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The Economics of eHealth

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INTRODUCTION

The value of research

Information and communication technologies (ICTs) are potentially powerful instruments to strengthen health systems, with innovations ranging from electronic health records to transmission of clinical data. These technologies show great promise in low- and middle-income countries (LMICs) whose health systems face severe financial, infrastructural, technical and human resource constraints. This is evident in the growing number of health service providers beginning to focus on mobile technologies to improve access and quality of health services[1].

At the same time, there is a growing debate about whether the touted potential of ICT benefits and savings can be actualized on a large scale, both in OECD countries and LMICs[2]. Over a decade of efforts to implement ICTs in healthcare demonstrate notable successes, but also costly failures[2]. Furthermore, despite a growing global interest in e- and mHealth, relatively little is known about the economics of eHealth. In fact, a recent paper notes that the failure to demonstrate the value of eHealth is one of the principal challenges to achieving widespread adoption of high-performing ICT initiatives[2]. However, the lack of hard evidence to support eHealth investments should be seen in the context of a rapidly developing field; other major economic sectors have embraced modern IT to improve productivity and effectiveness, and it is likely that the health sector can also share in many of these benefits. There is, however, a real need for economic analysis that can guide public and private investment decisions.

Given the increasing number of mHealth trials and level of interest in e- and mHealth, this is an opportune time to review the available data on the costs and benefits of e- and mHealth and suggest a roadmap for future research. This paper is intended to provide an outline of key economic and financial questions to pursue in the development of scenarios for in-country eHealth policy and strategy investments.

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[1] This paper reviews the economics of eHealth (of which mHealth is a part), though as a practical matter mHealth has the potential to predominate in LMICs due to the growing ubiquity of wireless, the relative absence of wired infrastructure, and the importance of delivering care to people with limited access to clinics and skilled health workers.

[2] OECD. "Improving Health Sector Efficiency: The Role of Information and Communication Technologies." Paris: OECD, 2010.

The term mHealth is defined in this paper as the provision of health-related services using mobile telecommunication and multimedia technologies[3, 4]. Mobile technology, general e-infrastructure, and eHealth infrastructure are interrelated entities, with mobile technologies serving as a key access technology in LMICs. Within ICTs, portable technology through the use of mobile devices (mHealth) is by far the fastest growing segment[1]. Examples of mobile devices commonly utilized in healthcare today include (but are not limited to):

- Mobile phones and smart phones
- Laptop computers and netbooks
- Global Positioning System (GPS) devices
- Mobile telemedicine/telecare devices
- Mobile patient monitoring devices

This paper focuses on technologies that are likely to have high potential to enhance healthcare delivery in LMICs. These include technologies that increase patient access to health services and information, and improve the way health professionals deliver health services. In most cases, mHealth exists as an extension and augmentation of existing IT-based health capability (eHealth), however limited that may be. Indeed, it is this combination that is likely to produce the greatest systemic benefits, though there are emerging solutions in the areas of patient access to information (e.g. peer-to-peer forums on the web), and in supply chain efficiencies (preventing counterfeiting, stock-outs), that are not dependent on the national healthcare systems, public and private.

The promise of e and mHealth in LMICs

The potential of mHealth and eHealth for resource-constrained environments becomes obvious when considering the following facts. 1) The global eHealth market is estimated at $96 billion and growing, with many innovations coming from LMICs[5, 6]. 2) 70% of all mobile phone users are in emerging markets, which are also the fastest growing markets[7, 8]. 3) Almost 90% of the world's population lives in areas with mobile phone coverage, providing a technology platform for mHealth applications[7, 9]. 4) By 2012, half of all individuals in remote areas of the world will have mobile phones[10]. 5) Smartphones

[3] Istepanian, R. and J. Lacal (2003). "Emerging Mobile Communication Technologies for Health: Some Imperative notes on m-Health." Paper presented at the 25th International Conference of the IEEE Engineering in Medicine and Biology Society, Cancun,Mexico.
[4] Mechael, Patricia N. "The Case for mHealth in Developing Countries." *Innovations.* Cambridge, MA: MIT Press, 2009.
[5] Boston Consulting Group. *Understanding the eHealth market.* Presented at "Making the eHealth Connection: Global Partners, Local Solutions". Bellagio, Italy: 2008.
[6] Gerber, Ticia, Veronica Olazabal, Karl Brown, and Ariel Pablos-Mendez. "An Agenda for Action on Global E-Health." *Health Affairs* 29:2 (2010): 235-238.
[7] International Telecommunications Union Statistics, 2010.
[8] Lambert, Olivier and Elizabeth Littlefield. "Dial Growth." *Finance & Development* 46:3 (2009).
[9] Vital Wave Consulting. "mHealth in the Global South: Landscape Analysis." Washington, D.C.: United Nations Foundation and Vodafone Foundation, 2008.
[10] Vital Wave Consulting. "mHealth for Development: The Opportunity of Mobile Technology for Healthcare in the Developing World." Washington, D.C.: United Nations Foundation and Vodafone Foundation, 2009.

constituted 14% of all handset sales in 2009, were by far the fastest growing segment (up 24%), and are predicted to reach parity with global feature phone sales by 2012, enabling a slew of more advanced mHealth applications. The rapidly increasing ubiquity, capability and innovation of mobile technologies stands in stark contrast to those of more conventional health technologies and health infrastructures in many LMICs, demonstrating the potential of mobile technologies to help a rapid scale up and improvement of health services to underserved populations.

The health care sector in many LMICs is constrained by the high financial and human resource costs, as well as lengthy implementation times, of expanding health facilities and training workforces based on accepted WHO standards. A recent report from UNICEF[11] argues for an equity-based approach to child survival as the most practical and cost-effective way of meeting the health Millennium Goals, and it is likely that mHealth will be a key tool in the arsenal of policies and programs to reach poor and under-served populations. Many policymakers are therefore exploring the extent to which ICT, especially mobile technologies, can augment or substitute existing health care models by focusing on distributed primary care and centralized administration. This approach leverages the limited ICT administrative capacity of the healthcare system, while extending health knowledge directly to villages and community health workers, using mobile solutions that include data collection, remote diagnostics, treatment checklists, decision support, and patient reminders.

More than 100 countries are now exploring the use of mobile phones to achieve better health. In Ghana, for instance, nurse midwives use mobile phones to discuss complex cases with their colleagues and supervisors. In India, mDhil[12] sends text messages giving information about various rarely discussed health topics and supporting prevention and patient self-management efforts. Rwanda uses a system of rapid SMS alerts, through which community health workers inform health centers about emergency obstetric and infant cases, enabling the centers to offer advice or call for an ambulance if needed[13].

mHealth and eHealth have the potential to overcome many traditional obstacles to the delivery of health services to the poor in LMICs, especially those of access, quality, time, and resources[4]. In particular, one obstacle many LMICs face in the delivery of health services is the shortage of health workers and poor distribution of existing providers. At present, 57 countries face critical shortages of health workers, with estimates ranging from a global deficit of 2.4 million to over 4 million doctors, nurses, and midwives[14, 15]. These problems are exacerbated by deficiencies in the skills, training, and distribution of the existing workforce, with the majority of highly skilled health workers located in urban centers[10].

[11] UNICEF. "Narrowing the Gaps to Meet the Goals." New York: UNICEF, 2010. http://www.unicef.org/media/files/Narrowing_the_Gaps_to_Meet_the_Goals_090310_2a.pdf.
[12] mDhil is an mHealth product that provides basic healthcare information to the Indian consumer via text messaging, mobile web browser, and interactive digital content. See http://www.mdhil.com/aboutus
[13] UN, Global Strategy for Women and Children's Health, 2010.
[14] World Health Organization. *The World Health Report 2006: Working Together for Health*. Geneva: WHO, 2006.
[15] World Health Organization and Global Health Workforce Alliance. *The Kampala Declaration and Agenda for Global Action.* Geneva: WHO, 2008.

Low-cost mobile technologies can overcome some of these barriers through the remote delivery of health services and information, thus leveraging existing health service delivery platforms. Low-cost mobile technologies can also play an important role in enhancing the effectiveness of health workers, while giving rural and periurban populations access to health resources where skilled health workers and conventional infrastructure are limited. For example, the government of Rwanda recently announced a $32m eHealth plan to coordinate and promote the use of technology to support healthcare delivery nationwide, with the ultimate goal of leveraging ICT mechanisms, including mobile technologies, to achieve universal health coverage[16].

Perhaps nowhere is there greater potential for mHealth than in accelerating progress towards the Maternal and Child Millennium Development Goals (MDGs)[17]. Poor women and children often have very low access to quality health services due to poverty, lack of physical access to health facilities, poorly trained health providers, and cultural factors that limit health care accessibility[18]. Many countries are successfully employing community health workers to provide a first line service to these neglected groups. e- and mHealth have the potential to enhance these services by providing first-line providers with information, low-cost and easy-to-use diagnostic and decision support tools, and access to remote diagnostic centers, while giving systems administrators real time, actionable information on their staff, supply chains, and emerging patterns. In summary, the e- and mHealth combination has the potential to increase progress toward global health goals, ranging from improved disease-specific outcomes such as HIV/AIDS and malaria, to strengthened health systems.

The economic evidence-base for e- and mHealth

Although there is a growing recognition of the potential benefits of e- and mHealth, the literature shows little research to date into the economic impact of such investments in LMICs. First, while many papers note the potential benefits of eHealth[9, 10, 3, 4], few take this beyond speculation, by measuring outcomes directly linked to e- and mHealth solutions. Second, much of the literature takes a micro-view of the field, restricted to a case-specific evaluation of existing technologies[10, 19, 20]. Third, as further discussed in the section "LMIC-specific cost analysis", the limited range of studies on the economics of eHealth is mainly confined to OECD countries[21, 22, 23], with perhaps rather limited relevance for the very different

[16] The New Times. "$32M Health Initiative Unveiled." www.newtimes.co.rw/pdf.php?issue=14315&article=19469. 1 September 2009.
[17] MDG 4: Reduce child mortality; MDG 5: Improve maternal health.
[18] World Health Organization. *Countdown to 2015: Tracking Progress in Maternal, Newborn and Child Survival. The 2008 Report*. Geneva: WHO, 2008.
[19] World Bank. *eCapacity Enhancement Project for the Health Sector in Sri Lanka.* Geneva: World Bank, 2005.
[20] eHealth Case Studies. http://www.ehealth-impact.org/case_studies/index_en.htm.
[21] OECD. *Improving Health Sector Efficiency: The Role of Information and Communication Technologies.* Paris: OECD, 2010.
[22] RAND Europe and Capgemini Consulting. *Business Models for eHealth*. Cambridge, United Kingdom: European Commission, 2009.
[23] Dobrev, Alexander, Tom Jones, Karl Stroetmann, Yvonne Vatter, and Kai Peng. *Study on the Economic Impact of Interoperable Electronic Health Records and ePrescription in Europe*. Germany: European Commission, 2009.

problems that LMICs face (including the continuing brain drain of ICT and healthcare workers to the developed world).

With this in mind, this paper aims to encourage further discussion and research around the economics of eHealth in LMICs. Some important questions for consideration include: 1) the costs of eHealth infrastructure; 2) regulatory structures which provide incentives at different levels of the health delivery system to encourage investment in, and use of, eHealth; and 3) measuring the outcomes of successful eHealth utilization, including anticipated return on investment (ROI). The need is not just to add up the costs of ICTs, but to compare the costs of a distributed approach to the current health service delivery cost structure. It should also be noted that eHealth and mHealth deployments to date have almost invariably been one-off solutions for specific problems, rather than standardized, integrated systems connecting and sharing information along the full continuum of care. A siloed approach can result in 1) interoperability concerns, and 2) the inability to promote scale. And finally, it is important to evaluate how eHealth is applied, as that will also determine its effectiveness.

In recognition that eHealth is already a rapidly progressing field, answers to these questions can help identify: 1) how to best leverage these technologies at lowest cost, and 2) how to prioritize initiatives based on need, availability of resources, and anticipated outcomes. Toward this aim, we have divided the paper into two main sections focused on the costs and benefits of eHealth. Each section will highlight specific questions for further research, setting the roadmap for ongoing research and analysis. Within each question, we review the available literature, propose promising areas of inquiry, and offer methods to generate economic models for planning and analysis.

LMIC-specific cost analysis

The literature on the cost of ICTs in health is largely limited to OECD countries, with a focus on the role of information and communication technologies in improving health sector efficiency, deriving value from eHealth systems, and assessing the economic impact of eHealth investments. mHealth is not the explicit focus of the research. Furthermore, while this analysis is useful as a starting point, it may not be entirely relevant for LMICs. First, most OECD countries are heavily urbanized, with generally universal access to healthcare. Much of the investment has therefore gone into health management information systems and hospital administration, rather than the use of mHealth to increase access for underserved populations. Second, the level of training of health workers, the public-private mix of healthcare financing and providers, the health and IT regulatory systems, and the capacity of the public sector to introduce new technologies may be very different in poorer countries.

It is therefore important that separate studies are carried out in LMICs. These broad-based studies need to focus on LMIC-specific issues, including 1) the introduction of mobile technologies in remote, rural areas; and 2) the training of community health workers to use mHealth technologies. Outlined below are potential approaches to assessing e- and mHealth costs, including an examination of the impact of mHealth on overall healthcare costs, the drivers of cost within mHealth itself, and incentive structures to drive down costs of mHealth. This can include cost-effectiveness, cost-benefit, and cost-utility analyses as economic evaluations. Regardless of approach, it is important to maintain an LMIC-specific lens within each approach in order to address the deficit of research on mHealth costs within LMICs.

Impact of eHealth on health costs

Historically, in rich countries, technological innovation has tended to drive healthcare costs upwards[24]. Overall costs rise as new, expensive products are diffused to increasingly broader segments of the patient population. It has proved difficult to control demand, even if the efficacy of the new product is not yet well demonstrated. For example, within the United States there are many market incentives for consumers to overuse new products, in turn driving overall costs up. Information technology may also fail to decrease the costs of health administration. Contrary to the overall experience of business and government enterprises outside of health, where ICT has increased productivity, a recent HIMSS survey showed that while U.S. hospitals have increased their use of IT, there was no indication that it lowered costs or streamlined administration[25].

It is a reasonable hypothesis, however, that the introduction of low-cost mobile technologies has the potential to reverse this trend, at least as far as delivering health services to poor, underserved populations in both rural and urban areas. The cost of mobile phones, other hand-held devices, and

[24] Beever, Charles and Melanie Karbe. *The Cost of Medical Technologies: Maximizing the Value of Innovation.* McLean, Virginia: Booz Allen Hamilton, 2003.
[25] Healthcare IT News. "Health IT savings estimates are 'wishful thinking,' say Harvard researchers."

computers has declined dramatically over the last decade even as capabilities have increased. Similarly, mobile bandwidth capacity is increasing as costs decline[26]. Remote collection and transmission of diagnostic data by community health workers to centers with a critical mass of computer programs, skilled technicians and doctors (and computers) to interpret the data should be more cost-effective than often unsuccessful efforts to train and deploy an adequately skilled workforce in rural areas (and develop the requisite rural infrastructure). eHealth can provide transformative alternatives to increase the productivity of healthcare. However, since e- and mHealth are still in their relative infancy in LMICs, there is little concrete data and research to test hypotheses of this kind.

Potential methods for evaluating such trends include:

- *Analysis of relevant technology cost trends outside of healthcare.* This would allow for the extrapolation of trends in general ICT costs to potential cost shifts in health ICTs. While there is little direct evidence on the impact of ICTs on the cost of healthcare in LMICs, it is well established that ICT unit costs are declining rapidly. For example, according to U.S. Bureau of Labor Statistics consumer price data for computer equipment and mobile phones[27], the price of computers has dropped drastically, with a 20% annual decrease from 1999 to 2003 and an 11-12% annual decline for the last three years. The evaluation of non-healthcare technology costs over time is appealing as an immediate proxy for the lack of readily available data on eHealth-specific costs globally.
- *Analysis of cost of increased consumption of health services as a result of mHealth.* mHealth is largely intended to provide increased health access to people that are typically excluded or hard to reach. Studies of mHealth's impact on total health expenditures would compare the cost of this increased use with the cost if the same services had been delivered and consumed in the traditional manner.
- *Country-specific case study.* As previously noted, available research on costs related to e- and mHealth are typically restricted to OECD and EU countries[21, 22, 23], and may have limited value for policymakers in LMICs (although providing a useful starting point in study design, monitoring, and evaluation). Further, most trials of mHealth in LMICs are of single source solutions. To better understand cost trends in LMICs, it will be necessary to carry out a series of case studies in countries with a diverse range of development and health challenges. Potential countries for research include India, China, Nigeria, Ghana, Rwanda, and South Africa. These studies need to be broad and deep enough to reflect a complete system or subsystem, such as maternal care within a district. This will allow the full range of costs and benefits to be addressed.
- *Segmentation of the eHealth LMIC market*. Understanding segmentation of the consumer market is important in understanding product and service functionality, and the potential impact on prices. eHealth has yet to be subjected to this discipline as it is still in its early stages of development and largely driven by government grants and research donations. The

[26] To put this in context, in rural India, mobile phone coverage is 25 per 100 population, with higher costs in rural than in urban areas due to power shortages. Only 50m people, largely in urban areas, have broadband access and there are serious capacity constraints (evidence provided to author). However, scale up is likely to be rapid.
[27] U.S. Bureau of Labor Statistics: Consumer Price Index. http://www.bls.gov/cpi/

Rockefeller Foundation-funded Center for Health Market Innovations database[28], housed by Results for Development Institute, may reveal useful information that can help identify the level of adoption of mobile technologies by market demographics. For example, it appears from studies by the Development Fund of the Global Systems for Mobile Communications Association (GSMA) that 24x7 health information call centers are a valued and profitable service in a number of LMIC countries[29]. This information can help organizations developing mobile devices to focus on the subset of the population most likely to adopt the technology, based on need, interest, and rate of return. It can also help organizations identify differences in product considerations when defining market segments.

Drivers of cost within eHealth

In order for eHealth to fulfill its potential, the likely drivers of cost within the eHealth infrastructure should be assessed and, in turn, successful methods to contain costs identified. Such analysis first requires the identification and assessment of the individual drivers of cost within e- and mHealth, as outlined below. In recognition that an assessment of cost drivers should not be the sole focus of a financial analysis of eHealth, the cost drivers outlined below serve as a starting point for future research.

Potential methods for evaluating key cost drivers include:

Production process

- *Upfront investment in planning the eHealth infrastructure.* This can stand as a fixed or variable cost, but is an inherent part of eHealth infrastructure development. This can include the human resources, technology development, and initial training costs, as well as the costs of developing metrics to measure eHealth performance over time.
- *Assessment of integrated, interoperable systems (platforms) vs. a one-off approach.* ICTs have proliferated globally because standardization and competition have driven down costs and addressed consumer needs very effectively. Thus far, eHealth and mHealth investments have often been the opposite: primarily one-off projects to solve specific problems. A more efficient approach is to seek to replicate the scope and scale of the global wireless industry through the standardization of the architecture and interfaces of underlying hardware and software. This will allow the technology to be interoperable and support the full continuum of care through the sharing of platforms and common utilities. While there are certainly country differences in policy, content and infrastructure development, there are many similarities that can be leveraged to promote scale and reduce costs. Another example of deployment efficiency is the ability to host mHealth applications in large, secure data centers; this can help mitigate the need for IT infrastructure and expertise at the local level. It can also promote the sharing and implementation of best practices more quickly (due to fewer nodes to upgrade).

[28] Center for Health Market Innovations. http://healthmarketinnovations.org

[29] Ivatury, Gautam, Jesse Moore, and Alison Bloch. *A Doctor in Your Pocket: Health Hotlines in Developing Countries.* London: GSMA Development Fund, 2009.

- *eHealth's impact on human resources.* The impact of ICTs on the deployment of health workers, such as physicians, is critical to evaluate in determining overall costs. While distributed care obviously cannot always substitute for actual practitioner-to-patient care (for example, if surgery is required), it can enhance the quality of diagnostic and treatment services and greatly increase patient access, especially to initial primary care. For example, a telemedicine link between a specialist located in an urban setting and a patient in a rural setting promotes access, but may not change the cost structure. However, a distributed health system where functions currently designed to be performed by doctors or nurses in a clinic setting are transferred to less expensive health workers in the field (or to computers), enabled and monitored with ICT, saving only the critical cases for the doctors to review, may significantly impact the cost structure.
- *Cost savings as a result of the existing wireless market infrastructure.* A key issue for mHealth is the cost and capabilities of wireless hardware and services. These are generally already shared with non-health services, resulting in cost savings. Furthermore, private entities have developed such infrastructures with private investment, taking advantage of global economies of scale. There is a clear upward trend in capabilities (as evidenced by the introduction of higher capacity networks and smart phones), and a clear downward trend in costs of handsets and service. The latter is still relatively high in a number of developing markets. The primary determinant of cost of telecommunications to healthcare users will be some combination of competition in the overall market and any special arrangements made for health, either by a carrier for marketing reasons, or arrangements with the government.
- *Assessment of the cost-impact of sharing services between mHealth and other mServices.* The growing ubiquity of mobile technologies is resulting in the development of mServices, such as mobile banking, with an increasing emphasis on location-based services enabled by GPS. The cross-impacts of mPayments and mInsurance with mHealth is particularly interesting, with the potential to leverage common identification and registry databases. Given the overlap between mHealth and mServices, it would be useful to analyze the cost saving opportunities of shared devices, services and information platforms (e.g. shared promotion and education costs to the same users, common support and billing, etc.)
- *An examination of the relationship between cost and mass production*. Increased unit demand leads to volume production that pushes down unit costs in electronics. The GSMA led an initiative to reduce the cost of mobile handsets, by aggregating demand from a number of developing countries, and then developing a handset contract with an assured volume of 40 million phones[30]. If the forces of the global market can be brought to bear on mHealth, similar economies of scale are likely to prove true for mHealth technologies, and, potentially, mHealth services. Increased demand for mHealth technologies (resulting in part from the benefits of standardization) would allow vendors to reduce prices and increase market share and size. For example, a developer of a wireless ultrasound product currently prices an individual unit at US$5,000. However, the price would drop below US$1,000 per unit if there were a market for 100,000 units[31]. Standardization has other benefits. The mobile industry recently agreed to

[30] GSMA Embedded Mobile initiative. See www.gsmworld.com/our-work
[31] Anecdotal evidence provided to authors.

move to a universal power supply design, which, in addition to cost benefits, means any phone can use any charger. Further investigation, including discussions with technology manufacturers and suppliers will help determine whether such economies of scale in mHealth devices are likely to be the norm, or whether a market intervention is needed to aggregate demand (incentive structures for economies of scale are discussed below).

- *Impact of competition on product cost*. Competition has the potential to increase efficiencies and drive down costs amongst competing vendors. As such, it is important to survey the landscape of existing and potential competition for the specific eHealth product, in addition to opportunities for partnerships and economies of scale.

Public-private partnerships

- *Cost-impact of public-private partnerships (country case study)*. It is most likely that eHealth and mHealth will be offered in LMICs by a combination of public and private entities, with potential implications for costs. For example, wireless carriers may choose to host applications or services for free or reduced costs in order to stimulate overall wireless demand. Given that a number of these partnerships are already in development in countries like Brazil[32] and South Africa[33], they provide a real-time opportunity to collect and assess data on the cost impact of such relationships[10]. However, they are currently limited in scope. As the health value chain and the parallel economic value chain for integrated systems along the continuum of care are developed and understood, parties can develop sustainable partnerships where public and private interests are both served. In essence, how can each sector best direct the financial, technical, and operational responsibilities of developing an mHealth infrastructure in a cost-effective fashion? This is a critical area for public and private leaders to advance, creating examples that can be studied.
- *Case studies on end-to-end service along the continuum of care.* Recent reports have highlighted the need for dynamic public-private partnerships to help achieve MDGS 4 and 5[10, 34, 35, 36]. Trials of end-to-end systems to test the public-private model will provide opportunities to evaluate the impact of public-private partnerships on costs. One example is the recently announced Maternal mHealth Initiative[37]. One of its goals is to develop country trials of integrated ICT systems in maternal and child health through public-private partnerships.
- *Impact of donors on eHealth costs.* A key to driving down costs is standardization. Currently, donors are funding a wide range of individual, but siloed e- and mHealth initiatives; this approach may inadvertently hinder interoperability and standardization. Agreement between

[32] Nokia Data Gathering system through a partnership between Nokia and the Amazonas State Health Ministry.
[33] The Dokoza System through a partnership between Dokoza, State Information Technology Agency, Centre for Public Service Innovation, Centre for Scientific and Industrial Research and the Meraka Institute, South Africa's National Department of Health.
[34] Khan, M. Adil. *Achieving the Millennium Development Goals: The Public/Private Mix.* UN-DESA.
[35] Feezel, Charlie and Virginia Sopyla. *Achieving Millennium Development Goals through Public-Private Partnerships*. Boston: Harvard University.
[36] Taskforce on Innovative Financing for Health Systems, 2009.
[37] See www.mHealthAlliance.org

donors, LMIC policymakers and industry on architecture, standards and best practices should speed deployment, improve interoperability and drive down costs (as has been experienced in the computer and wireless industries over the last 25 years.)

- *The role of the public sector.* It is reasonable to assume that the private sector and civil society will continue to be important drivers of mHealth adoption, with many of the newest mobile technologies emerging from medical device and mobile technology companies. The public sector in LMICs will play an important role as purchaser and regulator, providing incentives or disincentives to increase uptake of mHealth and to reduce cost. It is likely that the overall healthcare and telecommunications regulatory structures will heavily influence the costs and speed of scale-up of mHealth. An analysis of the regulatory environment will therefore be necessary in determining the investment case for eHealth and mHealth. It would need to include the following: competition and price regulation; authorization of telecommunication/ICT services; universal access and service; radio spectrum management; legal and institutional framework; new technologies and impact on regulation[38]. Other factors, such as the relatively higher costs of provision of mobile phone access in rural areas needs to be considered[39].

As an example of the influence of regulatory systems, the global wireless explosion is generally credited to the decision by most countries (a) to license several wireless competitors, not just the incumbent wireline monopoly, and (b) to not regulate prices or services. In countries that have liberalized their infrastructure markets, some wholesale networks have emerged through the impact of market forces. In other countries, mobile operators are required by law to use the incumbent's network for backbone services, which may drive up the cost and/or reduce options for IT users[40]. Ethiopia still has a monopoly service provider so its wireless coverage lags far behind most other countries. This serves as a valuable case study of the downstream costs (and savings) for getting regulation correct.

In summary, it will be important to carry out case studies of different country regulatory systems to determine the healthcare and telecommunications regulatory structures that provide the best opportunities for low cost eHealth provision.

Potential questions for consideration include:[41]

- What are the reforms (e.g. in regulatory and licensing systems) needed to incentivize investment in, and utilization of, e- and mHealth services and devices?
- What incentives can the public sector put in place to drive down costs?
- What are the incentives for the public sector to support the development of a standards-based system, perhaps including a baseline information system platform?

[38] World Bank, infoDev and International Telecommunications Union, ICT Regulation Toolkit, 2010.
[39] For example, mobile operators may need to provide back-up power generators in areas with unreliable power supplies, thus increasing operating costs.
[40] Broadband for Africa, Developing Backbone Communications Networks, Williams D, World Bank 2010.
[41] Potential countries for evaluation against these questions include South Africa, Bangladesh, India and Brazil.

Analysis of downstream savings from investments in standardized mHealth platforms

Interoperability, defined as the ability to exchange and use information from another system or device, has proved to be challenging to implement. As systems move to machine-to-machine mode, simple connectivity is no longer adequate[42]. Furthermore, the addition of mobile communication devices adds completely new communication systems and rules. Interoperability is key to the scaling up of mobile health services in LMIC markets, and to ensuring end user convenience and flexibility in the utilization of mHealth devices and programs.

As such, it is important to build a basic health information platform to coordinate, guide, and support resultant individual mHealth initiatives. This will ensure interoperability among individual mobile technologies at the data communications layer, while addressing the challenge of scaling up mHealth programs. Furthermore, upfront investment has the potential to yield downstream savings, as individual mHealth devices will have the capacity from the outset to interface, share data, and leapfrog off one another's services. Through the development of a framework architecture, one can then create specific web, software, or mobile services for large-scale deployment in alignment with the existing architecture.

Potential methods for evaluating such trends include:

- *Case study of an end-to-end, integrated system, such as the Maternal mHealth Initiative of PMNCH, the mHealth Alliance and other organizations.* The initiative presents an opportunity to develop, measure, and analyze data on downstream savings as a result of the development of a standardized information system platform. This would also take an area-specific case study approach, focused on the use of a common information systems platform and offer the opportunity to evaluate the impacts of such a platform on costs.
- *Analysis of downstream savings from investments in information technology platforms outside of healthcare.* In particular, the development of the mobile phone infrastructure provides opportunities to study the benefits of the use of standards. The single GSM wireless standard used by most of the world and the global market buying and deploying it have been major drivers of innovation and cost reductions.

Determining the benefits of mHealth

As previously noted, there is little research on the benefits accruing from eHealth. Measuring the value-added of eHealth to global health outputs and outcomes will require cost-effectiveness analysis of such investments. Such analysis will help determine the objective value of eHealth investments, as compared with other investments that can improve patient health. Furthermore, it is important to recognize that

[42] Waegemann, C. Peter. "mHealth: The Next Generation of Telemedicine?" *Telemedicine and e-Health* 16.1 (Jan/Feb 2010) : 23-25. Print.

while eHealth may not decrease *overall costs* (even if unit costs decline, overall costs may rise as usage increases), it can still result in decreased unit costs for delivering specific services. And it can result in *increased benefits,* such as improved patient access to quality healthcare and patient satisfaction.

Measurement of mHealth costs and benefits can therefore help generate the data necessary to target and attract investments in mobile technologies, and prioritize these investments in the face of competing demands and resource constraints; in essence, developing an infrastructure that enables, first, greater health outcomes, and second, potentially lower costs. The measures described below push beyond commonly cited health outcomes, such as morbidity and mortality, and explore other metrics for evaluating program success.

Potential methods for evaluating such trends include:

- *Analysis of potential areas for cost savings and increased efficiency.* In evaluating the value of eHealth, it is essential to take into consideration the potential benefits to the overall health system, as captured below. The table outlines eHealth's opportunities for reducing costs and increasing efficiency as related to the patient and administration, and helps hone in on benefits that fall outside of outcomes tied to quality of care (eHealth's potential benefit to quality of care is discussed below). Further analysis should also take into consideration the extent of transformational change to business operations. Implementers must think through the layers of potential savings and efficiency gains, outlined in the table below, weighed against the level of change required for workflow and operations.

Health Systems: Examples of Potential Areas for Saving Costs and Increasing Efficiency	
Patient Issues	**Opportunities for Reducing Costs and Increasing Efficiency**
Patient registration	• One-time registration • Information available on subsequent visits • Serves multiple purposes (e.g. vital statistics registries in addition to care)
Creation of persistent record	• Improved speed and efficiency of care delivered • Information base developed for wide variety of direct care and administrative uses • Data is entered once
Payment for services	• Streamlined automatic billing, payment system • Documentation of billing, payment actions
Remote diagnostics	• Reduction of clinic visits • Saves time for patient • Improved patient triage • More efficient use of time of skilled health workers
Referrals	• Efficient access to closest available resources
Scheduling follow-ups	• Automatic messaging to public and providers
Disease surveillance	• Enables real-time surveillance, resource allocation
Public information	• More targeted distribution of information
24x7 call centers	• Decreased need for in-person clinic visits
Administration Issues	

Performance review	• Easier and more timely aggregation of data by factors including district, region, provider, and disease
Staff communications	• Voice and data communications increase efficiency
Staff management	• Ability to mine data to monitor staff performance through various filters, including at the individual or aggregate level • Ability to supervise staff in real-time
Staff training	• Combination of physical and eTraining may provide efficiencies over traditional model, particularly for "just-in-time" training
Payments	• Operations and record keeping efficiency • Fraud protection
Supply chain management	• Avoiding stockouts • Fraud protection, e.g. fake medicines
Research	• Development of data marts that can be leveraged for research • Reduce repetitive and costly primary research and data collection efforts.

- *Cost-effectiveness analysis of eHealth technology investments.* An evaluation of the benefits of eHealth programs should focus on clinical and social outcomes using reliable conversion factors[43]. The outcomes are focused on benefits to the patient and the provider, the two targets of eHealth technologies as discussed in the section on "The promise of eHealth." It is important, however, to translate the metrics to the end user of the specific technology. For example, smart phones could be used to help train community health workers in aspects of maternal and child health and the metrics should frame specified outcomes for mothers, newborns, and children resulting from the training. Further research should focus on the ability of eHealth to improve health systems outcomes as well, including but not limited to efficiency gains and strengthened service programs. The table below, derived from Dávalos et al[43], may serve as a starting point for measuring the value of clinical and social outcomes resulting from mHealth.

Representative Monetary Conversion Factors for mHealth Outcomes		
Client/Patient Perspective		
Outcome Measure	**Unit**	**Monetary Conversion Factor**
Medical Effectiveness		
Reduced morbidity[44]	Change in quality-adjusted life-years (QALYs)	Value of a statistical life-year from the value of a statistical life
Avoided mortality[44]	Avoided years of life lost	Value of a statistical life-year from the value of a statistical life
Healthcare services and others		
Increased access to healthcare	Indirect effect: Change in QALYs	Value of a statistical life-year from

[43] Dávalos, María E., Michael T. French, Anne E. Burdick, and Scott C. Simmons. "Economic Evaluation of Telemedicine: Review of the Literature and Research Guidelines for Benefit-Cost Analysis." *Telemedicine and e-Health* 15.10 (2009) : 933-949. Print.

[44] Potential opportunity to highlight outcomes specific to maternal, newborn, and child health.

		the value of a statistical life
Increased health knowledge/ ability for self-care	Indirect effect: Change in QALYs	Value of a statistical life-year from the value of a statistical life
Faster/accurate diagnosis and treatment	Indirect effect: Change in QALYs	Value of a statistical life-year from the value of a statistical life
Reduced waiting and/or consultation time	Missed hours/days of employment, classroom or leisure time	Average of minimum context-specific wage rate (hourly or daily)
Increased adherence to medical regimen	Indirect effect: Change in QALYs	Value of a statistical life-year from the value of a statistical life
Occupation		
Continuity of income	Missed hours/ days of employment avoided	Average of minimum context-specific wage rate (hourly or daily)
Increased employment/ leisure/classroom time	Missed days or hours of classroom time or work absences avoided; increased available leisure time	Average or minimum context-specific wage rate (hourly or daily)
Travel		
Money spent on travel: transportation	Distance	Mileage allowance rate or airfare cost to nearest referral facility
Money spent on travel: accommodation	Average cost for accommodations in referral location	1.00
Money spent on travel: other expenses	Money spent on local transportation and meals	1.00

Provider Perspective		
Outcome Measure	**Unit**	**Monetary Conversion Factor**
Healthcare services and others		
Reduced length of stay at medical facility	Days	Context-specific charges per inpatient day in facility
Avoided medical readmissions	Count	Context-specific charges per inpatient day in facility multiplied by the average duration of readmissions
Avoided inpatient visits	Count	Context-specific charges per inpatient day in facility multiplied by the average duration of inpatient visits
Avoided laboratory tests	Count	Average context-specific charges per emergency room visit
Avoided patient's transportation to healthcare facilities	Count	Average context-specific charges per laboratory test
Reduced length of consultations	Minutes or hours	Average context-specific physician or specialists' fee (hourly)
Other outcomes		
Increased medication adherence	Indirect effect: avoided use of healthcare utilization: number of inpatient visits, referrals, etc.	Average context-specific charges for specific healthcare services

Increased knowledge transfer among practitioners	Avoided referrals from knowledge transfer or hours/ days of training required to obtain same knowledge plus work time lost (in hours or days) for training	Average context-specific specialist fee (patient avoided costs should be included as well or cost per day of training plus work loss at average context-specific physician's hourly or daily fee)
Increased accuracy and faster diagnosis and treatment	Indirect effect: avoided use of healthcare utilization: number of inpatient visits, referrals, etc.	Average context-specific charges for specific healthcare services
Increased patient satisfaction	..	1.00 (willingness to pay for mHealth program)
Decreased travel and/or home visits for staff		
Increased employment time (productivity)	Days or hours	Average context-specific wage rate for nurses, physicians or other specialists (hourly or daily)
Money spent on travel: transportation	Distance in kilometers or miles	Cost to travel
Money spent on travel: accommodation	Average cost for overnight stay	1.00

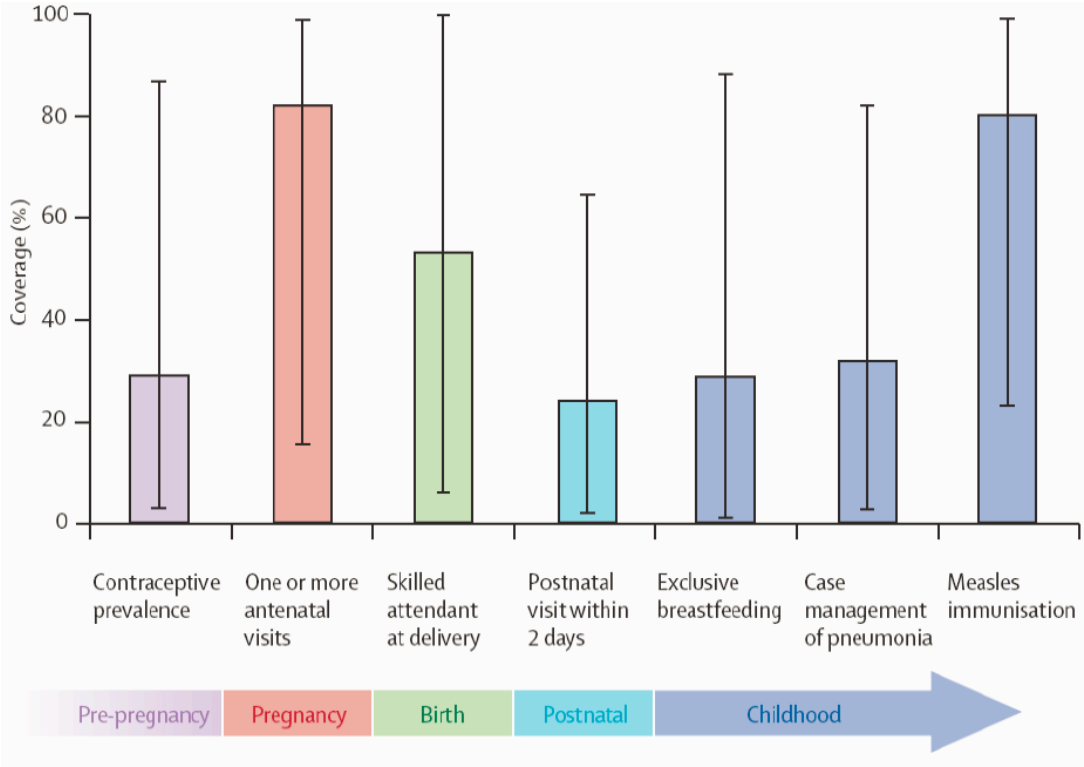
Other Stakeholders Perspective		
Outcome Measure	**Unit**	**Monetary Conversion Factor**
Healthcare services and others		
Increased productivity of workers (less travel, less illness)	Avoided missed days/hours of employment time	Average or minimum context-specific wage rate (hourly or daily)
More efficient access to health for special groups (informal sector, etc.): transportation costs, staff costs	Distance to referral facility and days/hours of work for staff	Mileage allowance rate for transportation and average daily or hourly wage rate for staff
Avoided cases of communicable diseases	Cases	Average medical costs (health resources utilization and staff) per case, average avoided loss of wages and productivity from illness per case

- *Cost-benefit comparison of mHealth technologies and alternative methods of health service delivery.* One of the key questions in determining cost is the standard against which to compare the value. There is now widespread agreement on the interventions, including health worker training and health systems infrastructure needed to reach the MDGs and these interventions have been costed[36]. Building on the metrics to measure mHealth benefits, as outlined above, further research could investigate mHealth outcomes as compared to traditional service delivery methods. For example, what is the difference in timeliness of treatment for a patient utilizing an mHealth device vs. a patient traveling in person to a medical facility? What is the difference in levels of patient satisfaction? This approach would not only provide a baseline point of comparison for program benefits and patient satisfaction, but also explore the potential for

cost-minimization as a result of mHealth technologies. Additionally, it would highlight areas in which mHealth may *not* provide cost-effective outcomes for health access and service delivery, thus providing the factors which determine when mHealth is best leveraged.

- *Maternal, newborn, and child health (MNCH)-specific outcomes analysis*. Mobile technologies are recognized to have much to offer in improving MNCH, with significant efforts under way now through the mHealth Alliance and other public-private partnerships to harness their potential. In the utilization of mHealth programs with the MDGs, however, it is important to direct efforts towards areas of greatest need. Fig 1 below identifies the gaps in the coverage of procedures within the continuum of care related to maternal, newborn, and child health, which if met, would significantly impact on the MDGs[45]. Future mHealth initiatives addressing MDGS 4 and 5 should target mHealth technology investments to these areas of greatest need. For example, could mHealth investments be used to improve coverage of post-natal visits within two days, by developing an SMS reminder service for pending appointments?

Fig 1. Coverage estimates for interventions across the continuum of care in the 68 priority countries (2000-2006).



[45] Source: Countdown to 2015: Tracking Progress in Maternal, Newborn and Child Survival. The 2008 report.

eHealth and Maternal and Child Health

This paper proposes two basic lines of enquiry into the economics of eHealth: 1) an examination of the drivers of eHealth costs, and 2) an analysis of the benefits – to patients and health workers – which can accrue from the introduction of eHealth systems. The paper sets out a basic roadmap for investigation which can support sound investment decisions for eHealth in LMICs. The central premise of this paper is that *systemic* investments in m- and eHealth can rapidly expand cost-effective quality health care distribution to under-served groups – this is essential if the global community is to reach the MDGs. An end-to-end systems approach is necessary to avoid costly and potentially mutually incompatible one-off solutions.

In developing a policy and research program to test this premise, it is essential to avoid one of the central problems identified in the literature review: individual studies of independent components. These are unlikely to provide the kind of information which policy makers will need to make large-scale investment decisions. As such, the proposed next step would be to identify a diverse group of three to four leading LMICs in the eHealth arena which could provide the platform for this research, to help guide policymaker decisions on eHealth investments. Within those countries, the proposal would be to create large scale trials of integrated systems (i.e. supporting the full continuum of care in an area, such as maternal care), as opposed to point solutions. These would be designed to produce answers to the key financial issues which policymakers face. The areas outlined suggest a framework for further research that can be applied through case studies in a variety of settings and for a range of audiences. Further, given the critical importance of women and children's health, the research should be focused in this area.

The previously cited 2010 UNICEF study *Narrowing the Gaps to Meet the Goals*, notes that millions of lives can be saved by investing first in the most disadvantaged children and communities[46]. The most impoverished child populations are faced with the greatest national burdens of disease, ill health, and illiteracy; as such, focusing on these children with the greatest need can greatly accelerate progress towards the MDGs and reduce disparities[47]. Using, for example, the "marginal budgeting for bottlenecks" (MMB) approach[48], eHealth planners and end users can estimate the costs of leveraging technology to leapfrog existing bottlenecks within healthcare delivery, and more specifically, within MNCH. eHealth's greatest promise for LMICs lies in its potential to leapfrog traditional obstacles to healthcare delivery in resource-constrained areas; and the MBB approach can serve as a starting point

[46] UNICEF. "Narrowing the Gaps to Meet the Goals." New York: UNICEF, 2010. http://www.unicef.org/media/files/Narrowing_the_Gaps_to_Meet_the_Goals_090310_2a.pdf.
[47] UNICEF. "New UNICEF study shows MDGs for children can be reached faster with focus on most disadvantaged." www.unicef.com. 7 Sept 2010.
[48] A results-based planning and budgeting tool developed by UNICEF, UNFPA and the World Bank that identifies system-wide supply and demand bottlenecks to adequate and effective coverage of essential health services.

for planning and evaluating e- and mHealth investments. The UNICEF research needs to be supported with a more detailed study of how mHealth and eHealth can help achieve its tactical goals.

Case studies for the application of eHealth to MNCH in systemic innovation trials need to be developed. In these cases, the investigation of the proposed research areas can help to guide analysis and decision-making from the outset, and in turn develop a framework for assessing ROI scenarios 5-10 years into the future.

Looking forward

With the rapid increase in the number of e- and mHealth projects, several trends indicate the potential for such technologies to overcome some core health obstacles in LMICs, particularly in resource-constrained areas. In particular, mHealth has the potential to contribute to the achievement of MDGs 4 and 5, providing mothers and children with increased access to health resources and services. However, it is essential to consider and quantify the full range of financial costs and benefits through rigorous economic evaluation. The need is not just to add up the costs of ICTs, but to compare, to the extent feasible, the costs of a distributed approach enabled by mHealth to the current health service delivery cost structure. The previously cited "Narrowing the Gap" UNICEF report points the way.

At present, there is little economic evaluation of eHealth, with existing research at too small a scale to reach generalizable conclusions for investment decisions. For eHealth programs to succeed, public and private health and IT stakeholders need to develop an investment case to drive scale up and sustainability of eHealth infrastructures. The economic models and scenarios provided in this paper will help measure, direct, and evaluate eHealth program performance and better target and attract public and private investment. Failure to do so could result in missed opportunities to harness the transformational power of eHealth networks and devices.

This paper focuses on promising areas for research to build such an evidence-base, through real-world case studies and economic models, and attempts to provide a preliminary framework of questions to pursue in the evaluation of the economics of eHealth. Although eHealth projects are already operating in a wide variety of countries around the world, and thus may provide useful data to generate a platform for informed decision making on investments in eHealth, we are not aware of any that have been designed as integrated systems (i.e. supporting the full continuum of care in an area, such as maternal care), as opposed to point solutions. The research and analysis outlined in this paper can help maximize the value added of future eHealth investments. The next step should be a carefully targeted research program across a diverse group of low and middle income countries using integrated systems as the subject.

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