The effects of the Introduction of Information and Communication Technologies on interaction dynamics between citizens, service providers and rulers in precarious health care settings: insights from an mHealth pilot experiment in rural Guatemala

José Tomás Prieto

École polytechnique
Institut Interdisciplinaire de l'Innovation i³
Centre de Recherche en Gestion

Thèse présentée pour l'obtention du titre de
Docteur de l'École polytechnique

Spécialité Économie et Gestion

José Tomás PRIETO

Soutenue le 25 mars 2015

Les effets de l'introduction de Technologies de l'Information et de la Communication sur les interactions entre citoyens, fournisseurs de services et gouvernants dans des contextes précaires de santé.

Un regard empirique à travers une expérience pilote de santé mobile en milieu rural au Guatemala.

Membres du jury:

Pierre-Jean BENGHOZI	Professeur - École polytechnique, France Co-directeur de thèse
Eric BROUSSEAU	Professeur - Université Paris-Dauphine, France Co-directeur de thèse
Laurent GILLE	Professeur - Télécom ParisTech, France Examinateur
Flore GUBERT	Chargée de Recherche - IRD, France Rapporteur
Anna KYDD	Directrice - The SHM Foundation, Royaume-Uni Examinateur
Patricia MECHAEL	Senior Advisor mHealth - UN Foundation, États-Unis Examinateur
Étienne MINVIELLE	Professeur - École des Hautes Etudes en Santé Publique, France Rapporteur
John O'DONOGHUE	Senior Lecturer – Imperial College London, Royaume-Uni Examinateur

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Jose Tomas Prieto Doctoral thesis

March 25, 2015

Doctorat de l'Ecole polytechnique en sciences économiques et sociales

Rapport sur la soutenance publique

At the end of the preliminary meeting of the jury, thereof designates as President Laurent Gille, Professor at Telecom ParisTech. The other members of the jury are Flore Gubert, Researcher at IRD (Examiner), Etienne Minvielle, Professor at EHESP (Examiner), Anna Kydd, Director SHM Foundation (UK), Patricia Mechael, Senior Advisor mHealth UN Foundation (USA), John O'Donoghue, Senior Lecturer in eHealth & Deputy Director Global eHealth at Imperial College, London, Eric Brousseau Professor at the University Paris Dauphine (Co-supervisor), Pierre-Jean Benghozi, Professor at the Ecole Polytechnique (Co-supervisor).

In his introduction, Jose Tomas Prieto recalls the origin of his research question, his original argument and the epistemological framework, milestones of literature and original methodological choices he has selected in consequence. Political engagement seems to be supported by Information and Communication Technologies. ICTs seem to be affecting traditional health care services as well. The association between the use of ICTs and change in societies is however difficult to establish and the relationship between them is often anecdotal. Jose Tomas Prieto's doctoral thesis is one attempt to present ICT-induced change through theory and experimentation.

After the introductory presentation of the doctoral candidate, the President gives the floor to the first examiner, Dr. Flore Gubert. She highlights that the thesis addresses a topic that is original and of high interest in the Guatemalan context as it explores both theoretically and empirically the potential role of e-health in improving access to health information and in empowering health-care seekers. It

is composed of six chapters, the first three ones presenting a state-of-the-art literature review on ICT-based health programs together with a theoretical framework, and the three last ones presenting the design and the insights of a mobile-health pilot experiment implemented in rural Guatemala. The thesis is well-structured, well-written in clear and concise manner and demonstrates that the candidate is able to go through all the searching steps from the elaboration of a unified theoretical framework to the design and implementation of a pilot randomized control trial. Despite its exploratory nature, the pilot experiment provides interesting insights on the potential impact of an ICT-based health program, and even though the robustness of the results is questionable given small sample size and potential endogeneity issues, they are promising and should encourage the candidate to replicate his experiment at a broader scale. Flore Gubert's overall appreciation of the thesis is thus highly positive.

It is then the second advisor, Pr Etienne Minvielle, to report his comments. He notes that the first part of the dissertation is very clear, and offers a precise analysis of different concepts related to his framework such as patient "empowerment", "social capital", and the role of gatekeepers in the use of mobile devices for sending preventing messages.

The empirical part (second part) offers an application of the theoretical framework through a pilot test study. This study is dependent on different practical and statistical concerns that sometimes limit the impact of the results. However, many very interesting findings can be noticed, such as the need to combine human relations between participants and the use of new mobile devices for improving the efficacy of preventing messages. As a result, the dissertation of Jose Thomas Prieto gives important insights about the potential added-value of new information technologies for improving health care prevention program in the context of vulnerable populations.

After the first two advisors, it is then the turn of the other members of the jury to make their comments.

For Dr John O'Donoghue, it is imperative that research conducted at all levels (industry, Masters, PhD, Post-Doctorial etc.) generates meaningful and quantifiable impact. The work presented by Jose Tomas Prieto is multidisciplinary in nature and applied in a real world setting. The thesis addresses the following research question: can mHealth supports community healthcare workers in low resource settings to assist mothers as part of their breastfeeding regime? The results presented are more focused on the community healthcare workers and their level of interaction, with little data presented on the impact on the mothers and their breastfeeding regime. The results presented are meaningful as they highlight the impact of three different interaction models 1) vertical, 2) horizontal and 3) hybrid. Post PhD it would add a great deal of value if these models were assessed with regards to their impact on the mothers. The level of effort required to assess the 3 models of interaction is significant.

The relative impact of these three models over other social media methods (Twitter, Facebook, etc.) is not known. One could argue that these methods could have a bigger impact in the support of mothers and their breastfeeding regimes. This would require a multi arm RCT which is out of scope of the PhD. The next examiner, Mrs Anna Kydd, declares to have been very impressed with the approach that Jose Tomas Prieto took to his thesis in terms of differentiating between horizontal and vertical interventions in mHealth within the context of a country such as Guatemala. She reminds she

has considerable experience working in the field of mHealth in low to middle income countries and there is very little mention of this difference with almost an assumption that mHealth is all about one directional communication to the user. Jose Tomas Prieto work has helped to contribute to this research gap in the low to middle income countries.

Mrs Anna Kydd asks Jose Tomas what he thought were the challenges of introducing what he is calling a hybrid platform (vertical and horizontal interventions) in Guatemala in the context where there is a severe lack of resources in terms of medical staff and medication and whether it was appropriate to implement an mHealth intervention in these circumstances.

Then, Prof Laurent Gille also congratulates Jose Tomas Prieto for the experimental setup developed in a remote area of Guatemala and welcomes the clarity of words developed in the thesis, both the precision and the caution with which the results are presented. He asks Mr. Prieto on two methodological points, first the possible bias introduced by the lost population during the investigation and for the other, the ability of the experimental setup to discriminate clearly what Mr. Prieto called a horizontal approach from a vertical approach. He feels that concretely, populations must fall within a qualified hybrid situation considering all means of communication available to them.

He also wonders about the possible interaction between the beliefs of any kind of these populations and medical information provided to them. Furthermore, the relationship between patient and physician is mediated by a technical device here a telephone and a SMS platform, or even a written language. This mediation is considered neutral in the experimental protocol in place. However, some take into consideration the relationship between a patient and his caregiver fall under a singular dialogue and that empathy, the doctor's authority, his knowledge, its respect and listening of the patient, play a major role in the process of accession to the prescription or healing. Is it a possible bias considered in the experimentation?

Pr. Pierre-Jean Benghozi, one or the co-supervisor, opens the last word, first thanking all members of the jury. He notes that the thesis of Jose Tomas Prieto has very many qualities that make it a symbolic approach of the work may be conducted at Ecole Polytechnique. The arguments and the very clear answers to questions also demonstrate a real mature thinking. The research topic is primarily an issue for knowledge, in tune with the most recent developments on Internet governance and the economic and social effects that accompany the development of ICT. In addition, this research is not simply an exercise in academic style: the choice of empirical field investigation on health issues in developing countries reflects sensitivity and a remarkable embeddedness in social concerns.

Jose Tomas Prieto's approach is quite original and fertile. It expresses, in the analysis and the methodological choices, his abilities to capture the main topics of the literature (digital economy, health economics, behavioral sciences, public administration) and to implement concepts and methods needed to answer his research questions. Thus the thesis mobilizes theoretical modeling approaches, econometrics, interviews as well as methods for in situ pilot experiments quite at the forefront of modern approaches in economics. Beyond the interest of the subject and the quality of the process, the discussion and results also demonstrate the maturity of the research. Jose Tomas Prieto not only brings elements of knowledge on unfamiliar terrain, it provides first - especially

through the concepts of collaborative governance - an original analysis and understanding of the role of ICT in social economy and social organization of relations between citizens, rulers and technology players. These results shed a particularly stimulating light on the public intervention, especially in health policy. Pr. Benghozi concludes, finally emphasizing the international dimension of the thesis.

Pr. Eric Brousseau, the second co-supervisor, highlights that any assessment of the dissertation of Jose Tomas Prieto should start from the fact that it was impossible to undertake a test per se of the impact of communication technologies on healthcare provision. So the choice was made to perform a feasibility study on the impact of a mobile phone based service in a specific context; and on prevention behaviors rather than care provision per se. Thus, the outcome of this remarkable piece of research should not be judged as if it was an applied study to be relied upon to make decision. However, it provides very useful insights, not only to build future large-scale field studies, but also, from a more theoretical perspective, on the causal relationships to be further investigated. Second, he reminds the process that led the applicant to start from very large and broad questions — namely, the impact of ITs on political dynamics, as suggested by the Arab Spring, and the processes of institutional transformations explored by the broad literature on institutions and development — to identify more specific questions — the factors explaining how governments might be incited to improve public good provision — then to the specific subject of the dissertation. He underlines the ability of José Tomas to make the best use of the comments he received, to explore new literatures, to question his own past work, and to rebuild something totally different, while consistent, at each step. It was one of the nicest processes of dissertation making he experienced. He then congratulates José Tomas and asks him to keep his modesty, and his eagerness to learn, and his social ambition for the future. He thinks that not only the result but also the process that resulted into this dissertation highlight that José Tomas is a high potential researcher, and that he would succeed and be useful whether he would embrace an academic career or a one more oriented toward research-action.

After each member of the jury made her/his point, Jose Tomas Prieto had the opportunity to respond stating its findings and methodological elements. His answers made clear the issues at stake and satisfied the jury.

After deliberation, the jury decided unanimously, to award Jose Tomas Prieto with the doctoral degree in economics and social sciences, with "very honorable" mention. The jury stressed on this occasion that the Ecole Polytechnique does not deliver higher mentions (formal felicitations e.g.).

ÉCOLE POLYTECHNIQUE
UNIVERSITÉ PARIS-SACLAY

Palaiseau, May 12th 2015

CERTIFICATE

The President of Ecole Polytechnique, certifies that:

Mr Jose Tomas PRIETO
born on June 17th 1985
in Guatemala - GUATEMALA
Has completed all the requirements of the PhD at Ecole Polytechnique.

Mr Jose Tomas PRIETO successfully defended his dissertation on March 25th 2015 and had the document accepted in final form on March 25th 2015.

Speciality: Humanities and Social Sciences
Title: *The effects of the introduction of Information and Communication Technologies on interaction dynamics between citizens, service providers and rulers in precarious health care settings. Insights from an mHealth pilot experiment in rural Guatemala.*

The jury was composed as follows:
Mr Pierre-Jean BENGHOZI, Supervisor
Mr Eric BROUSSEAU, Examiner
Mrs Flore GUBERT, Referee
Mr Etienne MINVIELLE, Referee
Mr Laurent GILLE, President of the committee
Mrs Anna KYDD, Examiner
Mrs Patricia MECHAEL, Examiner
Mr John O'DONOGHUE, Examiner

Mr Jose Tomas PRIETO's degree will be officially conferred at Ecole Polytechnique in a public defence ceremony in 2016.

Frank PACARD
Director, Doctoral School
of Ecole Polytechnique

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José Tomás PRIETO
25 mars 2015

I3 - CRG CNRS - UMR 9217
Bâtiment ENSTA – 828, Boulevard des Maréchaux
91762 Palaiseau Cedex, France.

L'Ecole Polytechnique n'entend donner aucune approbation ni improbation aux opinions émises dans les thèses ; ces opinions doivent être considérées comme propres à leurs auteurs.

Cafés du 6ème,
Paris.

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Preamble

Four years ago, political events in Northern Africa captivated the attention of citizens of the world. It is difficult to forget that in December 2010, Mohamed Bouazizi set himself on fire as a protest against police abuse in Tunisia (Fahim, 2011; Worth, 2011), and that Tunisians took to the streets to vent their frustration at the government. The weeks of intensive protests led to the ousting of President Zine El Abidine Ben Ali on January 14, 2011 (Davies, 2011).

In 2012, a telecommunications operator in the Maghreb granted special access to anonymous details about the activity of mobile users[1], precisely at the time of instability in Tunisia. The data presented Internet, voice and SMS exchanges from the beginning of November 2010 to the end of March 2011. These digital footprints uncovered citizens' communications during a defining historical moment.

Traditionally, activity in a telecom network is in great deal predictable[2], and complex statistics are not always required to anticipate trends: intense use of Internet in the evenings, high text-message activity during the week-ends and peaks of activity in New Year's eve are typical examples. Phone call activity in the Tunisian's telecom network followed these rules for most of the 4-month window. The few exceptions, however, were captivating.

Daily and weekly patterns were clearly disrupted at the beginning of 2011. The number of daily calls peaked on the 15th of January, the day after the President's expulsion from Tunisia. Text-messaging behavior suffered unexpected alterations from December 2010 to January 2011, precisely during important mass protests. More than 7 million text-messages were sent, versus 4 to 5 million in a normal day. The 19th of January was, by far, the most active day with over 16 million SMS sent through the telecom operator's network.

Internet use revealed perhaps the most intriguing transformation. Activity, in terms of bytes downloaded and uploaded, peaked between the 10th of December and the 16th of December 2010. The irregular intensification of Internet activity actually *preceded* the drastic political changes.

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[1] Very special thanks to K. C. for granting access to the data.

[2] I first became aware of the predictability of users' activity in telecom networks during a research opportunity in Gabon in 2011. For details, however, see Roberts (2011).

The behavior of Tunisian mobile subscribers at the end of 2010 illustrates a correlation that has been increasingly discussed in the literature: socio-political evolution is accompanied by Information and Communication Technologies. Today, however, a *causal* link between the use of ICTs and political evolution cannot be established. The problem is that there is still too little solid evidence to argue that technologies have indeed changed socio-political and socio-economic outcomes. In 2012, the challenge to shed light on this puzzle was taken, in a different context...

Résumé

Les Technologies de l'Information et de la Communication (TICs) sont ubiquitaires dans les systèmes de santé. Les innovations récentes, allant des services publics en ligne aux objets connectés, sont adoptées avidement par patients, hôpitaux et gouvernements, partout dans le monde. L'influence des TICs sur la qualité et les coûts des services de santé a été largement étudiée. Pourtant, leurs impacts sur les interactions entre individus restent méconnus, notamment dans les contextes précaires de santé, où peu de recherche théorique a été effectuée.

Cette thèse tente d'éclaircir les effets de l'introduction des TICs dans les environnements précaires de santé. Dans ce but, elle décrit, dans la première partie, un cadre d'analyse intégrateur et multidisciplinaire, inspiré de développements en économie de la santé, en sciences comportementales et en administration publique. La formulation de ce cadre de référence permet de suggérer plusieurs hypothèses en relation avec des résultats de santé, la co-production de services, et les interactions entre individus en présence de technologie mobile. Dans la deuxième partie, la méthodologie qui a été menée pour tester le modèle est présentée. Ici, les discussions principales se centrent sur l'étude d'impact d'une expérience pilote de santé mobile qui a été réalisée dans le Guatemala rural.

Les contributions principales de ce travail reposent sur le modèle théorique qui a été créé et sur la stratégie expérimentale qui a été déployée pour vérifier sa validité. Les résultats montrent l'intérêt d'un arrangement organisationnel particulier: des communautés virtuelles de mères indigènes exposées à des services de soutien, à des conseils provenant de professionnels de la santé, et à des échanges rapides *via* message de texte (SMS). La gouvernance de l'information et des services devient *collaborative* lorsque individus, fournisseurs de service, et décideurs cherchent à résoudre les défaillances du *status quo* sanitaire.

Mots clés: santé mobile; allaitement; économie; santé; évaluation; impact; e-health; développement; politique; comportement; maternal

Summary

Information and Communication Technologies (ICTs) have ubiquitous influence on health systems. From smartphone applications and web services to wearable devices and the Internet of Things, innovations are eagerly adopted by patients, clinicians, health centers and governments worldwide. Although their effects on health outcomes, quality and costs have been previously studied, little effort has been made to describe their implications on interactions between individuals. The assessment of their impact is particularly difficult in low-resource health settings, where fundamental dynamics have been disregarded by theoretical studies.

This thesis was constructed as an attempt to reduce gaps in the literature about the effects of the introduction of ICTs in low-resource health settings. In the first part, it draws on empirical and theoretical insights from health economics, behavioral science and public administration to consolidate a unified framework. Its formulation allows to derive empirically testable hypotheses regarding health outcomes, co-production of services and actor interactions when mobile technology is *introduced*. In the second part, it presents the methodology used to generate unique data and to test some of the model's predictions. Principal discussions and conclusions focus on the impact evaluation of a mobile-health pilot experiment that was run in rural Guatemala in the context of newborn and maternal care.

The novelty of the thesis lies in the proposed theoretical framework and in the adopted experimental strategy. Results from the pilot experiment highlight the interest of a peculiar organizational setup —virtual communities of indigenous mothers exposed to social support, expert advice and timely medical response via text-message— for precarious health care contexts. Discussions, albeit limited in scope by the exploratory nature of the intervention, shed new light on the impact of ICT-based heath programs in poor contexts. *Collaborative governance* between citizens, service providers, governments and research entities seems appropriate when sustainable changes in health systems are needed. Analyses are of timely relevance for countries looking to scale-up interventions with potential to induce healthy attitudes in underserved areas.

Keywords: mobile health; Guatemala; economics; health; impact evaluation; e-health; development; political; behavior; breastfeeding; maternal

General introduction

Information is *not* power.

Not today, when it's so easily found. On the contrary, the endless repositories of openly-accessible information, sometimes reliable and sometimes questionable, complicate the location of the *truth*. Individuals are compelled to rely on *digital data gatekeepers* like search engines or social networks to locate the facts that ought to be consumed. As these intermediaries grow in popularity, they also seem to gain power, because they are trusted with the responsibility of filtering information, even when the rules of their algorithms are intentionally obscure[1]. Almost imperceptibly, gatekeepers provide individuals with technically-biased arguments, ideas and opinions[2].

Information is not power; it's just not enough. However, data gatekeepers *hold* power.

Gatekeepers in control should be able to extract informational rents in an era where humans continuously leave digital information trails. News media have revealed that governments and intelligence agencies worldwide have eagerly invested in information technology to supervise markets, to catalyze public management processes, and to keep an eye on the citizenry (Lohr, 2012; Risen and Poitras, 2014; Savage, 2014). From a different perspective, it has also been argued that virtual social networks and mobile technology have played a key role during citizen uprisings (Zuckerman, 2009a, 2009b; Zhang et al., 2010; Attia et al., 2011; Desouza and Lysenko, 2011; Klischewski, 2014; Sandoval-Almazan and Gil-Garcia, 2014), and the question of whether technology platforms were a major cause of political change during and after the Arab Spring in 2011 continues to be debated.

But if the control of Information and Communication Technologies (or ICTs) is an empowering mechanism, who is truly powerful today then? The answer is

[1] Google's and Facebook's algorithms are purposely protected by patent and copyright laws. For details, see Benghozi (2008).

[2] "There may be links out there, but if you can't find them through a search engine they might as well not exist" (Toobin, 2014). Parallels could be drawn between this *digital data gatekeeper bias* and the more studied news media bias, which allegedly affects votes and reputation in political environments. For details about the news media bias, see Gentzkow and Shapiro (2005), Groseclose and Milyo (2005) or DellaVigna and Kaplan (2006).

cumbersome. In fact, the notion of control itself is relative because information is *governed* at different levels. In some cases, it might be judicious to see control as a property of individuals (such as their access to technology or their digital dexterity), but in some other, the notion might just be best related to the ownership of infrastructure. The role of technology during uprisings in Egypt, Tunisia, Iran and Moldova is one example. Although the use of social network websites and mobile communications fostered citizen collaboration, it is claimed that governments were able to selectively restrict information flows in telecom networks (Sutter, 2011; El Gazzar et al., 2011). These *informational wars* that introduced noise in communications sought to discourage or encourage citizens from engaging in political demonstrations.

The role of technology in health care is a second example. High-income countries have shown that the adoption of ICTs in health systems sparks change. Hospitals and health providers have improved management, responsiveness and quality of services (Athey and Stern, 2000; Minvielle et al. 2014), and electronic networks have been deployed at national levels in order to homogenize health standards, facilitate citizen mobility and increase population's welfare (European Commission, 2009, 2010). Studies based on the high-income experience have also shown that patients have acquired a more active role through the use of mobile applications. The self-management of long term conditions like diabetes and asthma is now supported by a few health apps (Patrick et al., 2008, Ackerman et al., 2010; Huckvale et al., 2012), but in 2015, half a billion smartphone owners will be using a health care app. In three years, one and a half billion people are projected to use a mobile health app (research2guidance, 2013).

The effects of information technology in health care are of particular interest because the historical relationships that have been moulded for centuries between patients, health providers and governments might be *inadvertently* affected. The fundamental bond between patients and doctors, for instance, is known to be colored by informational asymmetries: doctors are trusted because they hold information particularly difficult to obtain and because they are supposed to act on the patients' best interests. It is however surprising that the question of control and empowerment has seldom been treated and hardly ever been included among the arguments that justify the *introduction* of technology in health care. Very little has been said about the potential changes to the relationship between patients and doctors when information technology inaugurates health information channels in precarious contexts. For now, ICTs in public health spaces of low-income countries have mainly been promoted by enthusiasts who, based on the

experience of high-income countries, *intuitively predict* improved coordination and low-cost management[1].

Uncertainties of the effects of the introduction of ICTs are amplified by the fact that poor health care settings are not entirely understood. The truth is that health care economics is greatly inspired by the experience of developed countries. Careless comparisons between rich and poor establishments might therefore prove inaccurate because the cultural lenses through which underserved populations look at illness do not necessarily match mainstream approaches. Plus, private care cannot be afforded by the majority of citizens who require free health services, which, sadly, are usually mediocre. Unique and complex behavioral characteristics of individuals lead to unique arrangements that make poor settings different from the rich ones.

As a result, the health reform strategies of low-income countries that are based on the experience of richer countries make abstraction of two fundamental problems. On one hand, the solutions that have been deployed in high-income countries have ignored the effects that technologies might cause on individuals' empowerment and behavior. Solutions have in fact ignored the potential changes in historical dynamics between patients, service providers and governments[2]. On the other hand, the answers for rich settings might not necessarily be the ones for the poor ones. For now, the hype around the democratization power of technologies is just *expected* to be true, and only a few authors like Van der Boor et al. (2014) have suggested that the traditional *North-to-South* diffusion of innovation framework actually fails to explain the new sources of ICT innovation in developing countries. The empirical gaps in the study of the introduction of ICTs in poor settings and the theoretical gaps in health care dynamics present a timely research opportunity to shed light on important *unknowns* in the health care context.

This thesis was developed in an attempt to decrease both research gaps. Its main contributions are threefold. First, it puts forward a theoretical model inspired by the health care setting in precarious contexts. Second, it introduces a novel methodological strategy that was taken to test some of the model's propositions. And

[1] "It is easy for those of us who are aficionados of technology to see IT as some kind of panacea that will change historical relationships and have indigenous communities sharing information with other communities and cultural organizations. This kind of sentiment is likely to communicate naivety, arrogance and disrespect to indigenous people" (Dyson et al. 2006)

[2] For simplicity, we will use the terms rulers, deciders and governments interchangeably from this point forward.

third, it evaluates the impact of a preventive program particularly relevant for countries with adverse health indicators. The thesis should be seen as an effort to further elucidate the characteristics of low-resource health settings[1] and to understand the effects of the introduction of technology. Overall, it provides a comprehensive method to assess change in health care setups, when ICTs are freshly introduced in precarious environments.

The first part of the dissertation presents insights from health care economics, sociology and public administration in order to characterize some of the alleged effects of the use of ICTs in setups where three main actors (namely patients, service providers and rulers) constantly interact. This first section gives the reader an idea of the dynamics that have shaped a new health care environment with omnipresent technology. It should be clear that the identification and description of *all* the initiatives based on information technology exceed the scope of this research. Nonetheless, it is argued that all dynamics based on information and communication technology adopt one of the following fundamental forms: *horizontal bottom-up* dynamics ignited by citizens, *vertical top-down* initiatives promoted by public or private institutions, or *hybrid* dynamics involving interactions between service providers, rulers and citizens.

The first section of the thesis ends with a presentation of a general framework that models the effects of the introduction of mobile technology on interactions between three main stakeholders. A few seminal studies support the core arguments. Grossman (1972), for example, defined a handy model in which consumers, with an inherited initial stock of health that depreciated over time, invested on their own health capital, which depended on the consumption of medical services, education and other environmental factors. Grossman's model, however, is not perfect (Dardanoni and Wagstaff, 1987). Acton (1975) argued that in settings where medical services are delivered for free, travel times act as prices, and therefore, the longer the travel times, the smaller the demand for medical services (Acton, 1975; Santerre and Neun, 2010). These and other theoretical insights are used to construct an integrated framework in Chapter 3.

[1] Sachs (2012) explains that two basic aspects of poverty limit health-care coverage in low-income settings. The first is that in a poor economy, many households do not have the means to pay for any health care at all. The second basic aspect of poverty is that the governments of low-income countries often lack adequate domestic budget revenues to ensure universal access to basic health services even if the government is disposed to guarantee universal access to health care.

The second part of the dissertation, starting in Chapter 4, focuses on an mHealth[1] pilot experiment designed in the Summer of 2013 and launched at the beginning of 2014. Inspired by the recent methodologies that defend that "the field is used as a lab where variation necessary to test specific ideas is generated experimentally" (Duflo, 2006), the experiment sought to *test* some of the theoretical predictions in the first section of the thesis. Project *Patojitos,* or *little ones* in Guatemalan affectionate slang, was launched 35 kilometers away from Guatemala City, in the village La Azotea in San Juan Sacatepéquez. Patojitos looked at different interventions that could help support breastfeeding practices among nearly one hundred mothers through the use of mobile technology, while at the same time allowing to identify new interaction dynamics between service providers and rulers. Patojitos was purposely designed to include participants from underserved rural areas.

The reader will note that two recurring arguments emerge throughout the exposé. The first is that ICT platforms seem to reduce informational asymmetries and foster new interaction dynamics among and within groups. In this respect, the pilot experiment Patojitos created a virtual environment where a particular group of patients —mothers with newborns— were given access to information, via a feature phone (a simple mobile phone), in one out of three possible setups: unidirectional top-down streams of information, micro-communities, or hybrid micro-communities in contact with health professionals. Although main insights come from a small-scale experiment, topical questions are addressed: in which setup is it more efficient to disseminate public health messages, in unidirectional or in participative setups? How do patients behave when they are given access to fluid streams of information and to supporting communities?

The second argument is that ICTs empower individuals by allowing them to collaborate more efficiently in public and political matters. Repeatedly, it has been argued that ICTs foster a revitalized democracy by making information exchanges fluid and by facilitating interactions among individuals (Fountain, 2003; Vedel, 2003; Siau and Long, 2005). But is the *introduction* of communication channels driving citizens towards political engagement? Or instead, is there a period of technological discovery before engaging in political debates? The pilot study Patojitos takes an empiric look into these political economic questions and attempts to understand dynamics among indigenous women when technology is introduced in an underserved health care environment. Patojitos generated data

[1] Pronounced "/ɛm/-health" and thus preceded by an indefinite article "an", an mHealth intervention refers to the practice of delivering health services through mobile technology.

that allowed to address these questions separately; results and discussions are presented in the final chapters.

Few research studies have tried to fill the previously presented research gaps. This is one of the first attempts to assess the multi-level effects of the introduction of ICTs in low-resource health settings using a theoretical-based experimental setup. The results that are presented throughout the chapters will give the reader a clear understanding of the arrangements that develop when the valves of technology let streams of information irrigate arid social canals. Discussions and conclusions throughout the dissertation should aid in the design and implementation of new and larger-scale experiments. They should also provide guidance as to how to refine technology-based programs in developing countries.

Overview of Chapter 1: The ubiquity of ICTs in health: self-care, tribal-care and e/m-health

Governments, individuals and service providers seem to implicitly agree on the fact that exposure to health information leads to a more independent role of patients and to more efficient health care. The first chapter presents a survey of the initiatives that have changed traditional health care. Some of the tools that have allowed patients to take charge of their own health are characterized. The limits of these self-driven initiatives are also exposed. Insights from two in-depth case-studies about the quality and reliability of software applications for smartphones and tablets (called *apps*) are used to illustrate vulnerabilities of health ICTs. Increased access to information and to online communities also creates spaces for patients to interact and share their experiences, knowledge and advice. The arguments are illustrated by a case study about the use of mobile health interventions in low-resource settings to fight against social isolation amongst patients with HIV/AIDS.

The chapter provides an evidence-based overview of the technological initiatives affecting health and health behavior. It also motivates necessary intuitions to justify components of the conceptual model in Chapter 3.

Overview of Chapter 2: Framing the empirical panorama with a literature review

The second chapter of the thesis presents a review of the literature in order to frame the observations in Chapter 1. Based on health economics, the chapter describes the concept of self-care as the ability of individuals to *produce good health*. Then, the *social capital* framework is used to take into account the societal characteristics of populations and to elaborate on the link between behavior, communities and health. The reasons behind the benefit-from-cohesion concept is subsequently explained using the co-production framework, common in public administration studies. Discussions suggest that co-production, boosted by electronic governance mechanisms, can be an efficient way to promote health and to support long-lasting, positive changes in health care environments.

As of this point, the reader will have gained a clear notion of three main dynamics powered by ICTs (horizontal bottom-up, vertical top-down, and hybrid) that govern the interaction of citizens, service providers and rulers in health settings.

Overview of Chapter 3: A model for the analysis of the effects of mobile technology in low-resource health settings

This chapters uses empirical and theoretical insights from the previous chapters to describe the standard dynamics taking place in low-resource health settings. Then, it offers a model of the effects of the introduction of mobile Information and Communication Technology. Only *simple* mobile technologies and not others such as the Internet or personal computers are considered for three primary reasons. First, mobile penetration rates are high in low-income countries. This makes the model empirically testable in a wide variety of low-resource settings in the world. Second, citizens in low-resource settings are used to manipulate mobile technology, and phenomena like digital inclusion are *less significant*. And third, mobile technology characteristics allow personal and more constant exposure to information flows.

The chapter, as the reader will discover, allows to derive empirically-testable propositions. Some of them were tested in a real-life environment and results are presented in the second part of the thesis.

Overview of Chapter 4: The pilot field experiment Patojitos in Guatemala

The second part of the thesis starts with the presentation of an mHealth experiment and describes the context of the impact evaluation. The reader must keep in mind that the intervention was a pilot study, a *test* experiment. Temporal and financial considerations prevented the recruitment of numerous participants, and implications of cross-sectional analyses are limited to the particular context of the project. Patojitos[1] was launched in 2013-2014 in close collaboration with The SHM Foundation in London, the principal funder and partner, and with the support of the Innovation and Regulation in Digital Services Chair (created by Ecole Polytechnique, Telecom ParisTech and Orange) and of Universidad Francisco Marroquín in Guatemala. The Ethics Board of the School of Medicine from Universidad Francisco Marroquín approved the intervention on the 25th of October 2013, and granted access to a clinic in San Juan Sacatepéquez for the recruitment of participant mothers. Patojitos was an mHealth intervention attempting to promote recommended breastfeeding practices among mothers of low-resource health settings.

The pilot experiment required a memorandum of understanding between several institutions before ignition. As the project leader and creator of the study, José Tomás Prieto (JTP) was supported by his academic advisors, and did the following during the pilot experiment: request ethics approval for the pilot through the Universidad Francisco Marroquín by creating and submitting a research protocol; perform the analysis of the findings; obtain mobile phones for participants; lead and manage the pilot in close collaboration with the SHM Foundation and the Universidad Francisco Marroquín (for local coordination); manage the technical requirements and the maintenance of the intervention with the team based in Guatemala; send text-messages to participants; be a point of contact for the team; monitor the group messaging platform; and design and write the final reports and subsequent articles.

The SHM Foundation was responsible for: monitoring the pilot in close collaboration with JTP, the project leader; ensuring that the technology platform for the bottom-up intervention was ready so that participants could take part using a mobile phone; managing and allocating the budget for the pilot with the funds made available by the funders; contributing to the writing and diffusing of sum-

[1] Website: http://patojitos.org (archived at http://www.webcitation.org/6TDtiQxiw). Trial registration identification number in the clinicaltrials.gov registry: NCT02263118 (Prieto, 2014).

mary findings from the pilot. Universidad Francisco Marroquín assisted in the design and execution of the participant recruitment strategy and granted access to a clinic in Guatemala for recruitment; assisted in the consolidation of the protocol documents and validated them before submission to the Ethics Board; provided local coordination for the pilot experiment in close collaboration with the project leader; and granted ethics approval.

Overview of Chapter 5: Exposure to information, co-production and the effects of the introduction of ICTs on health: assessing the results of *Patojitos*

In this chapter, some of the propositions of the general model of Chapter 3 are tested using data from the pilot experiment Patojitos, a health-promoting program. Based on interviews performed at the beginning and at the end of the project, changes in knowledge and self-reported behavior regarding breastfeeding practices were measured among mothers who often face the challenge of *exclusively* breastfeeding. Although the sample was small, the chapter attempts to characterize growth patterns of participants' infants. Health economic insights derived from the model in Chapter 3 (such as the effects of price times and exposure to medical information on health outcomes) are also tested in this chapter.

The qualitative nature of the information that was shared during the field experiment is described in detail. Patterns of use and participation, response rates and response times for the created *neotribes* are provided. The chapter presents a factual demonstration of the forms of co-production that emerged during the pilot experiment.

Overview of Chapter 6: Bargaining capital, spaces of negotiation, and Information and Communication Technology in health care environments

This chapter takes a political economy strategy to explain the potential effects of technology in political dynamics of low-resource settings. Do ICTs create spaces of interaction for citizens, service providers and rulers to bargain on the provision, the quality and the right to access to health services?

The chapter attempts to extend the model of constitutional development in Brousseau (2010) by focusing on its public service delivery components. The goal of Patojitos was to identify the phenomena leading to the occurrence of communication dynamics between the three main actors, and the context in which they occur. The eclectic nature of the concept of bargaining dynamic in low-resource health care settings is underlined. Based on the text-message communication dynamics between participant mothers, it is shown that, under the constitutional theory of development framework, ICTs are spaces of negotiation where citizens engage in special vertical and horizontal bargaining dynamics.

The argumentation flow

Figure 1 shows a visual guide to the dissertation. The reader will find it useful while reading through the chapters.

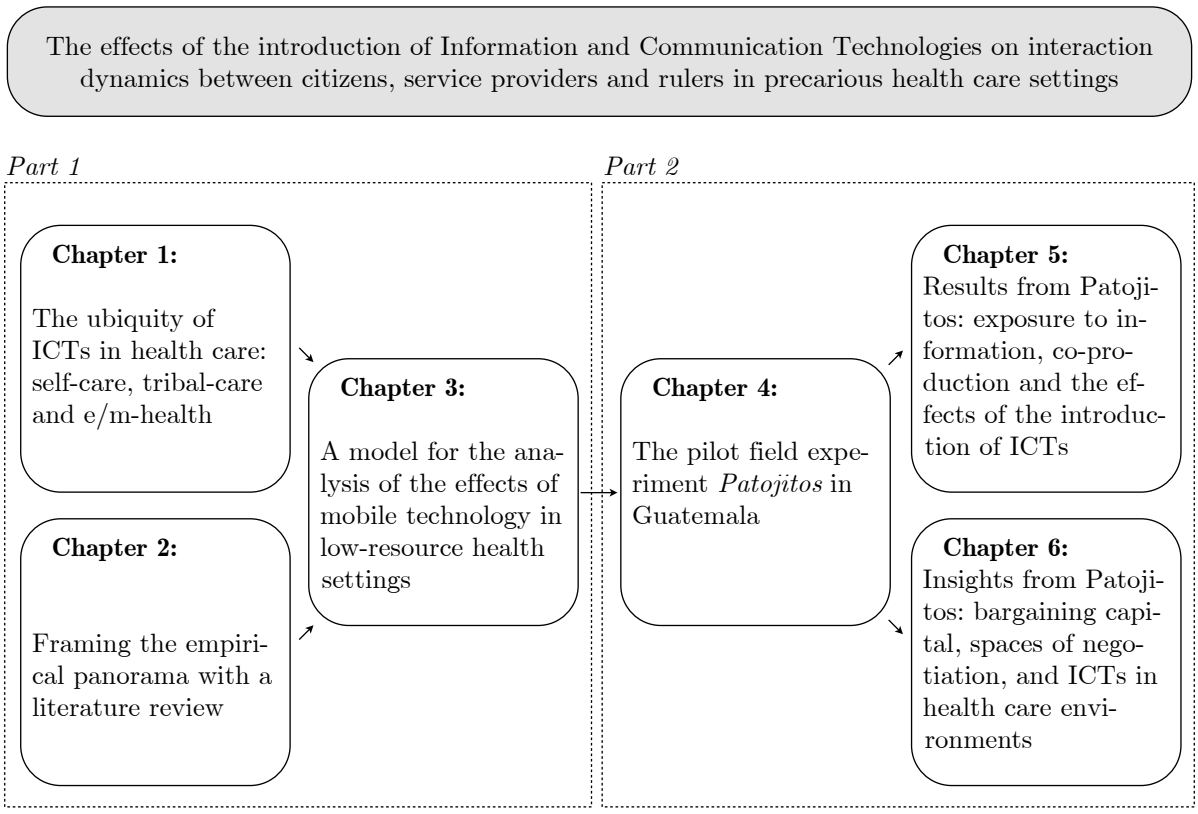

Figure 1.1 The argumentation flow

"Cuius rei demonstrationem mirabilem
sane detexi hanc marginis exiguitas non caperet."
Pierre de Fermat, 1637[1]

General conclusion

We started the dissertation by presenting two areas that haven't been sufficiently examined in the literature so far. On one hand, studies have ignored dynamics between patients, service providers and rulers in precarious health care contexts. Most of what we know comes from the experience of high-income countries. On the other hand, literature fails to explain the effects of the introduction of technology in the health care arena under one unified theory. These research gaps are inconvenient, specially when technology-related health care reforms in developing countries are inspired by the high-income experience. The main goal of the thesis was therefore to shed light on interactions in the low-resource health setting, and on the effects of the introduction of technology in poor settings.

In Chapter 1, we showed that variation in quality, privacy and security practices in ICT platforms raises concerns about potential health risks and about the ability of existing regulation to reduce risks and to solve problems related to vulnerabilities. Health information providers should warn about possible quality and privacy threats in virtual networks and, ideally, provide expert and prompt feedback to worldwide audiences, eager to consume publicly available, inexpensive health services. Public health regulators should be ready to intervene when ICT platforms might encourage the adoption of unhealthy behavior.

People's behavior is dynamic and difficult to evaluate. Regulation, however, needs to reflect and support changing norms in societies. The implementation of appropriate governance for fast-changing health ICT-platforms is consequently challenging. The regulation of the quality of information in global networks alone would require considerable efforts at national and international levels. Only recently, novel governance mechanisms have been put forward for health *apps* (Huckvale, Prieto et al., forthcoming), but even these need enhanced collaboration. We finalized Chapter 2 by highlighting the potential benefits of co-

[1] "I have found a truly marvelous proof of this proposition but this margin is too narrow to contain it" (proposed translation by Weisstein, 2013).

productive settings in health systems. In agreement with recommendations in the literature (Fuchs, 2000; Frank, 2004), we exploited the potential for interdisciplinary and multidisciplinary research and showed that *co-production* can improve availability and quality of health services. It can also guarantee the viability of governance, or rather, e-governance, by allowing constant negotiations between health care actors in interactive ICT platforms. In addition to being comprehensive and consistent, e-governance arrangements can be feasible, sustainable and affordable.

Based on these insights, we explained in Chapter 3 how the main *ICT forces* — top-down vertical initiatives directed at citizens, horizontal bottom-up initiatives ignited by citizens, and hybrid interactive dynamics between citizens, service providers and rulers— affect health care settings in precarious contexts. We elaborated an elementary conceptualization of medical services, and suggested one unifying framework to describe the changes ignited by the triadic form of technology in poor health care settings. The model, the first of this multidisciplinary nature, provides one integrated theory to analyze the effects of the introduction of mobile ICTs.

The nature of the propositions derived from the model *had* to be tested. Inspired by today's methodological strategies in research, we ran a small-scale field experiment in rural Guatemala. This test evaluation sought to simulate our categorization of ICT forces in health care by creating, experimentally, a horizontal environment (citizens communicating through mobile technology), a vertical environment (citizens being exposed to unidirectional information), and a hybrid context (citizens and service providers communicating through a mobile platform). We then measured and compared the impact of interventions. The experiment generated initial evidence for our theoretical predictions, in a real-life setting. In agreement with Duflo (2006) and Duflo et al. (2007), we found insightful results by combining theoretical intuitions and empirical insights from the field. Due to the exploratory nature of the intervention, however, implications of analyses are limited to the particular context of the project.

Health knowledge, self-reported health behavior and infant health

Vertical and hybrid platforms guaranteed the learning and the maintenance of accurate knowledge about breastfeeding practices during the experiment. Horizontal platforms, however, induced the opposite effect, and cases where participants

forgot the correct message, or assimilated an incorrect one, were identified. Unlike outcomes in vertical and hybrid platforms, changes in knowledge in horizontal platforms were similar to those in the control group.

Although mHealth has been viewed as a promising tool with the ability to foster positive behavior change, more evaluations need to be conducted to establish stronger evidence (Gurman et al., 2012; mHealth Summit 2014). Results of our study contribute to the reduction of this gap. *Health knowledge* was associated to self-reported *health behavior change*, a useful result in the behavioral change literature. The large majority of individuals who learned (or remembered) the exclusive breastfeeding message changed to (or kept) an optimal behavior. In contrast, the large majority of individuals who never became aware of the exclusive breastfeeding message either kept or adopted a sub-optimal behavior.

The learning of the correct breastfeeding message, however, did not lead to an improvement of the weight-for-age anthropometric indicator of babies. Results are based on a small sample, but it is possible that breastfeeding was *not enough* to improve the weight-for-age of babies. It is also possible that the proxy variable for gains in health (the change in the weight-for-age indicator) failed in revealing other important, meaningful aspects of infant development.

When we compared outcomes across groups, we saw that infants of mothers with access to hybrid platforms presented significant gains in health, controlling for the initial stocks of health. In agreement with our model in Chapter 3, the mean gains in stocks of health of babies in hybrid arrangements were higher than those of babies of other groups (with the same weight-for-age at enrollment). In fact, the stocks of health of infants improved with mothers' exposure to medical services in informational forms. Receiving more health-related text-messages predicted a small increase in the stock of health of babies, controlling for exposure to social support and for the importance of health for participants. A more detailed analysis showed that the mean gains in z-scores of babies of mothers receiving medical information increased with consumption of diagnosis services. Exposure to Prevention or Treatment text-messages did not yield comparable effects, which highlights the importance of prompt diagnosis services in precarious contexts.

In disagreement with the model of Chapter 3, however, increases in waiting times did not predict a decrease in the demand for health. In fact, the likelihood of obtaining an answer to a medical inquiry, and not the time individuals waited before they got one, had the most significant impact on the demand for medical

services in their informational form. Mothers demanded more medical services, in an informational form, when they were likely to get an answer in their neotribes. The observed attitudes of participants in virtual-health spaces were therefore not different from the attitudes observed in public health clinics, where patients wait in line for several hours, even when they do not have the certainty that they will receive any treatment.

Hybrid platforms guaranteed the stream of accurate information and affected positively people's knowledge and general behavior. Extra attention should be paid to the role of social support channels and to the effects of highly responsive diagnosis services. Although results are based in the analysis of a small population, some of the interpretations motivate the construction of new rounds of experiments in a broader public health context. Our work suggests that low-cost informational communications could support, to an extent, the reduction of some health inequalities in precarious contexts. The findings contribute to the efforts of public and private institutions (like the mHealth Alliance, the Clinton Health Access Initiative, J-PAL, or the Bill & Melinda Gates Foundation) currently trying to improve newborn and maternal care in developing countries.

Co-production of good health and empowerment

Co-production can take many forms. In fact, contemporary labor relies on collaboration: through crowdfunding[1], politicians have successfully found sponsoring alternatives (Kappel, 2009). Artistic work develops around common norms and through collaboration (Becker, 1984). Precarious health care contexts are not that different. We showed that collaboration between individuals in a specific health care environment emerged, spontaneously, in horizontal and hybrid platforms.

Ostrom (1996) warned that designing institutional arrangements that help induce successful co-productive strategies is far more daunting than demonstrating their theoretical existence. Part of the problem stems from the nature of the goods typically produced in the sector (St Leger, 2003). Data from the field experiment Patojitos, however, showed that interactive communication channels can foster co-productive environments. During the study, co-production dynamics developed as a collective strategy to produce unavailable, yet needed services like social support and diagnosis services. ICT-based co-production dynamics, however,

[1] Crowd-funding is usually defined as the act of informally generating and distributing funds by groups of people for specific personal, social, political, entertainment or other purposes.

might remain experimental as long as there is limited insight into their impact and viability (Linders, 2012), and future work should focus on the possibilities of long-term interventions.

We took a deep look into the *elasticity* of co-production dynamics. Response rates to health questions in neotribes were close to 60%. Three quarters of responded questions were answered in approximately forty minutes. The results are encouraging in the particular context of San Juan Sacatepéquez: participants had to wake up early, travel for 30 to 60 minutes to get to their local clinics, and wait hours only to *possibly* get treatment. It is not too bold to suggest that these conditions might be similar in other precarious contexts. Access to horizontal and hybrid platforms, de facto tribal interpreters, allowed individuals to demand and consume services promptly. Future work could evaluate the possibility of using algorithmic, autonomous solutions to set the quality of information and further improve the responsiveness of medical services in their informational forms.

Co-production is related to *empowerment* (Wilson, 1994; Needham, 2008). Interviews with indigenous women at the end of the experiment confirmed the association. But even participants exposed to vertical platforms reported that they could "fight against incorrect advice". They felt they were being taken care of; that they were being given the opportunity to learn. The anonymity of the platform encouraged participants in horizontal and hybrid platforms to communicate their thoughts regarding health care conditions, sometimes for the first time in their lives. Bargaining dynamics between individuals and rulers adopted the form of complaints. The political conversations revealed participants' discontentment with the quality and availability of health care services: recurrent topics were excessive waiting times in clinics, and insufficient and disrespectful medical staff. The study, unfortunately, did not assess changes in the political environment of health care in San Juan Sacatepéquez. Although a letter was sent to the Mayor of San Juan Sacatepéquez to inform about the anonymous comments of participant mothers (details in Appendix D), the effects will only be perceived in the long term.

As our model suggested, horizontal and hybrid forms of ICTs affected the social capital of individuals in virtual communities, which led to the organization of physical reunions. Recurrent exchanges in virtual communities allowed participants, who had never met before (except for the two sisters in group 2), to develop a high degree of intimacy. The platform provided enough flexibility to promote the idea of a social reunion, to organize it, and to refine details prior to the

meeting. Empowerment was not experienced by individuals only. Health professionals perceived benefits as well. The introduction of hybrid platforms modified the traditional approach to care. Service providers were able to control the dissemination of misleading information and prevent avoidable harm.

Bosch et al. (2009) argued that *multidisciplinary teamwork* is a necessity in modern health care organizations, but little is still known about the underlying mechanisms of such teamwork. This dissertation makes the strong case that the *complementarity* of simple technologies has the potential to foster valuable interactions in poor health care contexts. Horizontality unveils needs, misconceptions and concerns, while verticality guarantees a supply of accurate informational products and services. Together, horizontal and vertical platforms supported efficient, cyclic interactions during the experiment. The theoretical value of hybridity was clear, but only the *field* showed its practical virtues. Hybrid platforms helped attaining health outcomes, regulating information flows, and providing rich contextual data to researchers, providers and rulers, who could use it to refine management, production and delivery of services. More generally, results might be useful from a public health perspective, specially when flexible, low-cost solutions are needed. Our depiction of micro-institutions, created by virtual communities of interacting agents in the precarious context, sheds new lights on health care realities and on health care analysis.

Lessons learned and recommendations for future work

Important assumptions of the model were carefully discussed in Chapter 3, but inevitably, our interpretation of health care systems is influenced by insights derived from existing literature. Our intuitions are also conditioned by the fact that we are, ourselves, service consumers and untrained co-producers of health services; our understanding of medical science is biased by our personal experience. Although independent reviewers find the model accurate, some simplifications might hide special features of, for example, health care services in *despotic* regimes or in dangerous, violent environments. The general framework for the assessment of the effects of the introduction of mobile technology in low-resource health settings is consequently not perfect and should be refined with findings from new empirical evaluations.

The model we presented in Chapter 3 described the introduction of technology in a general medical setting in which treatment, prevention and diagnosis services

were produced by quality-maximizing and patient-maximizing providers. Our experiment, however, sought to promote one particular preventive behavior (exclusive breastfeeding) as a strategy to test propositions regarding Treatment and Diagnosis. Consequently, the experiment tested special cases of the general model. The way in which the experiment was launched was an important determinant of the outcomes, because services were *meant* to be complementary, not substitutable, in the sense exposed in Chapter 3. The mHealth platform was used mainly to solve issues related to babies and it is unquestionable that the activity of participants was conditioned by the initial orientation of the project. Future work should foresee that a broader mobile health experiment, or an experiment dedicated purely to Treatment services, can reveal new insightful data. The consideration of a larger set of medical issues could allow the identification of new needs. It could also generate more robust comparisons between the complementarity or substitutability of services in mHealth, as the general model suggests.

A more refined experiment should also consider additional variables to allow more solid interpretations. Indeed, technical problems could have explained the activity variations in neotribes in our study, but only a larger sample would allow to compare activity trends across groups. Other effects to consider would be those of interpersonal relationships on health institutions or arrangements. The sisters in neotribe 1 did not attend the recruitment session nor the final interview together, and we only became aware of their relationship at the analysis phase, when we noticed that they had the same last name. The effects of relationships cannot be neglected though. Indeed, previous work has measured the effects of interpersonal relationships, affected by geographical distance, in agrarian institutions (Gubert and Fafchamps, 2007). A third factor to take into account would be the complementary of instruments to ensure consistency between participants' behavior self-reports and *reality*. For example, text-message exchange in virtual communities could be further analyzed to perceive longitudinal changes in nutrition and other maternal and newborn health aspects. And finally, a more complete study in the context of newborn care would need to take a richer set of measurements into account (the number of illness episodes or babies' body-mass-index, for example).

At design, we did not consider important cultural specificities that certainly affected outcomes. The sharing of personal identifying information in neotribes is one example. This type of information might be a concern when there are employment, security and social implications. Forthcoming work should evaluate the importance/insignificance of this issue in the low-resource health setting. A second example is the context of sexual discrimination in which the project was run.

Mothers who were particularly inactive in neotribes mentioned that their husbands sometimes took the experiment's cellphone to work. Several conversations in neotribes revolved around domestic violence at different levels, which confirmed the dominant, authoritative role of men in this rural area. Political and economic activity in low-resource settings seems to be driven by men, and therefore, other stakeholders need to be involved in order to better assess, for example, the bargaining capital of a society in the low-resource setting, and to maximize positive impacts. Future work should take this into account by involving husbands at recruitment phases, for example. A third example is the relationship between women's age and babies development. Older women in rural settings might be less attentive to health information and might rely mostly on their personal experiences. Future work should dig deeper into this highly likely age divide.

In practice, a complex study design with a small sample, like ours, may seem *too ambitious*: observations and insights are rich, but the potential for generalization is compromised. Patojitos should be seen as a pilot field experiment, an exploratory study, that generated data in a specific low-resource setting of the Latin-American reality, in a short period of time. Although we used randomization to assign participants to groups, it would be inaccurate to use the findings to carelessly predict outcomes in other environments. From 100 recruited participants, only 78 came back for final interviews. 22 were lost to follow-up. Lau et al. (2014) argue that researchers should be mindful of loss to follow-up when rolling out mobile health interventions in developing country settings. Future work should therefore elaborate on the financial sustainability of the experiment in order to extend its duration and to increase the potential size of the sample, as a significant proportion of participants will be lost to follow-up.

For Patojitos, mobile phones and phone credit were donated by a telecom operator. Operation costs were covered by a non-profit organization. Interestingly, however, participant mothers shared their interest in continuing to receive health-related messages at the end of the experiment. More importantly, they shared their willingness to pay for services if the costs of individual SMSs stayed low and if health information continued to be related to their current reality. This opens the possibility for new business strategies that could support sustainable mHealth interventions in precarious settings. Recent discussions in mHealth research, an exploding research field and start-up market, point indeed to the need of creating sustainable partnerships to ensure long-term, positive effects in health outcomes. Sustainability, compatibility of platforms and cost-effectiveness are some of the most important gaps to be overcome in mobile health research in the next years

(Mechael, 2012; mHealth Summit, 2014). The willingness to pay for mHealth is therefore a topical finding.

Overall, findings of Patojitos suggest that simple technology, coupled with appropriate virtual organizational arrangements, might foster the viral dissemination of *accurate* health information in underserved areas. By including pivotal members of communities like midwives and community leaders, the promotion of preventive behavior at low costs might have a greater impact. The cost-effectiveness of mHealth interventions in a long term public health strategy should be further studied too. It is undoubtedly one of the most important elements to assess in future developments. Specifically, how much money can public administrations save in the long term if we invested today in mobile health programs? In the future, will populations exposed to preventive mHealth in low-resource contexts require cheaper medical services? Studies will need to undertake the challenge of comparing preventive care (in terms of health outcomes and financial viability) to the traditional *reactive* care in low- and middle-income countries.

Epilogue

Our goal of shedding light on interactions between individuals in low-resource health settings was attained by testing a novel theory of effects of mobile technology in rural Guatemala. The model is applicable to diverse environments and extendable to different technologies. The experimental strategy was useful to assess and compare the impact of the introduction of three forms of mobile technology. We confirmed that *information is not necessarily power* in poor health care environments. In order to become an empowering mechanism, information has to flow through special channels that enable interactions, collaboration and governance of information between key stakeholders.

The presented results have timely relevance for Guatemala, where chronic malnutrition rates are among the highest in the world and, sadly, only a small percentage of the population has access to health services. The government's recent decision to cut the Expansion of Coverage Program budget, that was established in 1997 to improve coverage of health and nutrition services in rural areas, has further compromised health care for millions of individuals. If hybrid platforms are capable of bringing about positive health change in a large scale, it is crucial to test them further and to quantify their cost-effectiveness in the long run. It is our intention to continue to work on the sustainability and appropriateness of

mHealth in precarious contexts.

What we presented in this dissertation is the result of meticulous work. The details of the experiment Patojitos were rigorously described to ensure reproducibility. To benefit the most from our study, the presented results should be used to design new, larger-scale interventions. Sustainable collaborations between citizens, public administrations and research organizations are therefore crucial if further research is to be conducted and if long-term solutions are to be developed. At the time this paragraph was written, we were having conversations with public and private entities in order to scale-up the intervention Patojitos. The Foreign & Commonwealth Office (FCO) awarded us a small grant in October 2014 to conduct a feasibility study for a scaled-up version of Patojitos. The study will start in February 2015.

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List of abbreviations and acronyms

AIDS	Acquired Immunodeficiency Syndrome
ANOVA	Analysis of variance
Apps	Software applications for smartphones and tablets
ARV	Anti-Retroviral
AZT	Azidothymidine: antiretroviral drug FOR HIV/AIDS
BCC	Behavior Change Communication
CCSVI	Chronic Cerebrospinal Venous Insufficiency
CD4	Cluster of differentiation 4
CI	Confidence Interval
CONSORT	Consolidated Standards of Reporting Trials
D	Diagnosis (in Chapter 3)
E-governance	Electronic governance (also written egovernance)
E-government	Electronic government (also written egovernment)
E-health	Health practice supported by electronic tools (also written ehealth)
E-participation	ICT-supported participation in processes involved in government and governance (also written eparticipation)
H	Stocks of Health (in Chapter 3)
HAART	Highly Active Antiretroviral Therapy
HIT	Health Information Technology
HIV	Human Immunodeficiency Virus
HTTPS	Hypertext Transfer Protocol Secure
ICT(s)	Information and Communication Technology (Technologies)
IT	Information Technology
J-PAL	The Abdul Latif Jameel Poverty Action Lab in MIT
JTP	José Tomás Prieto
mHealth, m-health	Health interventions based on mobile technology
MAMA	Mobile Alliance for Maternal Action
MGRS	Multicenter Growth Reference Study
MIT	Massachusetts Institute of Technology
MRI	Magnetic Resonance Imaging
NCHS	National Center for Health Statistics
NHS	National Health System in the UK
P	Prevention (in Chapter 3)
PM	Patient maximizing providers (in Chapter 3)
PMTCT	Prevention of Mother to Child Transmission programs

QM	Quality maximizing providers (in Chapter 3)
S	Symptoms (in Chapter 3)
SD	Standard Deviation
SIMs	Subscriber Identification Module
SMS	Short Message Service or text-message
T	Treatment (in Chapter 3)
Telecom(s)	Telecommunication(s)
UK	United Kingdom
UNICEF	United Nations Children's Fund
US, USA	United States of America
WHO	The World Health Organization