que Mutua Universal ha incorporado recientemente. Esta es la última herramienta de telemedicina implantada por la empresa, por lo que de momento no está integrada completamente con la historia clínica del paciente.

Esta herramienta se utiliza únicamente por los fisioterapeutas, permitiendo que estos pauten una serie de protocolos personalizados para que el paciente haga en su domicilio. Es un modelo híbrido, combinando sesiones presenciales con sesiones en el domicilio.

Esta herramienta es una plataforma online que cuenta con Inteligencia Artificial, permitiendo el envío de *feedback* al paciente en tiempo real de cómo mejorar el ejercicio que esté haciendo.

En relación con la adopción y uso de las herramientas de telemedicina, la doctora López Lera destaca que, pese a que su evolución es constante y las soluciones han mejorado notablemente durante los años, aún queda camino por recorrer para que tanto los pacientes como los profesionales se acostumbren. Reconoce que la pandemia del COVID19 supuso un punto de inflexión en la adopción de la telemedicina, pero insiste que el factor clave para el éxito sigue siendo la gestión de cambio. Esta gestión debe abordarse tanto con los pacientes como con los asistenciales, dado que hay algunos profesionales se siguen oponiendo al uso de estas herramientas alegando que “no tienen tiempo”, como comenta la doctora. Sin embargo, el verdadero objetivo de estas herramientas es precisamente la optimización de los tiempos y la mejora de la eficiencia asistencial.

Concepción López subraya además la importancia de la formación continua y de involucrar a los usuarios desde el inicio de cada proyecto y hacer seguimientos. Estos proyectos deben ir acompañados de acciones motivacionales, seguimiento de la actividad y escucha activa de las opiniones para plantear mejoras o nuevos evolutivos que en el inicio no se contemplaban. Solo de esta forma, añade, es posible identificar mejoras y evolucionar las herramientas para adaptarlas a las necesidades reales de los profesionales y pacientes.

Appendix B. Questionnaire to Oriol Puig Palau

Oriol Puid es el director de Proyectos Asistenciales en Mutua Universal y encargado del proyecto LINCE de Mutua Universal.

Parte I. Proyecto LINCE

1. ¿Podría explicar brevemente en qué consiste el Proyecto LINCE y cómo surgió la idea en Mutua Universal?

El proyecto LINCE es la aplicación de la rama de la inteligencia artificial del aprendizaje automático o machine learning, para generar modelos predictivos en el ámbito de la gestión asistencial de la Mutua Universal.

Con el proyecto Lince, Mutua Universal desarrolla varios modelos predictivos basados en la información histórica de la gestión realizada por sus profesionales asistenciales, de manera que partiendo de una base de aproximadamente 60 variables disponibles para todo proceso clínico, podemos anticipar situaciones específicas y personalizadas a cada paciente como es , por ejemplo, el tiempo de duración de una baja laboral.

2. ¿Qué problemas se busca resolver?

Con Lince, Mutua Universal busca incorporar información y criterios en el proceso asistencial que permitan optimizar los recursos asegurando la mejor calidad asistencial para nuestros pacientes.

3. ¿Qué ventajas se espera obtener en la gestión de procesos asistenciales a través de este proyecto?

La principal ventaja de usar lince, es que podremos priorizar nuestras actividades y atenciones sanitarias asegurando que cada una de ellas se lleve a cabo en el momento más idóneo.

Con esta premisa, conseguiremos que la actividad de nuestro colectivo asistencial se concentre en las actuaciones que aportan más valor añadido reduciendo de esta manera actuaciones innecesarias.

Además, podremos realizar estas actuaciones en el momento más oportuno para conseguir la mejor recuperación de nuestros pacientes así como nuestros objetivos de gestión.

4. ¿Qué retos han surgido/planean que surjan durante la implementación del modelo?

Varios son los retos que hay que afrontar con un proyecto como es el del lince

Hay retos del ámbito tecnológico. Es importante dedicar tiempo y recursos a disponer de una base de datos adecuada que permita desarrollar los modelos predictivos con las máximas garantías.

Así mismo, y aún dentro del ámbito tecnológico, el proyecto supone un reto también en lo referente a la integración entre los diferentes sistemas de información que participan del proceso.

Otro reto mayúsculo consiste en conseguir la implicación de la organización en el proyecto. Sin el adecuado apoyo de los grupos calve de la organización (dirección, sistemas, recursos humanos) proyectos de esta magnitud son difíciles de llevar a cabo y de asegurar su éxito.

Pero quizás, el mayor reto sea la realización de una gestión del cambio adecuada con la que conseguir convencer aquellos que en última instancia van a ser beneficiarios del proyecto el; Es imprescindible que ellos crean en el proyecto y en el cambio que con él se va a producir en su día a día, que entiendan los beneficios que les va a comportar este cambio para que pueda llegar a transformar su actividad de la manera esperada.

¿Qué precauciones considera necesarias para garantizar el correcto uso de este modelo predictivo?

Lo principal es que todo el mundo entienda cuál es el objetivo que se persigue con la incorporación del modelo predictivo, que vean los beneficios que puede aportar y que lo integren en su día a día como una herramienta más de trabajo que les ayuda en su gestión.

Debe considerarse, además, el modelo predictivo como algo dinámico, en continua evolución y por tanto en continuo análisis. Es importante realizar las auditorías del modelo que permitan asegurar su bondad e implementar las acciones necesarias para asegurar su correcto mantenimiento y evolución.

Parte II. Impacto de la telemedicina en general

1. ¿Qué opina del uso de la inteligencia artificial en general en el sector salud?

La inteligencia artificial (IA) considerada como el conjunto de disciplinas de software, lógica, informática y filosofía destinados a la creación de algoritmos, programas y mecanismos que sean **capaces de aprender y razonar como humanos**, tiene que desarrollar un papel muy importante en el sector de la salud.

El uso de la IA en el sector salud está viviendo un momento de expansión acelerada y transformación profunda. Aplicaciones directas como el **Diagnóstico clínico asistido** que permite a los profesionales consultar evidencia médica validada en tiempo real, mejorando la toma de decisiones clínicas sin reemplazar el juicio médico, o la **Medicina personalizada** donde se desarrollando herramientas que combinan biomarcadores, datos clínicos y algoritmos para adaptar tratamientos a cada paciente, o la **previsión de recursos sanitarios** necesarios para atender servicios de urgencias...

Los campos de aplicación son casi ilimitados, son tantos como procesos en los que participan los propios profesionales de la salud... pero siempre teniendo en cuenta aspectos fundamentales:

ética y responsabilidad: ¿Quién responde si una IA comete un error? La supervisión humana sigue siendo esencial.

Con Lince, por ejemplo, usamos IA predictiva, pero al final la decisión es siempre del profesional, que tomará esa decisión con la ayuda u orientación que Lince le ha proporcionado.

Además, con Lince tenemos que asegurar que no se generen sesgos en la atención asistencial, y en eso el profesional es, por descontado, fundamental.

Privacidad y seguridad de datos: El manejo de información médica sensible requiere altos estándares de protección. Esto no es nuevo, siempre ha sido así, pero la irrupción de la IA abre nuevas puertas y un uso mucho mas intensivo de esta información con lo que estos aspectos toma mayor relevancia si cabe.

Desigualdad tecnológica: No todos los sistemas de salud tienen la infraestructura para adoptar estas tecnologías de forma equitativa.

La IA no viene a sustituir al profesional sanitario, sino a potenciar su capacidad diagnóstica, terapéutica y operativa. Su integración está marcando un antes y un después en la medicina, pero debe hacerse con visión ética, regulatoria y centrada en el paciente

2. Desde su experiencia, ¿cómo describiría la evolución del uso de tecnologías digitales en el ámbito sanitario durante los últimos años?

Quizás no somos del todo conscientes, ... pero en mi opinión, y en el ámbito de la salud, los cambios promovidos con la digitalización y las tecnologías que la apoyan han sido vertiginosos.

En un inicio quizás se enfocaban a mitigar ineficiencias en el ámbito mas puro de la gestión, buscando reducir burocracia o agilizando procesos más administrativos. Sin embargo, en los últimos años su penetración ya en el “core” de la salud nos ha revelado un potencial casi inimaginable, donde todo lo que podamos imaginar puede tener cabida. Interpretación de imágenes diagnosticas – hecho, robot quiúrgico – hecho, ...

3. ¿Qué ventajas y desventajas considera que tiene el uso de la telemedicina en los centros?

En nuestro caso, somos una Mutua de Accidentes de trabajo, el uso de la telemedicina nos ha permitido 2 cosas fundamentalmente:

La primera es la universalización de la atención. No tenemos especialistas en todos los centros, pero por medio de la telemedicina podemos llegar a ellos, estén donde estén, desde cualquiera de nuestros centros. Aseguramos así que todos nuestros pacientes, dispongan de los mismos recursos y de la misma buena atención.

La segunda, optimizar los tiempos de nuestros sanitarios y los de nuestros pacientes, a los que evitamos desplazamientos y molestias innecesarias. Y desde nuestra perspectiva, conseguimos descongestionar hasta cierto punto los centros asistenciales y nuestras salas de rehabilitación lo que favorece un mejor clima de trabajo y seguramente una mejor calidad en la atención prestada.

4. ¿Qué visión a futuro tiene sobre la telemedicina?

Con el desarrollo tecnológico “desbocado”, estoy seguro que la telemedicina cada vez jugará un papel mas relevante en la atención sanitaria. Siguen siendo muchas las patologías en las que la telemedicina queda relegada a un segundo plano por precisar de exploraciones físicas o por precisar de pruebas diagnósticas que deben realizarse en los Centros Asistenciales.

Estoy seguro que con el avance de la tecnología, esta situación irá cambiando y pocos serán los escenarios en los que la telemedicina no pueda jugar un papel u otro.

5. ¿Cree que en el futuro el éxito de las organizaciones sanitarias se medirá más por su capacidad de tratar pacientes o por su capacidad de anticiparse a las enfermedades gracias al análisis de datos?

Es una pregunta difícil, con truco... mi respuesta será salomónica: ambos aspectos serán sumamente relevantes.

- Es imperativo avanzar en la “prevención”, sin duda. Es una obligación con un impacto evidente en impedir enfermedades, en mejorar la calidad de vida de pacientes, en ahorros de costes a todos los niveles...
- Pero, por otro lado, enfermedades y pacientes existirán y es igual de importante saber tratarlos adecuadamente.

Son dos aspectos que necesariamente conviven y deben ser considerados.

¿En el ámbito en el que se mueve Mutua Universal? Pues ahí, quizás la parte de la anticipación y la prevención nos resulte más “interesante” ya que nos permitiría evitar procesos que tratamos hoy en día.

6. ¿Puede la telemedicina llevarnos a mejores indicadores de salud en la población en un futuro próximo o el impacto en este sentido será más bien limitado?

La telemedicina puede ayudar, que duda cabe. Pero por si sola no conseguirá mejorar la salud o los indicadores de salud.

Como hablábamos anteriormente, la prevención, los hábitos saludables (que cierto es se pueden llegar a monitorizar con telemedicina), son fundamentales para que la salud de la sociedad se vea reforzada...

Pero al final el abordaje debe ser mas holístico, hay que contemplar todos los factores que influyen en esos indicadores de salud, la situación geopolítica, la economía, ... como grandes influenciadores globales, pero también aspectos mas individuales como los aspectos psicosociales o el entorno familiar seguirán jugando un papel destacado al que la telemedicina poca contribución podrá tener.

Appendix C. Questionnaire to Concepción López Lera

Contexto: Este cuestionario forma parte de un Trabajo Final de Grado en Business Analytics sobre el impacto de las nuevas tecnologías en las prácticas y resultados para los pacientes en términos de salud.

1. En una escala del 1 al 10, ¿cómo valoraría el impacto general de la telemedicina en la atención sanitaria ofrecida por Mutua Universal?

8

2. ¿Hasta qué punto considera que estas tecnologías han contribuido a una medicina más personalizada? (1 = nada, 10 = totalmente)

8

3. ¿Cómo describiría la evolución del modelo híbrido desde su implementación?

☐ Muy positiva

☒ **Positiva**

☐ Estable

☐ Negativa

4. ¿Qué grado de aceptación observa entre los profesionales respecto al uso de herramientas digitales?

☐ Muy alto

☐ Alto

☒ **Medio**

☐ Bajo

5. ¿Qué grado de aceptación observa entre los pacientes respecto al uso de herramientas digitales?

☐ Muy alto

☐ Alto

☒ **Medio**

☐ Bajo

6. ¿Cuál considera que ha sido el principal obstáculo a la hora de adoptar de estas herramientas? (Respuesta abierta)

Modificar la forma de trabajo, Formación práctica

7. ¿Cuál es el perfil principal de los pacientes de telemedicina? ¿gente que vive en zonas remotas o tiene dificultades para desplazarse? ¿gente que podría acercarse al centro de salud, pero les resulta más cómodo la telemedicina? ¿jóvenes/mayores? ¿mujeres/hombres? ¿o es un perfil transversal?

Es un perfil transversal

8. ¿Qué beneficios percibe que los pacientes asocian a la atención digital? (Respuesta abierta)

Desplazamientos solo en casos necesarios. Atención personalizada y seguimiento más continuado.

9. ¿Qué limitaciones observa entre los pacientes a la hora de adoptar estas herramientas? (Respuesta abierta)

En algunos casos existe brecha digital

10. ¿Qué aspectos considera esenciales para seguir mejorando la evolución digital? (Respuesta abierta)

Gestión del cambio efectiva. Seguimiento del proyecto. Incorporación de mejoras planteadas por los usuarios

11. ¿Cómo imagina el papel de la telemedicina dentro de 5 años en Mutua Universal? (Respuesta abierta)

Modelo asistencial híbrido totalmente integrado. Incorporación de nuevas herramientas.

12. ¿Puede la telemedicina llevarnos a mejores indicadores de salud en la población en un futuro próximo o el impacto en este sentido será más bien limitado?

Sin duda, facilita la asistencia personalizada, el seguimiento continuado y la racionalización de los recursos.

Appendix D. Supporting Document: Proyecto LINCE

Mutua Universal. (n.d.). Premios Aslan – Proyecto LINCE. Institutional document.

Appendix E. Python code used for empirical analysis

```
# -*- coding: utf-8 -*-
"""Tfg_Analytics_Lucia.ipynb

Automatically generated by Colab.

Original file is located at
    https://colab.research.google.com/drive/1YEBk9jxGC-KFttUhJj5Vg0BWj6B90aJo

***The Digital Remedy: How technology is transforming the health sector**
##### Lucía Moreno Sebastián | TFG Business Analytics april 2026
"""

# Libraries
import pandas as pd
import numpy as np
```

```

import matplotlib.pyplot as plt
import seaborn as sns

import statsmodels.api as sm
import statsmodels.formula.api as smf

# Load dataset
df = pd.read_excel("Digital_Health_Data.xlsx")
df.head()

"""### **Initial inspection of the data**

Before proceeding with the empirical analysis, it is necessary to inspect the
dataset in order to identify:
- the available variables,
- their data types,
- the number of non-null observations,
- and the presence of missing values.

This step helps determine which variables are suitable for the descriptive and
regression analyses.
"""

df.info()

"""The first cleaning step consists of removing countries for which no Digital
Health Maturity phase is reported. Since Digital Health Maturity is the main
explanatory variable in the analysis, observations without an assigned phase
cannot be included.

After this filtering step, the distribution of countries across maturity
phases is examined in order to understand the composition of the sample used
in the descriptive analysis.
"""

phase_order = ["Phase 2", "Phase 3", "Phase 4", "Phase 5"]

df_clean = df.copy()

# Eliminar países sin fase asignada
df_clean = df_clean[df_clean["Digital_Health_Maturity"] != "Not Available"]

# Contar países únicos por fase
counts = (
    df_clean.drop_duplicates(subset=["Country"])
    ["Digital_Health_Maturity"]
    .value_counts()

```

```

        .reindex(phase_order)
    )

counts

"""## **Descriptive Analysis**

#### **a) Distribution of countries across Digital Health Maturity levels**

##### Before examining the relationship between Digital Health Maturity and
health outcomes, it is useful to describe how countries are distributed across
maturity phases. This provides context for the descriptive and regression
analyses by showing the composition of the sample.

The following figure reports the number of countries in each Digital Health
Maturity phase after excluding observations without an assigned maturity
level.
"""

colors = ["#c6dbef", "#9ecae1", "#6baed6", "#2171b5"]

plt.figure(figsize=(5,5))
plt.pie(
    counts,
    labels=counts.index,
    autopct="%1.1f%%",
    startangle=90,
    colors=colors
)

plt.title("Distribution of Countries by Digital Health Maturity Level")
plt.show()

"""#### **b) Mean health outcomes by Digital Health Maturity level**

To explore the descriptive relationship between Digital Health Maturity and
the selected health outcomes, the average value of each numeric indicator is
computed by maturity phase.

This provides an initial overview of whether countries with more advanced
digital health systems tend to exhibit better health outcomes before
introducing regression controls.
"""

phase_order = ["Phase 2", "Phase 3", "Phase 4", "Phase 5"]

grouped = (
    df_clean

```

```

        .groupby("Digital_Health_Maturity")
        .mean(numeric_only=True)
        .reindex(phase_order)
    )

grouped.head()

"""In the following sections, we are going to be focusing on four variables:
life expectancy at birth, mortality infant rate, maternal mortality ratio and
incidence of tuberculosis.

##### **c) Descriptive Analysis of the chosen variables**

**c.1) Life Expectancy and Digital Health Maturity**
"""

plt.figure(figsize=(7, 5))
sns.barplot(
    x=grouped.index,
    y=grouped["life_exp_birth"],
    hue=grouped.index,
    palette="Purples",
    legend=False
)

plt.xlabel("Digital Health Maturity Level")
plt.ylabel("Life Expectancy at Birth (years)")
plt.title("Life Expectancy by Digital Health Maturity Level")
plt.show()

"""**c.2) Infant mortality and Digital Health Maturity**"""

plt.figure(figsize=(7, 5))
sns.barplot(
    x=grouped.index,
    y=grouped["mortality_infant_rate"],
    hue=grouped.index,
    palette="Reds",
    legend=False
)

plt.xlabel("Digital Health Maturity Level")
plt.ylabel("Infant Mortality Rate (per 1,000 live births)")
plt.title("Infant Mortality by Digital Health Maturity Level")
plt.show()

"""**c.3) Maternal mortality and Digital Health Maturity**"""

```

```

plt.figure(figsize=(8, 5))
sns.boxplot(
    data=df_clean,
    x="Digital_Health_Maturity",
    y="maternal_mortality_ratio",
    order=phase_order,
    palette="Oranges"
)

sns.stripplot(
    data=df_clean,
    x="Digital_Health_Maturity",
    y="maternal_mortality_ratio",
    order=phase_order,
    color="black",
    alpha=0.35,
    jitter=True
)

plt.xlabel("Digital Health Maturity Level")
plt.ylabel("Maternal Mortality Ratio")
plt.title("Maternal Mortality across Digital Health Maturity Levels")
plt.show()

"""*c.4) Tuberculosis incidence and Digital Health Maturity*"""

plt.figure(figsize=(8, 5))
sns.stripplot(
    data=df_clean,
    x="Digital_Health_Maturity",
    y="incidence_tuberc",
    order=phase_order,
    jitter=True,
    alpha=0.6,
    color="steelblue"
)

plt.xlabel("Digital Health Maturity Level")
plt.ylabel("Tuberculosis Incidence")
plt.title("Tuberculosis Incidence across Digital Health Maturity Levels")
plt.show()

"""## **Regression Analysis**

This section estimates the association between Digital Health Maturity and
selected health outcomes across countries.

```

The baseline specification follows the empirical strategy presented in the dissertation. For each health outcome, an OLS regression is estimated using:

- Digital Health Maturity as the main explanatory variable
- internet usage as a control for general digital development

Since the dataset is cross-sectional, the results are interpreted as associations rather than causal effects.

"""

```
df_reg = df_clean.copy()

# Convertir Digital Health Maturity a número (extrae 2,3,4,5)
df_reg["Digital_Maturity_num"] = (
    df_reg["Digital_Health_Maturity"]
    .str.extract("(\d)")
    .astype(float)
)

# Convertir Internet usage a numérico
df_reg["individuals_using_internet"] = pd.to_numeric(
    df_reg["individuals_using_internet"],
    errors="coerce"
)

# Convertir outcomes a numérico
outcomes = [
    "life_exp_birth",
    "mortality_infant_rate",
    "maternal_mortality_ratio",
    "incidence_tuberc"
]

for var in outcomes:
    df_reg[var] = pd.to_numeric(df_reg[var], errors="coerce")

df_reg.head()

def run_regression(outcome):

    df_model = df_reg.dropna(
        subset=[outcome, "Digital_Maturity_num", "individuals_using_internet"]
    )

    Y = df_model[outcome]
    X = df_model[["Digital_Maturity_num", "individuals_using_internet"]]
    X = sm.add_constant(X)
```

```
model = sm.OLS(Y, X).fit()

print(f"\nRegression Results for {outcome}\n")
print(model.summary())

return model

model_life = run_regression("life_exp_birth")
model_infant = run_regression("mortality_infant_rate")
model_maternal = run_regression("maternal_mortality_ratio")
model_tb = run_regression("incidence_tuberc")
```

Declaración de Uso de Herramientas de Inteligencia Artificial Generativa en Trabajos Fin de Grado

ADVERTENCIA: Desde la Universidad consideramos que ChatGPT u otras herramientas similares son herramientas muy útiles en la vida académica, aunque su uso queda siempre bajo la responsabilidad del alumno, puesto que las respuestas que proporciona pueden no ser veraces. En este sentido, NO está permitido su uso en la elaboración del Trabajo fin de Grado para generar código porque estas herramientas no son fiables en esa tarea. Aunque el código funcione, no hay garantías de que metodológicamente sea correcto, y es altamente probable que no lo sea.

Por la presente, yo, **Lucía Moreno Sebastián** estudiante de **E6 Analytics – Business Analytics y Relaciones Internacionales** de la Universidad Pontificia Comillas al presentar mi Trabajo Fin de Grado titulado *“The Digital Remedy: How technology is transforming the health sector”* declaro que he utilizado la herramienta de Inteligencia Artificial Generativa ChatGPT u otras similares de IAG de código sólo en el contexto de las actividades descritas a continuación

1. **Brainstorming de ideas de investigación:** Utilizado para idear y esbozar posibles áreas de investigación.
2. **Referencias:** Usado conjuntamente con otras herramientas, como Science, para identificar referencias preliminares que luego he contrastado y validado.
3. **Metodólogo:** Para descubrir métodos aplicables a problemas específicos de investigación.
4. **Interpretador de código:** Para realizar análisis de datos preliminares.
5. **Constructor de plantillas:** Para diseñar formatos específicos para secciones del trabajo.
6. **Sintetizador y divulgador de libros complicados:** Para resumir y comprender literatura compleja.

Afirmo que toda la información y contenido presentados en este trabajo son producto de mi investigación y esfuerzo individual, excepto donde se ha indicado lo contrario y se han dado los créditos correspondientes (he incluido las referencias adecuadas en el TFG y he explicitado para que se ha usado ChatGPT u otras herramientas similares). Soy consciente de las implicaciones académicas y éticas de presentar un trabajo no original y acepto las consecuencias de cualquier violación a esta declaración.

Fecha: 21 de abril 2026

Firma: 