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Patterns of collaboration in mHealth: A network analysis

Giovanna Capponi [a], Nicoletta Corrocher [b,*]

[a] Copernicus Institute of Sustainable Development, Utrecht University, Princetonlaan 8a, Utrecht, The Netherlands
[b] ICRIOS, Bocconi University, Via Roentgen 1, Milan, Italy

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ABSTRACT

The use of mobile phones offers unique opportunities for information exchange and service provision within healthcare. Yet mHealth has historically been dominated by small scale, isolated initiatives. The main obstacle to scaling up mHealth projects is a lack of evidence on their performance, preventing the projects from receiving additional funding and limiting the scope for the development of best practices. In this context, an interesting potential form of successful innovation is the emergence of public-private networks. Despite sector fragmentation, there exists a network of public and private actors that could serve as a vehicle for knowledge sharing which is worth being examined. Through analysis of a sample of 196 projects involving 384 organizations, this study investigates patterns of collaboration within the mHealth ecosystem to capture the main trends in the structure and scope of the partnerships and examines the variables associated to project survival. Results show that projects implemented by at least one local partner are more likely to survive, as well as projects that involve a set of diverse (for-profit and not-for profit) organizations. Furthermore, the initiatives targeting communicable diseases, which are typically implemented in lower-income economies, are less likely to succeed.

1. Introduction

The use of mobile health (mHealth) technology and applications is a foundational development for health-related monitoring and controlling processes, and one which recently has proven to be crucial in the management of the COVID-19 outbreak (Pai and Alathur, 2020; Baudier et al., 2021). mHealth applications facilitate remote disease symptom tracking and support, as well as easier information exchange between patients and healthcare operators, thus providing important benefits in terms of cost and time efficiency (Baudier et al., 2021). However, a lack of awareness, a lack of access to the technology and an absence of the necessary infrastructure — in addition to the complexity of the healthcare ecosystem and the involvement of multiple stakeholders — can represent major hurdles to the successful implementation of this useful tool. Furthermore, important concerns related to data security and privacy, the differences among information management standards and the potential profitability of m-Health applications also exist (Baudier et al., 2021).

Mobile health was first introduced in 2003 as a part of the broader concept of electronic health (eHealth). The term refers to “the use of mobile devices — such as mobile phones, patient monitoring devices, personal digital assistants (PDAs) and wireless devices — for medical and public health practice” (World Health Organization, 2016).

The growing enthusiasm for mHealth is mostly associated with the widespread availability of mobile devices and the low levels of literacy required to use them. The entire world population currently lives within the reach of a cellular signal: penetration rates reached 108% in 2019 at the world level, ranging from 140% in CIS countries to 80.1% in Africa. The share of the global population with Internet access increased from 16% in 2005 to almost 54% at the end of 2019. The picture changes, however, depending on countries’ development levels: in developing countries, only 19% of individuals were online in 2019 and only 40% of their populations were covered by an LTE type of network or higher (ITU Publications, 2019). Albeit at different levels, smartphones’ increasing capacity for rapid collection, storage and transmission of data offers unique possibilities for service delivery and information exchange. Specifically, mobile phone deployment within healthcare could improve functions such as disease surveillance, planning, decision making in clinical services, health promotion, disease prevention and training of health professionals (Leon et al., al.,2012). Vesselkov et al. (2018) show that mobile/wireless technologies were among the top five enablers of eHealth services between 2002 and 2016. Recently, mobile apps played a particularly important role in telehealth, especially to enable on-demand teleconsultation, to implement remote patient

* Corresponding author.
E-mail address: nicoletta.corrocher@unibocconi.it (N. Corrocher).

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monitoring or provide artificial intelligence-based virtual nurse services (Vesselkov et al., 2018).

Despite such enormous potential, the mHealth sector has historically been dominated by small-scale, isolated initiatives addressing specific problems of a small population over a fixed period of time. The main obstacle to scaling up has been identified as a lack of evidence demonstrating mHealth project performance, which makes it difficult to secure ongoing financial funding (Mechael and Searle, 2010). In this respect, the sustainability of these projects crucially depends upon their acceptance by every stakeholder involved — practitioners and patients alike — and by the quality of the new relationship created through these innovative technological solutions (Bashshur et al., 2009; Baudier et al., 2021).

In its most recent survey on eHealth, the World Health Organization reported a remarkable increase in the availability of mHealth applications as well as in the share of mHealth projects reaching national scale. However, there is still little evidence of the quality, safety and reliability of mHealth projects, triggering concerns about their actual impact (World Health Organization, 2016). This evidence is mostly due to a general lack of guidance and common practices across projects, which would require higher levels of coordination and knowledge sharing across the different organizations involved in the mHealth projects (Liu et al., 2011; World Health Organization, 2016). In this context, a useful and relatively unexplored form of network are public-private services innovation networks (Djellal and Gallouj, 2016; Gallouj, 2002; Morrar, 2015), whose development derives from the need to foster innovations in public and non-market services. These types of networks constitute important organizational innovations that address different types of non-technological and social innovations such as those within the mHealth context.

The objective of this study is to investigate the patterns of collaborations within the mHealth ecosystem to capture the main trends in the structure and the scope of its partnerships. In particular, we aim to answer the following research questions: 1) What are the characteristics of mHealth partnerships? and 2) How do these characteristics affect the survival of mHealth projects? The dataset used to conduct this research is based on a collection of 196 projects retrieved from Health Unbound, a resource center promoted by the mHealth Alliance. These worldwide projects involve 384 organizations, mostly operating in partnership. Despite sector fragmentation, there exists a certain degree of overlap that can be mapped as a web of direct and indirect links. Following a network approach, we seek to identify the most central actors in the ecosystem and analyze their role and preferences in terms of partners and projects. In addition, we test whether and to what extent partnership composition and project-level characteristics affect project survival.

While the majority of mHealth projects have been implemented in developing countries, we find that the most central organizations are based in advanced economies, particularly in the USA. Core organizations are predominantly public and for-profit, with not-for-profit organizations occupying more peripheral positions. The results of our analysis of the determinants of project survival show that the presence of a local partner, i.e. an organization based in the country where the project is implemented, is particularly important for the long-term success of a project. Furthermore, public-private partnerships are positively associated with the probability that a project will be ongoing.

The study contributes to the existing literature on multi-stakeholder mHealth projects by examining the multi-level (network, organizational and national) determinants of project survival. Most of the existing studies look at the development of mHealth projects by classifying different initiatives and identifying common trends (Ahmed et al., 2014; Gorski et al., 2016; Yang and Kovarik, 2019). While project impact assessment is an effective avenue towards understanding what works and what does not, relatively less attention has been devoted to understanding the role different promoters of mHealth programs play in their survival, growth and effectiveness. The insights and evidence we report here support the idea that the more efficiently and effectively mHealth project stakeholders are linked to one another, the better they can share knowledge, best practices and timely recommendations. To the best of our knowledge, there is no systematic assessment of the composition of mHealth innovation networks, nor any analysis of how different organizations impact the performance of such projects.

The study has important implications for scholars and practitioners. First, it highlights a need for research into new forms of collaboration between the various stakeholders and forces involved in the complex mHealth ecosystem, including new actors such as technology providers, and the increasing influence of participatory design approaches (Patrício et al., 2019; Jefferies et al., 2019). Second, it shows the importance of local actor involvement in successful mHealth project development. This is in line with the idea that one of the most relevant aims of digital healthcare activities is to widely diffuse the access to healthcare, reaching even the most disconnected and rural areas, therefore reducing between and within country inequality (Baudier et al., 2021; Kraus et al., 2021). Third, it sheds light on the importance of jointly evaluating a project's overall structure/content and the context in which those projects are implemented in order to predict their success. This confirms that for mHealth projects to be successful — meaning that they effectively support the relationship between patients and practitioners with training, monitoring, communicating and screening (Yousaf et al., 2020) — the various stakeholders must be able to exploit the technologies to provide medical care, create value and manage the overall functioning of the project.

2. Public-private partnerships in mHealth

The process of digital transformation in the healthcare system, in particular the introduction of innovative services based on mobile technologies, has paved the way for the development of new institutional configurations and new business opportunities to manage medical practice that have an impact on a very heterogeneous set of stakeholders (Nudurupati et al., 2015; Elton, J. and O'Riordan, A., 2016; Kraus et al., 2021). Developing an mHealth project is a complex process that may involve many actors both private and public. This is because innovation in this field is not only based on R&D activity, but more and more on social networks and participatory processes involving different healthcare workers and patients (Gallouj et al., 2018). In low-income countries, the participation of an extremely wide range of stakeholders is critical to gathering necessary resources; it is difficult to set up profitable business models in the field without strategic financing and cross-sector interventions (World Health Organization, 2011). Establishing and maintaining trust-filled, long-lasting relationships among actors in the healthcare ecosystem — from patients to hospital administrators, from technology providers to public healthcare authorities — constitutes a fundamental condition for the process of value creation through innovative, technology-based healthcare projects (Kraus et al., 2021). In this respect, the literature has recently focused on the importance of patient-centered approaches (Mende, 2019), value co-creation and service dominant logic (SDL). Specifically, participatory design approaches are crucial to harnessing the benefits of digital health projects (Patrício et al., 2019; Jefferies et al., 2019).

If we look at the evolution of inter-firm collaborations in digital health, we observe that the sector has witnessed an important transformation from bilateral relationships between users and providers to multi-agent relationships, where different types of actors interact (Kraus et al., 2021; Rubalcaba et al., al.2012; Windrum and García-Goñi, 2008). The transformation has concerned not only the processes of value creation among the traditional stakeholders, but the overall ecosystem of healthcare, where new entrants have somehow disrupted the existing value chain (Schachinger, 2013; Kraus et al., 2021). Given the expansion and evolution of the healthcare ecosystem, developing partnerships can boost the impact of mHealth initiatives by fostering mutual learning, supporting common goals, harmonizing approaches and bringing credibility and visibility to mHealth projects

(Daniela, 2008). The existing literature on inter-organizational collaborations in digital health has highlighted that cross-sectoral collaborations are essential for the successful development and implementation of digital health initiatives (Sucala et al., 2017; Liu et al., 2019). While previously, health-related research was carried out almost exclusively in academic/medical contexts and largely with public funds, more and more new research models and platforms are emerging (e.g., Open mHealth, LifeGuide, Purple) (Sucala et al., 2017). However, misalignment of (business vs. scientific) objectives and expectations, differences in timelines and values and challenges inherent in cross-cultural communications might hinder an effective development of such partnerships.

Among existing partnership configurations, given the nature of the services involved, public-private partnerships seem to be particularly suited to developing successful innovations in mHealth services.

A public-private partnership (PPP) is defined as a long-term relationship between public and private partners where the public authority's role is to define objectives and monitor performance while the private sector normally carries out project development and implementation and assumes part of the financial risk by providing funding (Falch and Henten, 2010). For the public sector, leveraging partners' competences can lead to substantial efficiency gains, reducing duplication of effort and transaction costs while taking advantage of economies of scale. For the private sector, there are direct financial gains in the form of tax breaks and market identification, but also indirect benefits associated with brand and image promotion (Buse and Walt, 2000).

While traditional PPPs solely involve public and private organizations, the mHealth sector is seeing the increasing involvement of civil society. These broader forms of collaboration are defined as Multi-Stakeholder Partnerships (MSP) and they go beyond the public/private dichotomy (Falch and Henten, 2010). In particular, they bring together heterogeneous sets of individuals, possibly including NGOs, church groups, charitable foundations and academic institutions (Bäckstrand, 2006). It is very common for the industry to establish the grounds for partnerships that interface with the public sector via not-for-profit organizations (Buse and Walt, 2000). The influence of this "third sector" has been increasing in the past decades, both in developed and developing countries. The heterogeneity characterizing MSPs can be an advantage, because it combines a unique set of competencies; nevertheless, diversity in organizational mandates, interests and backgrounds poses significant challenges to their actual effectiveness (Bäckstrand, 2006).

Within this context, an important issue is the central role played by service organizations — such as health care organizations — in the development of non-technological, social forms of innovation. Following Gallouj et al. (2013), we argue that public-private service network innovations emerge as systems of different actors interact to co-produce not only technological innovations, but also social and service innovations (Gallouj et al., 2018). Non-technological and social innovations within hybrid, public-private innovation networks involve a variety of actors. Often, the organizations and individuals involved in these networks adopt unplanned, emerging innovation models (Gallouj, 2002). The health and medical sector provides numerous examples of partnerships established to form innovative care networks, with the mHealth sector constituting a relatively recent example of this. For example, mPedigree is a social initiative leveraging digital technologies and ground-level partnerships to secure pharmaceutical supply chains and exclude counterfeited products. Created in collaboration with Hewlett Packard (HP), mPedigree was launched in 2007 in Ghana and is currently operating in Nigeria, East Africa and India.[1] For example, MOTECH's "Client Data Application" was introduced in Ghana in 2009 through a partnership between the Grameen Foundation, Columbia University and Ghana Health Service. The ongoing project allows frontline health workers to digitize service delivery information and track care for patients, with a specific component targeting pregnant and postpartum women (Willcox et al., 2019). In the United States, the American Diabetes Association collaborated with Voxiva (now Welltok), a health software provider, to develop Care4life, a platform that offers customized plans to monitor diabetes.

These examples illustrate that far-reaching agreements are likely to have an important cross-country dimension and for this reason, it is relevant to mention the emergence of Global Public-Private Partnerships (GPPP). An article published in the WHO bulletin in 2000 defines a Global Public-Private Partnership (GPPP) as a collaborative relationship that transcends national boundaries and brings governments, corporations and intergovernmental organizations together to ensure the broad representation of interests (Buse and Walt, 2000). Nearly all mHealth initiatives are the result of a global collaboration between developed and developing countries, driven by opportunities such as mutual learning and cross-fertilization of competences (Sandhu, 2011).

More generally, in the past few decades both the scope and the expectations associated with Global North-South collaborations have changed. First, there has been a shift from the idea of providing solutions to development problems to the concept of endogenous capacity building. Creating partnerships that support research initiatives is recognized as a means of enabling developing countries to build problem-solving skills (Gaillard, 1994). In this view, the emergence of an international network would be beneficial to the effectiveness of North-South collaboration to the extent that it would enable information and results sharing across a wider audience (Binka, 2005). Moreover, the networking component can facilitate North-South technology transfer and South-South mentorship, leading to capacity proliferation and greater critical mass in terms of adoption (Mgone and Salami, 2009). In the specific case of mHealth, South-to-South collaborations can lead to the development of sustainable, culturally appropriate solutions that are transferable to similar environments (Curioso and Mechael, 2010).

However, health sector partnerships often suffer from poor representation of low-income countries, a tendency to choose expertise from exclusive communities and a general lack of independence due to funding sources (Buse and Walt, 2000). The main problem related to North-South collaborations in the context of capacity building is extreme inequality in terms of roles and participation: the North is often considered as the "giver" and the South as the "receiver" (Binka, 2005). Instead, the main ingredient for successful North-South partnerships would be the presence of a strong mutual interest, which enables both parties to gain from the collaboration (Gaillard, 1994). When applicable, reverse innovations, i.e. the process of creating innovations in developing countries before diffusing them to the developed countries, can represent an important driver for companies' participation in North-South partnerships in mHealth.

Additional problems can arise due to pluralism: since partnerships typically involve multiple institutions with heterogeneous backgrounds, it may be difficult to achieve and maintain good governance (Bäckstrand, 2006). In the context of global partnerships, the main challenges to good governance are associated with representative legitimacy and accountability. Since the interests of middle- and low-income countries are often under-represented, the distance between the global partners and the beneficiaries may lead to weak accountability and poor quality deliverables at the project level (Ibid.). The effectiveness and the transferability of solutions increases the closer the developers are to the problem (Curioso and Mechael, 2010).

3. Data and methods

3.1. Data collection

Over the last two decades, international organizations have made a considerable effort to classify solutions and expand coordination. The

[1] https://mpedigree.com/

major player is the World Health Organization (WHO), which in 2005 established the Global Observatory for eHealth (GOe), an initiative dedicated to the study of eHealth, its evolution and impact on health in countries.[2] Other actors are promoting knowledge sharing and creating networks to exchange best practices. For example, the Rockefeller Foundation, the UN Foundation and the Vodafone Foundation founded the mHealth Alliance, an organization that, from 2009 to 2014, worked toward building an evidence base for the use of mHealth and addressing key barriers to scaling up mHealth programs.[3]

The first round of data collection for this study is based on Health Unbound (HUB), an online resource made available by the mHealth Alliance. In 2014, the website hosted descriptions for roughly 560 worldwide mHealth projects. Our study excluded projects for which relevant information was missing or non-retrievable elsewhere and built a dataset consisting of 196 projects and 384 organizations. We classified the eligible projects depending on mHealth focus and final users. The organizations are classified by field of operation and whether they are for-profit, not-for-profit or public. We included project (and organization) country of implementation (origin) along with the income level per capita[4] in that country. In this context, a project can be implemented in one country, while being managed by organizations from different countries, including projects implemented by high-income organizations in low-income countries.

The second round of data collection recorded whether these projects were still active in 2020. After at least six years of activity, most of the ongoing projects had a website and were operating at the national level. We also retrieved information from the Center for Health Market Innovation database, a digital platform supported by the Bill & Melinda Gates Foundation, the Rockefeller Foundation and UKaid, which provides extensive coverage on projects implemented in developing countries.[5] This sampling strategy enabled us to garner a relatively long-term perspective on project success while keeping track of completed projects.

3.2. Data analysis methodology

We adopted a social network perspective to study mHealth partnership composition. In this context, a network is built upon the ties created through its affiliation, i.e. whether an organization collaboratively participated in the development of a specific project. We then rely on two main assumptions. The first is that co-promotion of a specific project creates social ties, providing opportunities for information sharing and the establishment of common practices in the long run (Scott et al., 2015). The second is that the links established by actors when participating in a project are kept over time regardless of the project's lifespan. While this is a strong assumption, by limiting the analysis to active projects (and, as a consequence, to active partnership) we would have encountered other restrictions. By relaxing the time constraint, we are able to include initiatives which are currently at the "completed" stage. In this way, we can construct a more representative overview of the mHealth sector and the structure of the ecosystem.

We then tested possible determinants of project survival using regression analysis. In our database, 44 out of 196 projects were still active in 2020, the others either suspended or left without additional funding after the pilot stage. We estimated logit models where the dependent variable indicates whether the project is still ongoing in 2020 (1= ongoing; 0 = completed). As for the independent variables, we tested both the characteristics of the partnerships and the features of the projects.

4. Results

4.1. Organizations and partnerships

We first present a description of the organizations involved in the sample. Fig. 1 shows that the majority of organizations are not-for-profit actors such as large foundations and research institutes based in high-income countries. While there is scarce participation by entities from low-income countries, we notice a relatively high involvement of organizations from middle-income countries, especially their governments. At the global level are mainly intergovernmental organizations. Considering that most of the initiatives have been implemented in low- and middle-income countries, the strong presence of developed countries might signal inequality of contribution within the collaborations (Binka, 2005). We will investigate this later in our analysis.

The organizations together comprise an affiliation network consisting of 1,070 indirect ties forming 40 components, of which 11 isolated nodes (see Fig. 2) .[6] The main component contains 297 nodes, which corresponds to 77% of the organizations.[7] Within this component, the maximum (valued) degree centrality is 85 and the average is 7, indicating that organizational participation levels are highly skewed, with few hubs dominating the entire network. Only 10% of the organizations have more than 10 ties. In terms of sectors, this top layer is quite mixed: even though the public sector prevails, there are central nodes also among for-profits and, to a lesser extent among not-for-profits. The most central organizations come from high-income countries (51% of those above 10 ties), with some less connected players in the other regions of the world. Interestingly, global organizations are not among the most central actors: 60% of them reaches a degree centrality which is below the average.

67% of the organizations in the sample network only took part in one project; just 5% were involved in more than 5 projects. Given that the average number of participants per project is 3, a small share of organizations are substantially more central than the others.[8]

The geographical dimension of a social network can influence the form and the content of a relation (Nag, 2009). Moreover, it can offer powerful insights into the extent to which we have North-South partnerships. To explore the spatial distribution of the mHealth network in this analysis, Fig. 3 maps the relationships generated from project participation. The organizations in our dataset are based in 48 different countries. Ties between countries featured on the map (1) are based on organizational affiliations, and (2) the darker the shade, the greater the frequency of collaboration. Therefore, a country hosting many organizations is more likely to have a strong presence within the geospatial network thanks to the ties created by those organizations.

The map shows that the network has global coverage, even though

[2] https://www.who.int/goe/en/

[3] Personal correspondence with Patricia Mechael, former Executive Director of the mHealth Alliance, highlighted that the mHealth Alliance was phased out in 2014 after an external evaluation uncovered that the platform accomplished its mission to catalyse the field. In the same year, an mHealth Alliance capacity building program started in South Africa where it was registered as a non-profit (HealthEnabled) to carry forward some of the unfinished work of the Alliance in policy, capacity building and research. Additional information can be found here: https://unfoundation.org/media/mHealth-alliance-plans-for-2014-move-to-south-africa/

[4] We use the thresholds indicated by the World Bank and classify a country as low income if GNI per capita in 2019 is <=1,035 USD; middle income if GNI per capita is between 1,036 and 12,535 USD and high income if GNI per capita is $12,536 USD or more (https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups).

[5] https://healthmarketinnovations.org/

[6] In this network, 94% of the ties between organizations take value 1 and the maximum value is 6, which only occurs for the link between the US Centers for Disease Control & Prevention (CDC) and the US President's Emergency Plan for Aids Relief (PEPFAR).

[7] The existence of a "giant" component is due to the high level of transitivity, which is typical of affiliation networks.

[8] http://www.vosviewer.com.

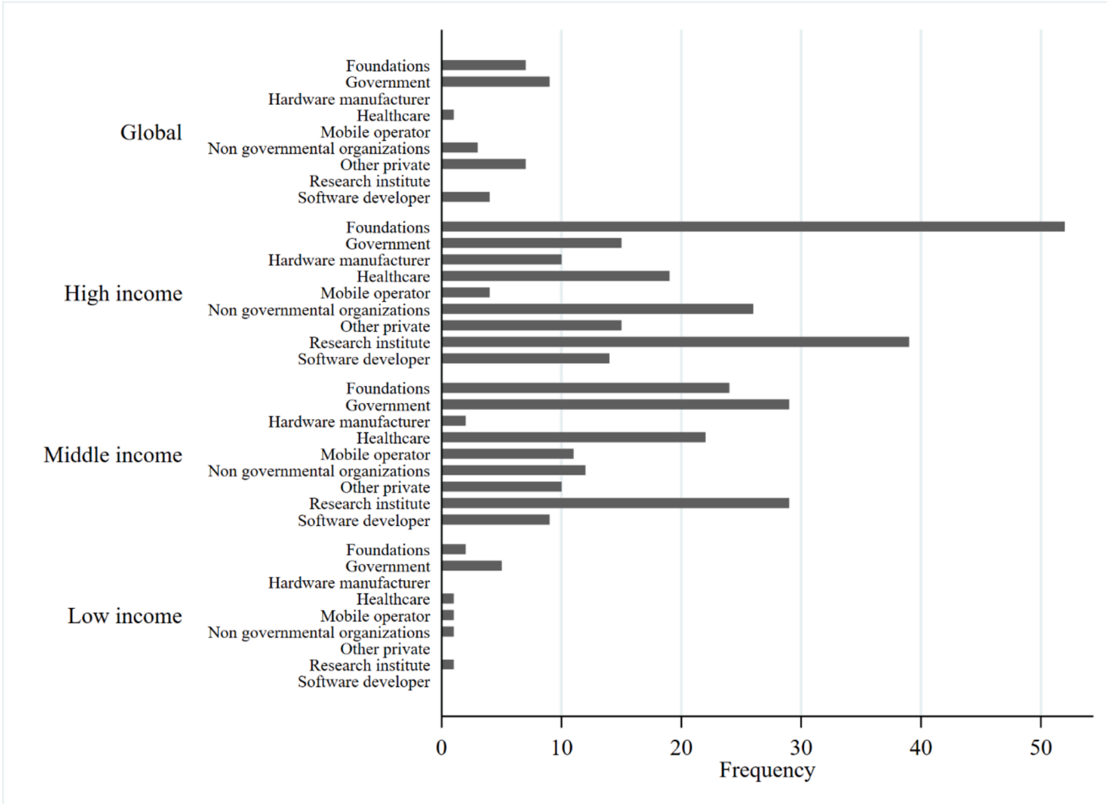

Fig. 1. Participant classification by activity and country of origin.

most projects are implemented in the South of the world, mostly in Sub-Saharan Africa, East Asia and Latin America. In addition, collaboration ties arise across countries and income levels, going well beyond geographical proximity. The ties differ substantially in terms of strength: most of the relationships display a low frequency (white) and only a few of them reflect more regular interactions (red and black). With no exceptions, the strongest ties involve the United States which, among others, hosts the four most central organizations (US Agency for International Development, Voxiva, US President's Emergency Plan for Aids Relief, and the US Center for Disease Control and Prevention).

In general, the participation of developing countries is strictly dependent on the locus of implementation of the mHealth program; they are more prevalent in some countries than in others. In absolute terms, Europe is the continent with the lowest participation intensity: there are only 11 organizations within the network's main component, and all of them have an above average degree centrality. European organizations in our sample include Nokia (Finland), the Royal Tropical Institute (The Netherlands) and BNP Paribas Foundation (France).

4.2. A core-periphery partition

We now explore the possibility that the network consists of two classes of nodes: a cohesive sub-graph and a class of less connected organizations. To do so, we permute the square matrix of the ties among organizations to obtain a core-periphery partition. As a fit function, we use the correlation between the permuted matrix and an ideal structure matrix consisting of 1 in the core block and 0 in the peripheral one. Relaxing the values of the ties and following this algorithm, we get a partition with a core consisting of 70 organizations and a periphery of 314. The core is connected and presents a density of 13.6% which is a substantial improvement considering that the same measure within the main component before the partition was 2%. The periphery is left with a density of 1% and the side blocks reach a level of just 1.3%. Fig. 4 displays the undirectional, non-valued network of the core class.

The actors with the greatest number of ties belong mostly to the public sector: American public institutions such as the US Agency for International Development, the US Centers for Disease Control & Prevention and the US President's Emergency Plan for AIDS Relief. Moreover, we have a strong presence of private companies such as Voxiva (software developer), MTN (mobile operator), Hewlett Packard (hardware manufacturer) and Johnson & Johnson (consumer products). Except for Johnson & Johnson, which acts mostly as a sponsor, the other three companies participate in mHealth project development as partners in-kind. In this respect, we observe that the mobile ecosystem is expanding as software developers and hardware manufacturers increasingly complement the role of mobile operators. Also, the presence of private businesses among the core participants indicates that the tangible and intangible benefits steaming from mHealth projects participation overcome the costs (Buse and Walt, 2000).

Except for Johns Hopkins University, there are no not-for-profit organizations in central positions. This outcome is not surprising, considering the diversity characterizing the third sector: civil society representation ranges from large foundations to small local entities. Furthermore, the role of not-for-profit organizations tends to be less substantial as it is mostly related to advocacy and campaigning: to a certain extent, they serve as a cushion between the actions of the public and the business sectors. For these reasons, the lack of centrality is somehow compensated by the presence of a high number of less central actors.

Central organizations are also characterized by a high level of 'betweenness': within the network they are present across a high number of the shortest paths. In particular, the US Agency for International Development, MTN and the US President's Emergency Plan for AIDS Relief are the most relevant with 25%, 19% and 18% respectively; followed by Voxiva, U.S. Centers for Disease Control & Prevention and Hewlett Packard. It is important to stress that apart from MTN, which is

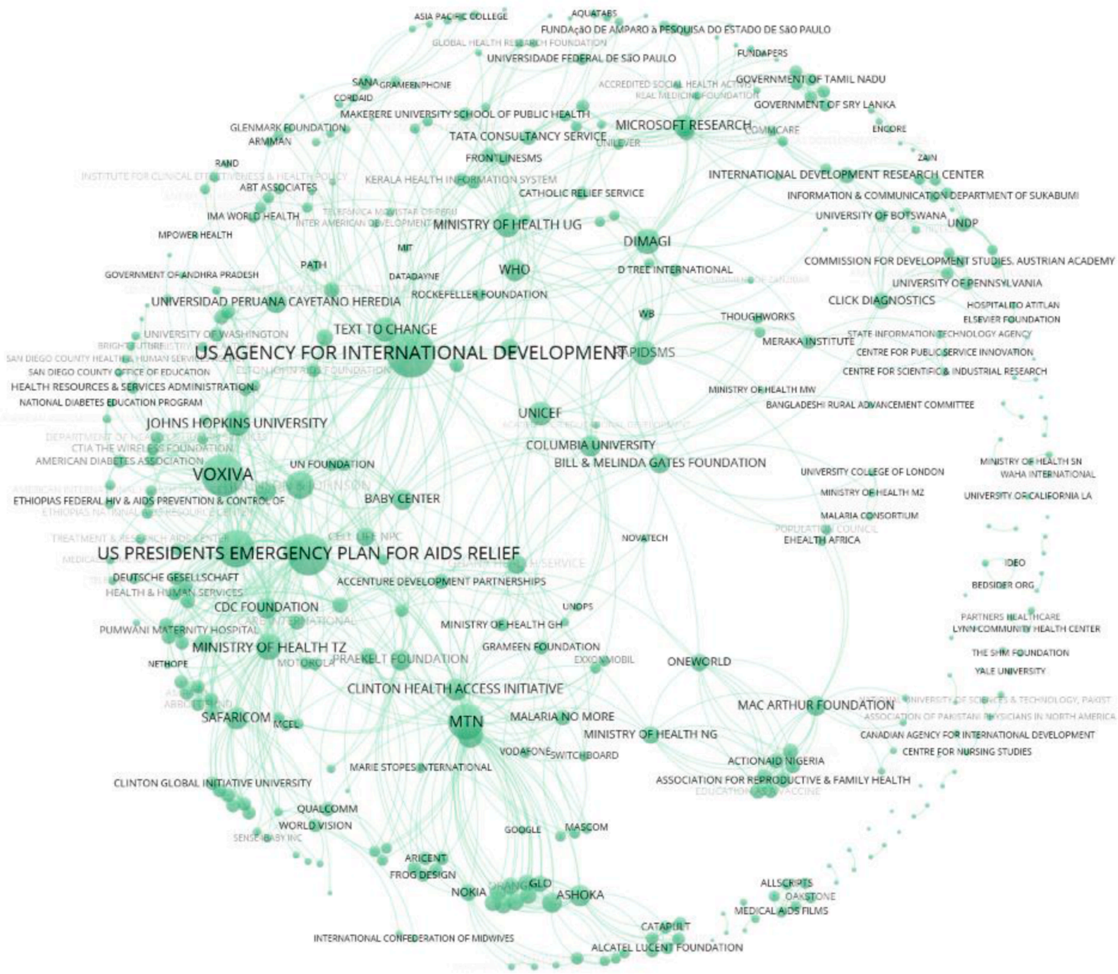

Fig. 2. Organizations' affiliation network Note: the size of nodes and labels is proportional to the degree centrality. Labels are displayed only for a selected number of organizations with a degree centrality above 2. The strength of the links is not displayed. This Figure was produced using VOSviewer (Van Eck and Waltman, 2010).

Fig. 3. Geographic representation of network of project participation Note: darker (red and black) links indicate a higher frequency of relational ties.

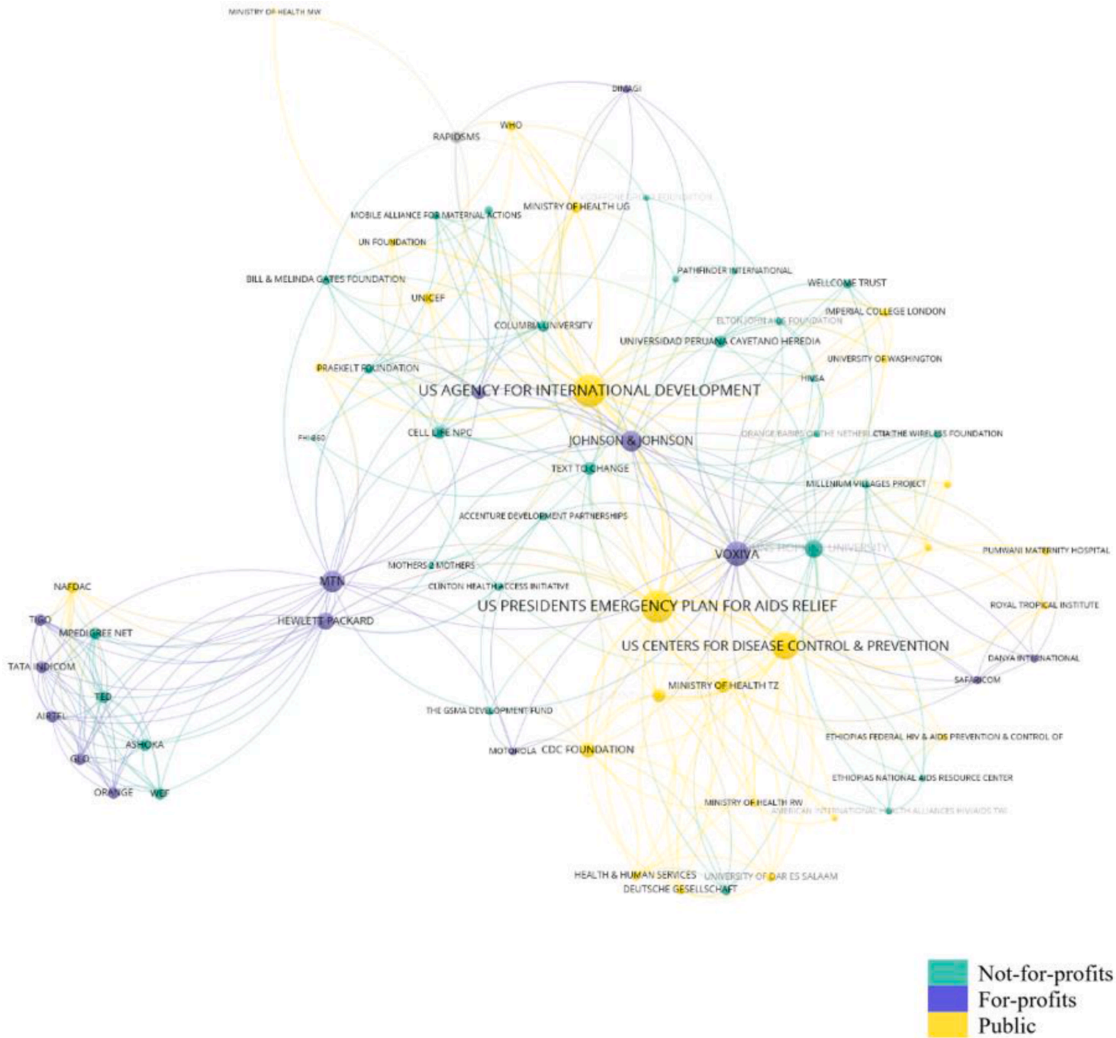

Fig. 4. The core network by type of organization Note: the size of nodes and labels is proportional to the degree centrality. This Figure was produced using VOSviewer (Van Eck and Waltman, 2010).

a South African company, all the other major organizations are based in the US, as an additional signal of North-South inequality (see Fig. 5).

4.3. Organizations and project characteristics

We now assess whether and how project typology changes depending on the centrality of the organizations. From the database, we find that the total number of initiatives promoted by at least one core-class member is 104, while the total number of initiatives promoted by at least two core class members is 52. Table 1 shows that the core is largely involved in projects addressing communicable diseases, which shifts from a share of 26% to a share of 44% when at least two core members are involved. The portion of initiatives addressing reproductive mother and newborn child health (RMNCH) remains largely unchanged, while the percentage of projects devoted to chronic diseases reduces. Given that most of the projects are implemented in developing countries, the results show that communicable diseases are still the prevalent concern in these contexts and that chronic diseases are not a major issue yet.

The proportions in terms of users remain practically unchanged across the three partitions, with 40–45% of the initiatives designed for patients, 45–50% for community health workers and around 10% for physicians (see Table 2). This evidence confirms that mHealth initiatives mostly address community empowerment and capacity building. The first two building blocks of the health system put forward by the WHO concern health workforce and service delivery; accordingly, the primary concern in low-income countries is the shortage of skilled personnel coupled with a large proportion of hard to reach populations (Syed et al., 2012). To improve health conditions, the use of mobile phones can increase patients' awareness and strengthen the intervention of community health workers by supporting them with training and prompt advice (Ibid.). This is an important outcome in relation to the potential of mHealth to manage the current and future diffusion of acute and chronic diseases, such as (for example) the current outbreak of Covid-19.

4.4. Determinants of project survival

The main aim of our empirical analysis is to explore the determinants of mHealth project survival, testing both partnerships and project attributes.

Starting with the former, we first look at the involvement of different types of organizations, introducing a set of dummy variables accounting for the different combinations of organizations in a project (e.g. 'only public', 'public for-profit', 'public not-for-profit'). As previously discussed, we expect diversity in the composition of the participants to play a positive role in fostering the survival and success of the projects.

Second, we include a set of dummy variables accounting for the country of origin of the organizations involved in the projects. Interestingly, there are only two projects entirely promoted by organizations

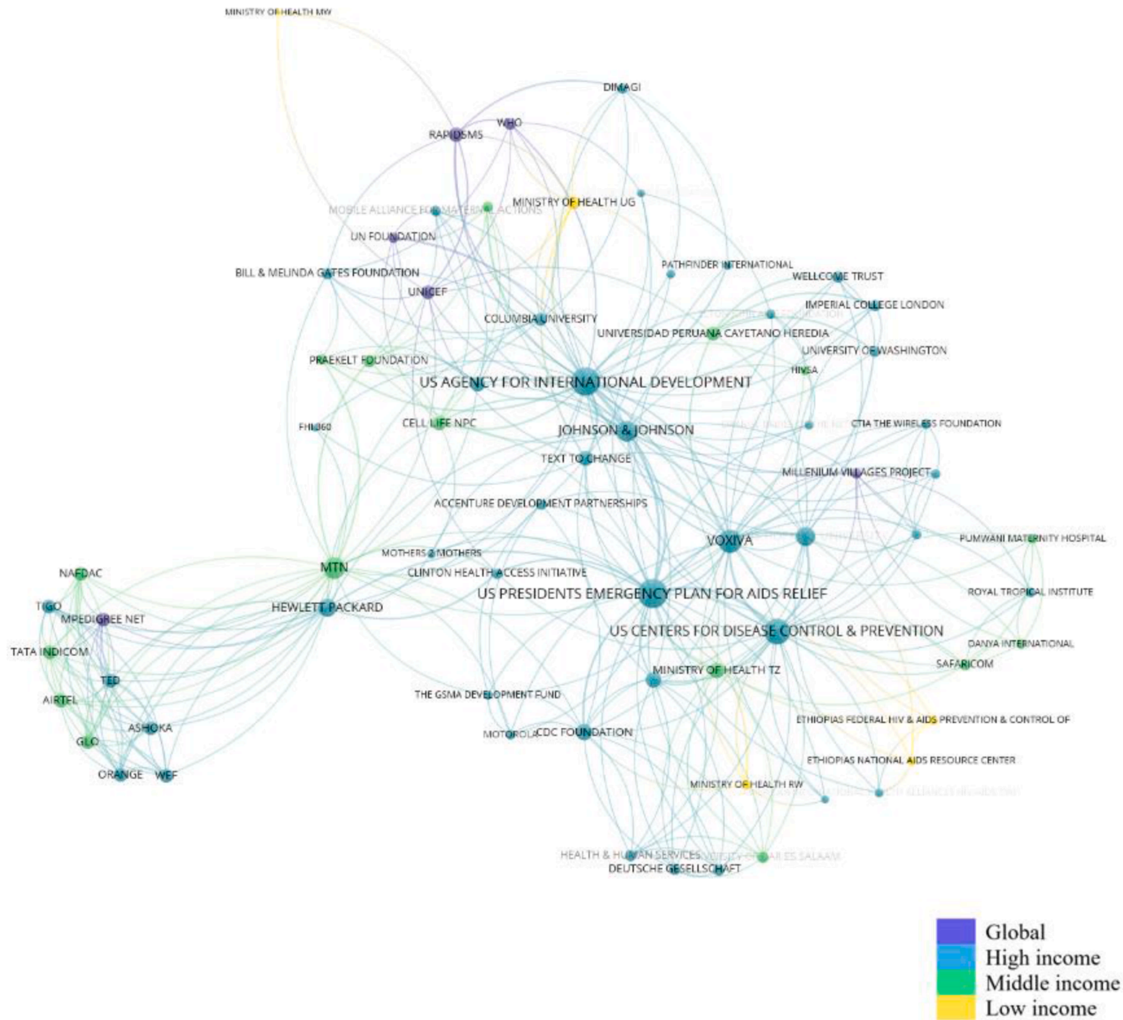

Fig. 5. The core network by the organizations' country of origin. Note: the size of nodes and labels is proportional to the degree centrality. This Figure was produced using VOSviewer (Van Eck and Waltman, 2010).

Table 1
Organizational centrality and project characteristics.

	Chronic diseases	Communicable diseases	General	RMNCH	Total
All projects	24 (12%)	51(26%)	67 (34%)	54 (28%)	196
At least one core member	12(11%)	36(35%)	28 (27%)	28 (27%)	104
At least two core members	2(4%)	23(44%)	15 (29%)	12 (23%)	52

Note: row percentages in brackets.

Table 2
Organizational centrality and project users.

	Physicians	Community health workers	Patients	Total
All projects	22(11%)	96(49%)	78 (40%)	196
At least one core member	9(9%)	50(48%)	45 (43%)	104
At least two core members	5(10%)	24(46%)	23 (44%)	52

Note: row percentages in brackets.

from low-income countries, and no projects promoted by a combination of actors from low and middle-income countries, confirming the presence of strong inequalities in terms of project participation. We also define a binary variable indicating the participation of a local partner. The deployment of successful mHealth projects requires the involvement of different stakeholders who are familiar with both the general features of complex mHealth projects and project management skills, and the specificities of the context. In this respect, we expected that the presence of a local partner could improve the likelihood of mHealth project survival.

Third, we control for the presence of at least one core-class member within the partnership (1=yes, 0=no) and the size of the partnership. Central actors work on several projects and can learn from a large pool of partners; we would therefore expect projects to benefit from this exposure. Similarly, projects developed by a large network of actors — possibly from different sectors and geographic areas — might be more likely to survive and thrive in the market. As far as project-specific characteristics are concerned, we include four variables accounting for the following features: project focus (chronic diseases, communicable diseases, RMNCH, plus a 'general' category); project theme (data collection and disease surveillance, emergency medical response, health information system and point-of-care support, health promotion and disease prevention, treatment compliance); project beneficiaries/users (community health workers, physicians, patients); the income level of the country where the project was implemented (high-middle-low income). Since one of the main objectives of mHealth (and telemedicine more generally) is to facilitate healthcare access everywhere, thereby reducing between and within country inequality (Baudier et al., 2021), we are interested in understanding to what extent the success of these projects can be associated with low and middle income countries.

Table 3 reports the results of the analysis. Model 1 tests the effect of the presence of at least one partner from the core and partnership size, which is operationalized as the number of organizations participating in a project. Model 2 and 3 look at the partnership composition in terms of stakeholders' type, Model 4 investigates the effects of the organizations' country of origin. All the models control for project-specific characteristics.

In terms of project characteristics, M1, M2 and M3 show that projects implemented in high-income countries have higher chances of survival compared with projects implemented in low- and middle-income countries. Accordingly, the initiatives targeting communicable diseases, which are typically implemented in lower-income economies, are less likely to succeed. Moreover, in M4, projects intended for community health workers and physicians are more likely to survive than those addressing patients.[9] On the one hand, community health workers and physicians can be easier to reach compared to patients, and their involvement means that the implementation of projects could be faster and the subsequent impact assessment might be easier to perform. On the other hand, the initiatives addressing resource planning and workforce shortages are more likely to attract the interest of both high-income and low-income partners: since developed countries' workforces diversify in remote and rural areas, planners might benefit from adapting projects that proved to be successful in developing countries (Syed et al., 2012).

Perhaps surprisingly, we find that the presence of a core-class partner did not improve a project's probability of survival. Arguably, since central organizations are involved in more projects by construction, they face higher heterogeneity in terms of project quality and risk level. Indeed, most of these organizations belong to the public sector. The size of the partnership is also not significant, potentially indicating that a high number of participants raises challenges in terms of coordination and governance.

As for the composition of the partnerships, we find that projects promoted by not-for-profit organizations alone are less likely to survive than those in which public and for-profit organizations are involved. In the previous section, we found that not-for-profits play a rather peripheral role within the network, which may prevent them from accessing relevant knowledge and resources. In addition, the coefficients of the organizations' dummies in Model 2 are all negative, indicating that diversity within the partnership is beneficial for project survival. This evidence is confirmed in Model 3, which shows that partnerships involving different types of stakeholders are more likely to be successful, particularly those formed outside of the public sector.

Finally, we find that organizations based in high-income countries are associated with projects that are more likely to survive. However, in line with our expectations, the presence of an organization from the country in which the project is implemented is strongly associated with the probability of project survival. This variable remains significant when excluding local partners that belong to the public sectors. In general, 70% of the projects in our dataset are promoted by at least one local partner and the share increases to 80% when considering ongoing projects alone. Arguably, this evidence indicates that local knowledge and capabilities are a necessary but not sufficient condition for the long-term success of mHealth projects. Table 4 provides a summary of the results of our empirical analysis.

[9] The coefficients are only significant in models 1 (10% level) and 4, but are positive in all models.

5. Discussion

The successful implementation of mHealth projects requires a variety of competencies, which often come from partnerships that span across very different sectors and countries. Several studies have recently emphasised the complementary roles that different stakeholders can play to promote such projects (see for example Liu et al., 2019). At the same time, cross-sectoral and cross-country collaborations may be challenging in terms of coordination, communication and expectations. In line with these contrasting concerns, we find that the size of a partnership has no effect on project performance, which suggests that the costs and benefits of having large networks/partnerships balance each other out. When looking at the specific characteristics of the partnership members, it is reasonable to argue that private and public actors are driven by very distinct incentives, rely on specific resources and experiences and work with very different time frames (Liu et al., 2019; Sucala et al., 2017). In line with this evidence, our study shows that the presence of for-profit organizations in a partnership helps the survival of the project, but we find no significant effects for the participation of public organizations. This suggests that private companies' incentive structures and skills may help both in terms of project selection and in terms of project implementation.

The findings of the empirical analysis also provide a useful perspective from which to consider the implications of network centrality. In the network we analyze, the most central actors are large public organizations from high-income countries. Centrality comes from collaborating with many other actors, which to some extent implies working on many projects. Surprisingly, we find that the involvement of these actors has no significant (positive) effect on a project's likelihood of survival. One the one hand, extensive involvement might be associated with both promising and risky projects. In particular, since central actors are mostly public organizations, we could expect them to promote projects that might be less appealing to private actors. On the other hand, organizations that work on many projects might be less concerned with individual project performance. The lack of business-oriented goals and expectations in the public sector may also lower the expectations in terms of project success and survival. This attitude would also be consistent with the systematic lack of impact assessment that still characterizes mHealth initiatives and prevents them from scaling up (World Health Organization, 2016). In other words, a broad exposure to the network can only be beneficial if it is coupled with an active effort to collect evidence and derive lessons from it.

The misalignment between goals and expectations is also likely to emerge among partners coming from different countries and contexts. In these cases, effective cross-cultural communication is thus crucial (Liu et al., 2019) to project success. Local partners could play a mediating role in this sense, serving as a bridge between external intervention and knowledge of the local context. As expected, we find that their participation — whether from the public or the private sector – increases a project's probability of survival. This dialogue could also accelerate the process of endogenous capacity building at different levels.

The complexity of stakeholder relationships is compounded by the nature of (digital) healthcare processes, which include clinical, administrative and technical tasks; data; patient users and other users (Laurenza et al., 2017). The success of mHealth projects in high-income vs. low-income countries confirms the idea that these innovations require technological support (infrastructure, bandwidth, software) as well as qualified medical staff. Furthermore, mHealth projects must be adopted by practitioners and patients (Baudier et al., 2021; Bashshur et al., 2009).

6. Conclusions

This paper investigates the characteristics of the networks behind the deployment of mHealth projects and studies the determinants of projects' survival. In doing so, it contributes to the existing evidence on

Table 3
Determinants of project survival.

DV=project survival	M1 Coef.	SE	M2 Coef.	SE	M3 Coef.	SE	M4 Coef.	SE
Organizations' attributes								
Only public			-0.74	0.76				
Only for-profit			-0.43	1.59				
Only not-for-profit			-1.41*	0.69				
Public and for-profit					1.13	0.73		
Public and not-for-profit					0.85	0.64		
For profit and not-for-profit					1.59*	0.7		
Multi-stakeholder partnership					0.96	0.78		
Only orgs based in HI countries							3.11*	1.53
Only orgs based in MI countries							-0.54	1.4
HI-MI partnership							1.08	1.11
Local partner							2.95**	1.11
At least one partner from the core	0.61	0.49	0.38	0.51	0.46	0.49	0.39	0.51
Partnership size	0.09	0.11	0.02	0.12	0.04	0.13	0.02	0.14
Project attributes								
Focus								
Chronic disease	-0.86	0.69	-1.02	0.73	-1.1	0.72	-1.26†	0.73
Communicable disease	-1.24†	0.65	-1.31*	0.66	-1.32†	0.68	-1.79*	0.74
RMNCH	0.47	0.44	0.48	0.45	0.52	0.46	-0.19	0.5
Theme								
Data collection and disease surveillance	-0.76	1.04	-0.97	1.18	-0.77	1.17	-1.90*	1.03
Emergency medical response	-0.2	1.06	-0.34	1.19	-0.23	1.17	-1.58	1.11
Health information system and point-of-care support	0.01	1.01	-0.14	1.16	0.08	1.13	-1.15	1
Health promotion and disease prevention	0.56	0.97	0.52	1	0.42	1.01	0.39	0.97
User								
Community health workers	1.05†	0.63	1.21	0.74	1	0.76	1.87*	0.74
Physicians	1.19	0.73	1.3	0.85	1.08	0.87	2.15*	0.88
Country								
High income	3.38***	0.87	3.28***	0.94	3.13***	0.99	0.65	1.6
Middle income	-0.2	0.5	-0.29	0.52	-0.32	0.49	-1.02	0.83
Cons	-2.51*	1.11	-1.7	1.16	-2.82*	1.19	-4.21**	1.6
Obs	196		196		196		196	
R2	0.2		0.23		0.23		0.25	
prob>chi2	0		0.01		0.02		0	

Note: logit models with robust standard errors, † if p-value < 0.1, * < 0.5, ** < 0.01, *** < 0.001.

Table 4
Summary of results.

Dimension	Evidence
Organizations and partnerships	The partnerships form a connected network with global coverage The participation levels are highly skewed, with few hubs dominating the network Most of the organizations are based in high-income countries
A core-periphery partition	Central actors are mainly public and for-profit organizations Central actors are mostly based in high-income countries
Organizations and project characteristics	Most of the projects are implemented in low and middle income countries Central actors are primarily involved in projects addressing communicable diseases 60% of the projects target community health workers and physicians
Determinants of project survival	Actor centrality and partnership size do not affect probability of project survival Sectoral diversity within the partnership is beneficial for project survival Projects promoted by organizations in high-income countries are more likely to succeed The presence of a local partner increases the chances of project survival

mHealth diffusion, by focusing in particular on the role and interplay of different public and private stakeholders within the networks and on the potential inequality across countries in relation to the success of mHealth projects. We found that there exists a highly connected network of organizations behind the implementation of mHealth projects. In terms of composition, the network displays a high heterogeneity of sectors and countries. Participation includes the public sector, for-profit and not-for-profit organizations, and it reaches global coverage. This suggests that global public-private partnerships represent an efficient way of managing mHealth projects that are complex, involve heterogeneous stakeholders and require the development of a diverse set of capabilities. However, actors' relative importance within the network varies substantially, and some categories are better represented than others. In particular, public authorities and private businesses have a higher frequency of collaboration compared to the third sector, which instead hosts a higher number of less relevant actors. Also, most of the central organizations are based in high-income countries, while actors from low-income countries are rarer. Considering that the majority of mHealth initiatives are implemented in low-income settings, that bias is likely to reduce the partnerships' representative legitimacy and accountability (Buse and Walt, 2000). Overall, the North-South inequality coupled with the weak participation of the third sector highlights the problem of low levels of local involvement, which may affect a partnership's ability to identify and pursue common goals (Gaillard, 1994).

This study has highlighted that a systematic assessment of the mHealth ecosystem can provide valuable information on the performance of the sector as a whole. The current outbreak of Covid-19 represents an important driver for the implementation and diffusion of mHealth applications and services related to electronic patient-reported data and digital contact tracing, opening up important avenues for the development of information exchange protocols that support diagnostic testing. However, it is important to underline that given the complexity of healthcare services and the need to involve different stakeholders in their implementation, most of mHealth initiatives remain limited in scope and might not manage to obtain enough funding to grow and expand at the global level (Mechael and Searle, 2010). In this respect, the emergence of public-private partnerships seems to be a promising form of networking for these projects to take-off.

By analysing the characteristics of the partnerships and the determinants of their success, both in terms of project-specific features and in terms of organizational peculiarities, it is possible to explain (at least partially) the drawbacks associated with existing mHealth programs and to derive some managerial and policy implications that are useful for practitioners and policy-makers who are interested in boosting the diffusion of such innovative projects.

First of all, there is a need to stimulate the emergence of networks comprising actors who are diverse in terms of scope and geographical location, since one of the main objectives of mHealth and telemedicine more generally is to improve access to healthcare everywhere and decrease between- and within-country inequalities. This is particularly relevant in light of the COVID-19 pandemic (Baudier et al., 2021).

Also, it is important to involve local actors — particularly in emerging countries — with knowledge of context-specific needs and the capacity to interact with local communities of health workers and patients. In this respect, it is important that healthcare authorities and policy-makers participate in actively stimulating the development of these projects, communicating the advantages and benefits of these innovative services to patients and doctors. Finally, given the technological developments associated with smartphones and wearable technologies, it would be relevant to create networks involving the manufacturers of products that can provide innovative solutions and improve the functionality of systems providing specific healthcare services. This is because widespread adoption of mHealth through wearables and apps not only represents a crucial step in future telehealth development (Vesselkov et al., 2018), it will also extends the reach of mHealth well beyond facilitating communication between patients and doctors or healthcare organizations.

The present work presents several limitations leading to potential avenues for future research. Our analysis was performed on a small sample of mHealth initiatives, and important characteristics were not included. In particular, it would be relevant to make a distinction between in-kind partners and sponsors, to better articulate the structure of the network and role of the partners. While private actors are generally business oriented, a sponsorship might rest on a very different set of incentives and expectations. Also, the temporal dimension could be investigated, along with a systematic collection of impact assessments to gain a deeper understanding of the project lifetimes. In this respect, our empirical analysis is built on the assumption that the projects for which we could not find evidence of activity in 2020 have been discontinued. It will be important to understand if organizational phase-outs take place as projects become self-sustaining or are merged with other initiatives, for example. This is especially relevant in the context of developing countries, in which failure to trace a certain activity does not necessarily mean that such activity has been discontinued.

CRediT authorship contribution statement

Giovanna Capponi: Writing – original draft, Data curation, Formal analysis. **Nicoletta Corrocher:** Conceptualization, Writing – original draft, Writing – review & editing.

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Giovanna Capponi is assistant professor in Innovation Studies at the Copernicus Institute of Sustainable Development (Utrecht University). She obtained a PhD in Economics at the Sant'Anna School of Advanced Studies in 2018 and an MSc in Economics and Management of Innovation and Technology at Bocconi University. Her main research interests concern the processes of innovation development and diffusion, appropriability strategies, innovation within firms and knowledge sharing.

Nicoletta Corrocher is a Lecturer in Applied Economics at Bocconi University and Research Fellow at ICRIOS. She obtained a Ph.D. in Economics and Management of Innovation at the S. Anna School of Advanced Studies in Pisa, and a Master degree in Science and Technology Policy at SPRU – Sussex University. Her main research interests concern the diffusion of innovation and industrial dynamics - particularly in ICT and service sectors - and the process of sustainable development.