HOW COULD HEALTH INNOVATIVE TECHNOLOGIES IMPROVE HEALTH OUTCOMES IN SOUTH SUDAN?

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ABSTRACT

South Sudan like many other sub Saharan African countries has poor health system especially those managed by the government. The country did not inherit many improved health facilities and equipment at the time of its session from The Sudan. Majority of health facilities are dilapidated and large section of the population mainly in the rural areas luck health services. The ministry of health is usually allocated with small budget which limits its functionality in the country sides where the majority of the people are located since more than 80 per cent South Sudanese live in rural areas. However, with the help of development partners, many health facilities have been rehabilitated and some equipped with medical devices that help save lives.

Knowing that change is imminent in delivering healthcare, in my thesis, I plan to find out how South Sudan could benefit from the wave of health innovative technologies in reducing maternal and neonatal mortality as key health outcomes in the country. I would be looking at the impacts and performance of health services in the country as a result technology. Looking at clinical informatics, I would also examine how information system has improved as a result of technology. From economic point of view, I would find out the expenses and cost associated with these improved health tools/ apps used at various locations. I would be looking at the modern tools or apps that are used in the country and also compare the gaps between private and public health services.

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ACRYNOMS

CH – County Hospital

DHIS – District Health Information System

EAHRC – East Africa Health Research Commission

EHR – Electronic Health Records

EWARS – Early Warning and Response System

FMOH – Federal Ministry of Health

GDP – Gross Domestic Products

GOSS – Government of Southern Sudan

HIV/AIDS – Human Immune Virus Acquired Immune Deficiency Syndrome

HRHP – Human Resource for Health Plan

HSDP – Health Sector Development Plan

HTI – Health technology Informatics

MAMA – Mobile Alliance for Maternal Action

MDGs – Millennium Development Goals

MoH – Ministry of Health

MMR – Maternal Mortality Rate

NMR – Neonatal Mortality Rate

PHC – Primary Health Care

PHCUs – Primary Health Care Units

PHCCs – Primary Health Care Centers

PHCPI – Primary Health Care Performance Initiative

SDGs – Sustainable Development Goals

SMOH – State Ministry of Health

WHO – World Health Organization

CHAPTER ONE - INTRODUCTION

1.1 Background

For over 40 years of quest for self-autonomy from the Sudan, the southern region of Sudan which in July 2011 formally attained her independence and joined communities of nations suffered great infrastructure devastation during the civil war. The country inherited huge gap in health care services from Sudan and quickly finds itself in the taxonomy of countries with poorest health status because it trails behind neighboring countries in health care indicators.

Before seceding from Sudan, the Ministry of Health (MoH) of the autonomous government of Southern Sudan was considered a separate administrative level functioning as an interface between the Republic of Sudan Federal Ministry of Health (FMOH) and the 10 states ministry of health (SMOH) in the south (Global workforce alliance). Despite Federal Ministry of Health attempts to formulate policies that put healthcare services at the center stage for all regions in Sudan following the "1998 health policy for Southern Sudan", South Sudan was the victim of significant regional health system disparities. With only three hospitals in a country size of France, the country after its independence had to struggle to provide health care serves; health facilities, health workers and improve doctor-patient ratio.

Sudan had several ambitious strategic plans such as the "Twenty-Five Year Health Strategy (2007-2031)", the National Health Policy 2007, and the Five-Year Health Plans for South Sudan (2007-2011). The government aimed at stretching health services in all the regions including Southern Sudan. The twenty-five-year health plan was designed with emphasis of equitable access to health care in the country. The people of Sudan were expected to lead a healthy life regardless of their localities and as well as socio economic status. The 25-year strategic plan

encompasses the introduction of health innovative technologies to assist and enhance health workers' performances in the country. The growing need for modern medical equipment to achieve Sustainable Development Goals (SDGs) meant the Sudanese Government had to adjust health financing procedures, ensuring funds are channeled to the right targets. Basing on the 25-year strategic plan, South Sudan should have benefited from the project four years (2007-2011) into the implementation of the plan especially the introduction of advanced health care technologies but the realities on the ground tells otherwise.

Driven by the global goal of achieving universal health coverage, Sudanese government set up guiding approach for health sector, The National Health Policy 2007. This framework was developed on the principles that The National Health System should be founded on solid policies, performance-based targets, and continuous quality improvement and client satisfaction. The Federal Ministry of Health at national level and the States Ministry of Health were tasked with institutionalizing the policy at all levels. All the states were to strengthen and clarify how it operationalize the healthcare services such as financing, use of advanced technologies and overall performance improvement in health sector.

South Sudan has so far formulated two health policies; the first health policy 2006-2011 was during the Interim Government when the country was an autonomous region of Sudan and it was developed based on the 2005 Interim Constitution of Southern Sudan which stipulated that every level of government in the country shall promote public health, create, rehabilitate and develop basic medical and diagnostic institutions as well as provide free primary health care and emergency services for all citizens (Constitution, 2005). The second health policy (2016-2026) was after seceding from Sudan and it became the first National Health Policy of South Sudan that sets a new paradigm in the operationalization of health sector in the country. The policy is

"cognizant of global health agenda such as; Paris Declaration of Aid Effectiveness, the Millennium and Sustainable Development Goals". In 2010, the autonomous government of Southern Sudan in its effort to establish health management information system in accordance with the National Health Policy developed by the FMoH in Khartoum, conducted Southern Sudan Household Survey II with support from development partners like United Nations Children's Fund (UNICEF). The specific objectives of the survey were to provide up-to-date information on the health status of women and children to understand differences related to health determinants such as poverty, education, gender, and residence type (urban/rural) and to monitor the progress towards achieving the Millennium Development Goals (MDGs).

The Five-Year Health Sector Strategy (2007-2011) was another short-term health care strategic package designed to address the weaknesses in the health sector. One of the key features of this plan was to strengthen the role of the Federal and State Ministries of Health in policy development and systems/services management (Sudan_HRHPlan_2012-2016). South Sudan adopted a decentralized system of health sector management. The country has four-tier health service structures that's the central, state, county and community levels where each level performs well defined roles and responsibilities according to the National Health Policy. The implementation and lessons learnt from the 2007-2011 Health Sector Strategy and the Southern Sudan Health Policy of 2006-2011 sets out a new framework in 2012 as a sign of political willingness for the sovereign government of South Sudan. The MoH of the GoSS commissioned Health Sector Development Plan 2012-2016 (HSDP) to facilitate health framework aiming to achieve a more efficient and responsive health services for the population of South Sudan (Ministry of Health, 2010). The government set a vision to have a healthy and productive population fully exercising its human potentials. To meet the above vision, the mission of the

government was to ensure South Sudanese population have access to basic health care of acceptable standards, affordable, sustainable and cost-effective. The HSDP with a strong theme "One maternal death is one too many" therefore, aims at strengthening prevention and control of communicable and non-communicable diseases, reinforcing Maternal and child health care and building up system in partnership with the communities and stakeholders. In this research, I will explore the healthcare system of South Sudan through the following steps.

1.2 Research Questions, Aims and Objectives

Aim: To show the importance of health innovative technologies in the reduction of maternal and neonatal mortality rates

Objectives:

a) To present evidence of the success of health innovative technologies to the health policy makers in South Sudan
b) To identify innovative technologies used in the prevention of maternal and neonatal deaths
c) To show the trend of maternal and neonatal mortality rate in the region
d) To show regional health expenditure as compared with South Sudan's budget for health
e) To recommend the use of the digital space in the reduction of maternal and neonatal deaths

Research Questions:

a) What are the benefits of health innovative technologies in achieving health outcomes?
b) How could the success story of health technology motivate health policy makers in South Sudan?
c) What are the common innovative technologies used in healthcare system?
d) How control variables such as GDP per capita, out-of-pocket expenditure and health expenditure per capita affect the use of technology in health?

1.3 Scope of the research

This research attempts to address the above guiding questions and objectives by exploring the diffusion of technology in health sector and how it has ultimately changed healthcare system in developing countries with specific interest to East African region where there is rapid growth of technology revolution. The research will provide the healthcare system of South Sudan before and after the independence and how it manages to rehabilitate after the recent civil wars. The research will exclusively discuss two health outcomes thus, maternal and neonatal mortality of South Sudan and the region and how some countries adopted health technologies in scaling down this rate. The research will proceed as follows;

Chapter 1: introduction which presents country profile and its healthcare system.

Chapter 2: provides the overall literature review beginning with the two health indicators and finishing with digital technologies in health sector including mobile phone penetration which is very important for information coverage.

Chapter 3: elaborates on South Sudan public health system and its national expenditure on health in comparison with the neighboring countries.

Chapter 4: presents the methodology for this research including the hypothesis

Chapter 5: presents the data analysis

Chapter 6: conclusion and recommendation

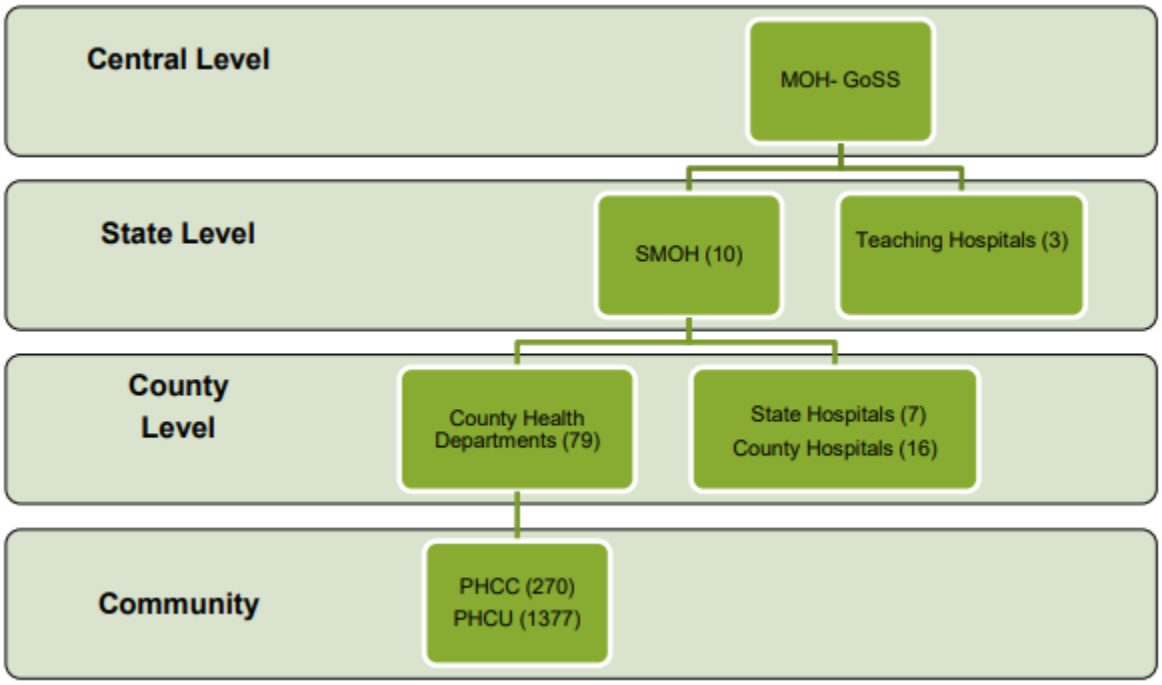
1.4 Qualities of Primary Health Care System in South Sudan

Primary Health Care (PHC) should reflect and evolve from the economic conditions and sociocultural and political characteristics of the country and its communities and is based on the application of the relevant results of social, biomedical and health and health services research and public health experience (Alma-Ata Declaration , 1978). Admitted as 193rd Member State of the United Nations, South Sudan was expected to join the rest of the world in providing universal health care defined by the noble primary health care vision of delivering "health for all by 2000". Although, health for all vision was generally not attained by large number of member states prior to the independence of South Sudan, and since the principles remain relevant till today, member countries are encouraged to continue playing vital roles in ensuring sound health care systems are established. Steady progress can be realized towards the commitment by building resilient national health system with people centered PHC that provides affordable and accessible health services to everyone.

In South Sudan, primary health care system is the corner stone for building effective and sustainable health standard. The country has four-tier health service structures; the Primary Health Care units (PHCUs), the Primary Health Care Centers (PHCCs), the County Hospitals (CH) and lastly the State Hospitals. The first two tiers; PHCUs and PHCCs form the primary health care system of the country. PHCUs provide most of the basic services, preventing disease

outbreaks and curing sick people. Geographically, PHCUs and PHCCs fall under Boma and Payam respectively. Boma and Payam are the lowest and second lowest administrative levels of South Sudan. It is at these levels the Alma-Ata Declaration would have been fully implemented.

Figure 1: The four tiers of health service in South Sudan



Source. Ministry of Health and Government of South Sudan (2011, pg.8).

In 2018, in its effort to produce better population health outcomes, South Sudan joined the rest of the world in committing to the new global commitment on PHC, the Astana Declaration 2018. The new declaration endorses the obligation of every government to guarantee the fundamental right of every citizen to the enjoyment of the highest attainable standard of health without distinction of any kind (Asanta Declaration, 2018). Therefore, the qualities and or characteristics of PHC is at the heart of health services.

The qualities of PHC can be measured by using the Vital Signs Profiles, a new measurement tool developed by the Primary Health Care Performance Initiative (PHCPI) for understanding primary health care systems. The model focuses on four factors that are essential in providing critical answers on the qualities and or characteristics of a PHC system. These four factors are first, the Financing indicator capturing overall government expenditure on primary health care. Second, the capacity of the system such as policies, infrastructure and human capital to serve people. Performance and Equity are the third and fourth indicators respectively. They measure the primary health care system services to the people's health needs and the effectiveness of the service to the needy regardless of their socio-economic status.

South Sudan PHC infrastructure is no doubt one of the least developed by international standards and also lagging behind at regional level. The independence war which devastated every sector including health system resulting into long-term negative health impacts was largely to blame. But also, the weak post-conflict health system of the government is another strong reason for the current dilapidated health care status. The government would have embarked on unshakable commitment on PHC and continue investing on the country's health system, shouldering the responsibility and limiting reliance on Non-Governmental Organizations (NGOs) that fill the void of service delivery in health sector. South Sudan National Health Policy 2016-2026, a ten-year health policy reform that becomes a new paradigm for health service delivery in the country, calls for adequate healthcare financing that fosters universal health coverage. The MoH plays pivotal role in ensuring health budgets receives increased funding to support PHC system. Before gaining independence, the MoH of GOSS with the guidance of the Southern Sudan National Health Policy 2007-2011 develops "a sound health sector financial management system, mobilize additional resources for health, and ensure expenditures are affected according

to the sector priorities and coordinated across sectors". (Health Policy, Government of Southern Sudan 2007-2011).

The capacity of PHC in South Sudan is inadequate with over 80 per cent of the population living in the rural areas, the few facilities concentrated at urban centers could become inaccessible due to poor road networks. The imbalance characteristics of health facilities affects MoH pursuit of meeting the reaffirmed principles of the universal health coverage, the Astana Declaration 2018. PHC requires government commitment in training, producing and maintaining health workers to serve even at the remote locations. In 2005, according to the first human resource policy, the HRH Policy 2006-201, the country had under ten thousand (9650) health personnel of whom only 3 per cent had university education. In 2013, International Organization for Migration (IOM) South Sudan found health facilities were significantly understaffed at all levels. There was apparent shortage of doctors at PHCCs and even the Medical assistants were largely absent at their duty posts. Due to the shortage and frequent absenteeism of the health workers, the overall satisfaction about health services was very low with 76.9 per cent of the respondent dissatisfied (IOM-Village-Assessment-Survey-Report-2013).

Over the years as the government transitioned to managing PHC and actively involving in producing human resource, by the end of 2015, with the support from Interchurch Medical Assistance – IMAWorld Health, about six thousand health workers were trained in Maternal and Child Health (MCH), nutrition and Human Immunodeficiency Virus and Acquired Immunodeficiency Syndrome (HIV/AIDS). There was complete report on disease surveillance and measle coverage through PHC service. The World Health Organization (WHO) and UNICEF were the development partners supporting the immunization campaigns in nationwide. In 2014, Liverpool School of Tropical Medicine found overall service availability was poor with

only 16 per cent health facilities offering Integrated Management of Childhood Illness services – (Tropical Medicine and International Health 2014).

On the equity indicator, the PHC is expected to provide effective and accessible health care service to all groups in the society. This expectation is enshrined in the national health plan 2012 that aimed at ensuring that 70 per cent of the population were within 5 kilometers of health service provider- (Geospatial Health 2017). Spatial accessibility to basic public health services revealed that in South Sudan, just about 29 per cent of the entire population were within 5 kilometers of a public health curative service which indicated how far behind the ministry of health goal of achieving its sector development plan ambition of 70 per cent. (Macharia M., 2017)

1.5 Scale of health technology innovations in South Sudan

Over the years, more countries and pharmaceutical industries have been redefining innovations in healthcare by using modern technologies for constantly checking patients' health and well-beings which led to noticeable behavioral and lifestyle changes. The advanced health modern technologies capture variety of spectrums such as m-Health which refers to the use of mobile devices for monitoring national healthcare services in combating non-communicable diseases and risks associated with them(*Kriza et al. - 2014 - A Systematic Review of Health Technology Assessmen.Pdf*, n.d.). eHealth is another health innovation that is rapidly growing globally due to "the transition of the healthcare industry into the digital healthcare system for patient's management and analysis" (Digital Health 2020). Electronic Health Record (HER) as part of

innovations in healthcare is a “digital version of a patient’s paper chart. They are real-time, patient-centered records that make information available instantly and securely to authorized users” – (HealthIT.gov).

South Sudan which is prone to epidemic outbreaks such as cholera, measles, yellow fever, etc. has not witnessed the use of health innovative technologies on larger scale due to repeated political and military conflicts that results to broken health system and poor infrastructures, under documentation of health and demographics. In 2011, however, the country launched District Health Information (DHIS) software package to manage nationwide health information. DHIS is a software developed for collection of health data, analyzing and disseminating on patient-based to support health information management. it has been adopted and used by many countries around the world. South Sudan rolled out the upgraded version, the DHIS2 in February 2019. It is “a modular web-based software package built with free and open source Java frameworks”. Besides the DHIS, the country also launched Early Warning, Alert and Response System (EWARS) to harmonize health indicators.

CHAPTER TWO – LITERATURE REVIEW

2.1 Introduction

This chapter assess articles, other reports that are already existing and they aligned with the use of health innovative technologies. Recent medical journals, articles from Google Scholar and WHO reports on health indicators were reviewed. Starting with health indicators, the chapter finishes with technologies in health domain.

Innovation is the creation of new ideas to solve various challenges. Technology innovation in the last decade has been growing fast in the healthcare domain. "Studies in Health Technology and Informatics (HTI) series was started in 1990 in collaboration with European Union programmes that preceded the Horizon 2020 to promote biomedical and health informatics research" (Transforming Healthcare Through Innovation in Digital Health- Ginige, Jeewani Anupama, Maeder, Anthony John 2018). The healthcare innovative technology trend encompasses wide range of health services in both developed and developing world. In Africa for instance, emphasizes have been put to scale up health technologies in the context of health challenges facing the continent such as maternal and neonatal mortality, access to health facilities and delivery of items in remote areas. According to UNICEF report 2013, only five countries in sub-Saharan Africa achieved the Millennium Development Goals 4 and 5 of improving child survival and reducing maternal mortality. Various literatures pointed that increase of both maternal and child morbidity and deaths especially in sub Saharan Africa reflects non-responsive healthcare systems that perpetuate widespread inequalities as a result of ineffective and unsustainable interventions. (Esama et al., 2017). On the wider scope, health innovative technologies comprise of Digital Health, Healthcare and Innovation, and Healthcare and Technology.

Technologies in healthcare have become the novel methods for national healthcare systems to provide quality and easy access to health services. In a post-conflict setting like South Sudan, technology in health could strengthen already under-staffed and dilapidated health care system.

2.2 Maternal Mortality and Neonatal Deaths

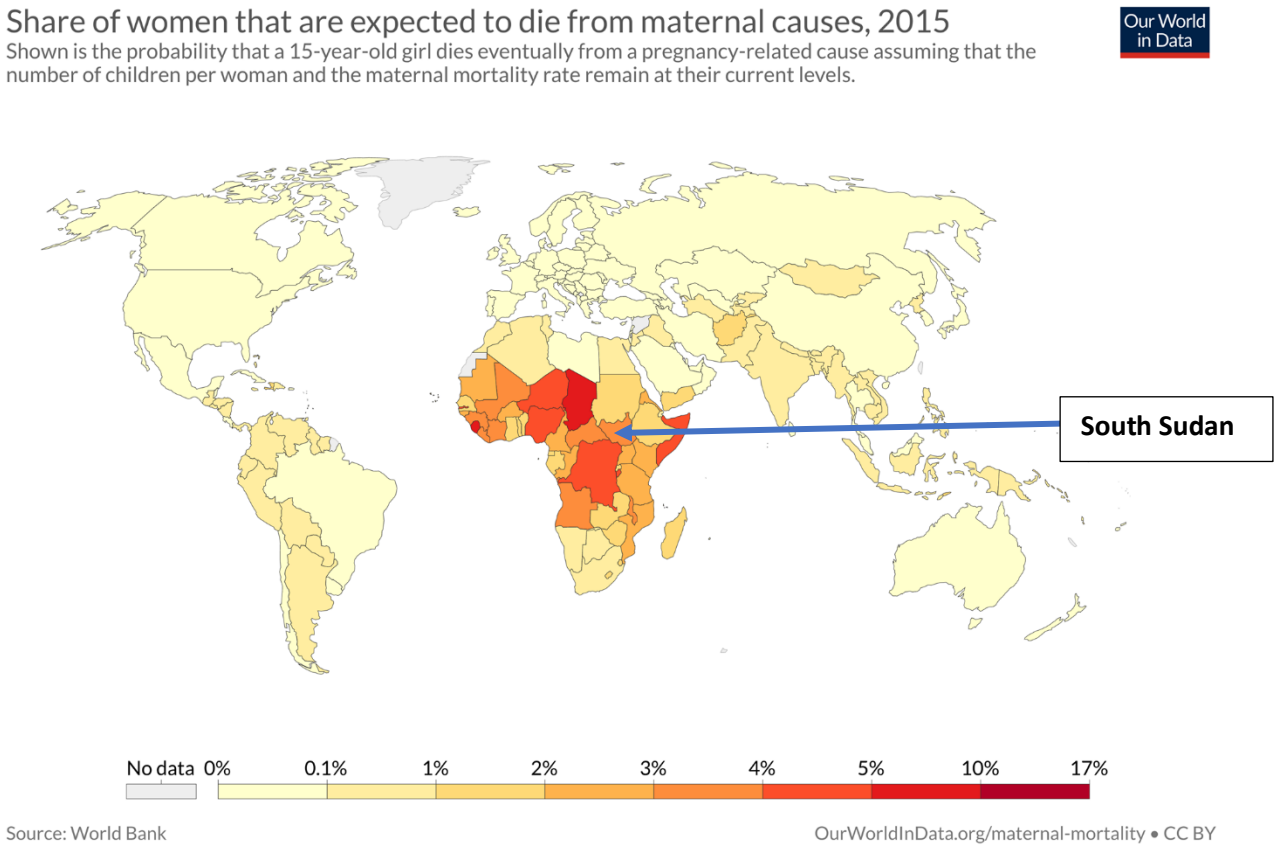
Maternal death is defined as the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes (M. Patwardhan et al., 2016). Maternal mortality which stands at 789 per 100,000 live births is one of the daunting health problems facing South Sudan since gaining independence in July 2011. In 2014, WHO reports indicated not only that South Sudan had high maternal mortality ratio but also showed alarming statistics of neonatal and under-five mortality rates at 39.3 and 99.2 per 1000 live births respectively. Lack of health personnel and devasted health facilities contribute to the rise of the mortality and from the Southern Sudan Household Health Survey 2006, the percentage of women who had skilled birth attendance during their pregnancy period were only 10% while ante natal visits were as low as 26%. Before secession, the central government in Khartoum launched initiative to reduce the under-five mortality rate in order to meet the MDG target of 41 deaths per 1000live births by the end of 2015. Subsequently, this effort lead to drop of under-five child mortality from 124 deaths per 1000 live births to 108/1000 indicating progress although not sufficient enough to achieve the MDG target (Rai et al., 2012).

Table 1: South Sudan Maternal Mortality Rate and Ranking in the world.

Similar Country Ranking	
Country Name	**Per 100K Live Births**
Sierra Leone	1,360.00
Central African Republic	882.00
Chad	856.00
South Sudan	**789.00**
Somalia	732.00
Liberia	725.00
Burundi	712.00
Gambia	706.00
Congo, Dem. Rep.	693.00
Guinea	679.00

South Sudan Maternal Mortality Rate - Historical Data		
Year	**Per 100K Live Births**	**Annual % Change**
2015	789.00	-4.13%
2014	823.00	-2.14%
2013	841.00	-1.87%
2012	857.00	-1.38%
2011	869.00	-0.80%
2010	876.00	-1.13%
2009	886.00	-4.53%
2008	928.00	-4.43%
2007	971.00	-5.73%
2006	1,030.00	-5.50%
2005	1,090.00	-5.22%

Sources of data:
Global Health Observatory May 2017
http://apps.who.int/gho/data/node.cco



South Sudan Health Statistics

Mortality and global health estimates	
Neonatal mortality rate (per 1000 live births) (2015)	37.9 [20.5-67.3]
Under-five mortality rate (probability of dying by age 5 per 1000 live births) (2015)	90.7 [56.4-143.6]
Maternal mortality ratio (per 100 000 live births) (2015)	789 [523 - 1 150]
Births attended by skilled health personnel (%) (2010)	19.4

Sources of data:
Global Health Observatory May 2017
http://apps.who.int/gho/data/node.cco

2.3 Neonatal mortality rate

Neonatal mortality rate is the number of neonates dying before reaching 28 days of age, per 1000 live births- (World Data Atlas, p.n.). Annually, millions of neonatal deaths are been experienced around the world accounting for around 44% of deaths of children below five years. Despite global decline in childhood deaths, neonatal deaths continue to occur especially in resource poor countries like South Sudan. A study on neonatal deaths confirmed that majority of neonatal deaths happen mostly in low- and middle-income countries with very limited healthcare infrastructures and insufficient resources to maintain them. Major tertiary hospitals lack basic care services and are far from the rural communities where most populations reside (Thomson et al., 2017).

Many countries have now laid down commitments to substantially reduce the rate of infant deaths among communities. India, for instance, which has the highest number of births in the world with neonatal rate (of 44 per 1000 live births) is encouraging free of charge prenatal care that is close to homes as the corner stone for reducing maternal and infant mortality rates. The campaign also addresses other key concerns such as lack of healthy behavior due to low level of education especially among first time mothers, and malnutrition.

WHO estimated that globally 2.5 million children died in the first month of life in 2018, bringing the average number of newborn deaths per day to around 7000 deaths amounting to "47% of all child deaths under the age of 5-years, up from 40% in 1990. About the same number of babies were born stillbirth (in 2015)" (WHO Fact Sheet, 2019, pg.1). In sub-Saharan Africa, the rate of neonatal mortality remains the highest in the world with 28 deaths per 1000 live births although there is variation within the countries due to different degree of commitment and political will by individual governments for comprehensive health care initiatives. The WHO in its global effort

to reduce infant mortality had been supporting sub Saharan countries in promoting health technology infrastructure in order to tackle challenges of health care deliveries. In Central and Southern Asia, the rate of neonatal deaths in 2018 was 25 deaths per 1000 live births making them to become the second highest region in the world after sub Saharan Africa. There are several issues that leads to the high neonatal death rate in Sub Saharan Africa, for example, the household income level and the level of education of the expectant mothers all affect the behavior of the pregnant women. The location of health facilities which are mostly sparse in rural areas also affects ante natal visits as a result, pregnancy complications might not be noticed until delivery.

In South Sudan, the neonatal mortality rate in 2018 stands at 40 deaths per 1,000 live births indicating some slight improvement in bringing down neonatal mortality in the country from 57.7 deaths per 1000 in 1999. The 40 deaths/1000 live births could be undercounted because in Sub Saharan Africa, many births occur at homes and they are not registered. For example, a population-based study in rural Gambia indicated that 84% of neonatal deaths occurred at home due to inadequate services of healthcare (Leach et al., 2016). They also found out that other factors such as insecurity, poor governance, lack of infrastructure, a weak economy, lack of a skilled educated workforce and geographic constraints lead breakdown of health system contribute to high ongoing unmet health needs like in the Republic of South Sudan.

2.4 Neonatal mortality ranking

South Sudan ranks 3rd in the world in 2018 just behind Central African Republic and Pakistan. There has been steady decline of neonatal mortality rate from 2005 up to 2014. In 2016, South Sudan slipped back to the same neonatal mortality rate level of 40.3 per 1000 live births it had in 2013 however, 2017 and 2018 had small consecutive decline of 40.1 and 40.0 respectively. On the other hand, the Sub Saharan African countries in the top ten (10) have shown some level of consistence in reduction of the rate of newborn babies.

Table 2: Top 10 Neonatal Mortality Rankings in The World

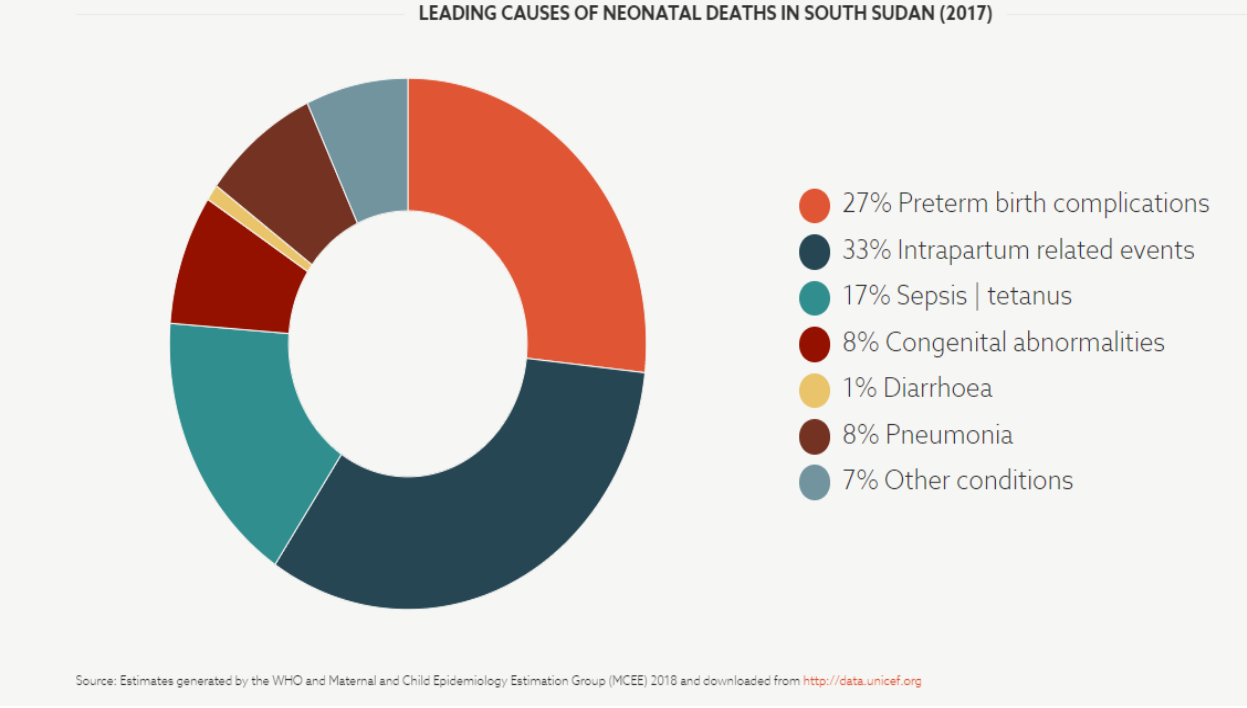
		2018	2017	2016	2015	2014	2013	2012	2011	2010	2005
3	South Sudan	40.0	40.1	40.3	40.1	40.1	40.3	40.7	41.6	42.9	50.1
1	Pakistan	42.0	43.0	44.0	44.9	45.9	46.8	47.8	48.6	49.4	53.4
2	Central African Republ...	41.2	41.8	42.6	43.3	44.1	44.8	45.5	46.3	47.0	48.9
4	Somalia	37.5	38.2	38.9	39.7	40.3	41.0	41.6	42.4	43.1	45.3
5	Afghanistan	37.1	38.1	39.3	40.5	41.9	43.3	44.6	46.0	47.5	54.7
6	Guinea-Bissau	36.6	37.4	38.3	39.2	40.1	41.3	42.4	43.7	45.1	50.9
7	Nigeria	36.0	36.4	36.6	36.8	37.0	37.3	37.6	37.9	38.3	41.8
8	Lesotho	34.9	35.5	36.1	36.8	37.3	37.7	38.0	38.2	38.5	39.6
9	Chad	34.2	34.8	35.4	36.0	36.6	37.1	37.5	38.0	38.4	40.3
10	Cote d'Ivoire	33.5	34.3	34.9	35.6	36.4	37.1	37.9	38.6	39.4	43.4

Source: World Bank

Some of the leading causes of neonatal mortality include prematurity/low birth weight, birth asphyxia, neonatal sepsis and birth trauma. A study conducted in the US about subnational variation in early neonatal mortality suggested that neonatal mortality could be reduced through minimizing exposure to unhealthy behaviors such as prenatal smoking and alcohol consumption,

and improving access to and quality of prenatal obstetric and delivery, and neonatal care (Straney et al., 2012).

In 2010, a retrospective study was conducted in one of the District Hospitals in South Sudan for the period of 2011 to 2014 on neonatal data. The study used Microsoft Excel to monitor neonate discharge, neonatal deaths including other patient outcomes. The study found the leading cause-specific mortality among neonates was Sepsis contributing to almost half of the mortality (49%), followed by neonatal tetanus which was about 15.8% of the mortality. Respiratory distress and asphyxia were the third and fourth leading cause of mortality respectively. However, according to WHO data in 2017, the cause specific neonatal mortality in South Sudan as shown by the pie chart below were different. Intrapartum related events and preterm birth complications were the top 2 leading causes of neonatal deaths in South Sudan in 2017.



2.5 Infant mortality

Infant mortality is the death of an infant before his or her first birthday while infant mortality rate according to Rutstein, is the number of infants dying before reaching one year of age, per 1,000 live births. It remains one of the trends of population health concerns to be addressed. A population-based cohort study in Ethiopia stated that high infant mortality rate (IMR) are attributed to the challenges facing society such as unfavorable social, economic, and environmental conditions during the first year of life (Weldearegaw et al., 2015). The above challenges equally applies to the health situations and difficulties in South Sudan. Child survival has gained attention of governments globally as such reducing infant mortality rate had become priority in all countries. International organizations like WHO, UNFPA and UNICEF are collaborating with various institutions for health in reducing infant mortality by advocating for improved access to health care, nutrition, hygiene and sanitation, and exclusive breastfeeding (Claeson et al., 2000).

In 2009, the Sudanese Journal of Public Health published a studied on "the level of determinants of infant and child mortality in Malakal town" in South Sudan. The infant mortality rate was found 86 deaths per 1000 live births while under five mortality hit 108 deaths per 1000 live births. The historical data on infant mortality rate shows South Sudan has high rate over the years with small improvement.

Table:3 South Sudan Infant Mortality Rate over time

Similar Countries Ranked by Infant Mortality Rate	
Country Name	**2020 Infant Mortality Rate**
Central African Republic	77.570
Sierra Leone	76.513
Chad	71.557
Somalia	66.702
Mali	62.360
South Sudan	**62.050**
Benin	58.341
Guinea-Bissau	54.407
Haiti	51.772
Comoros	51.345
Liberia	51.187
Burkina Faso	50.563

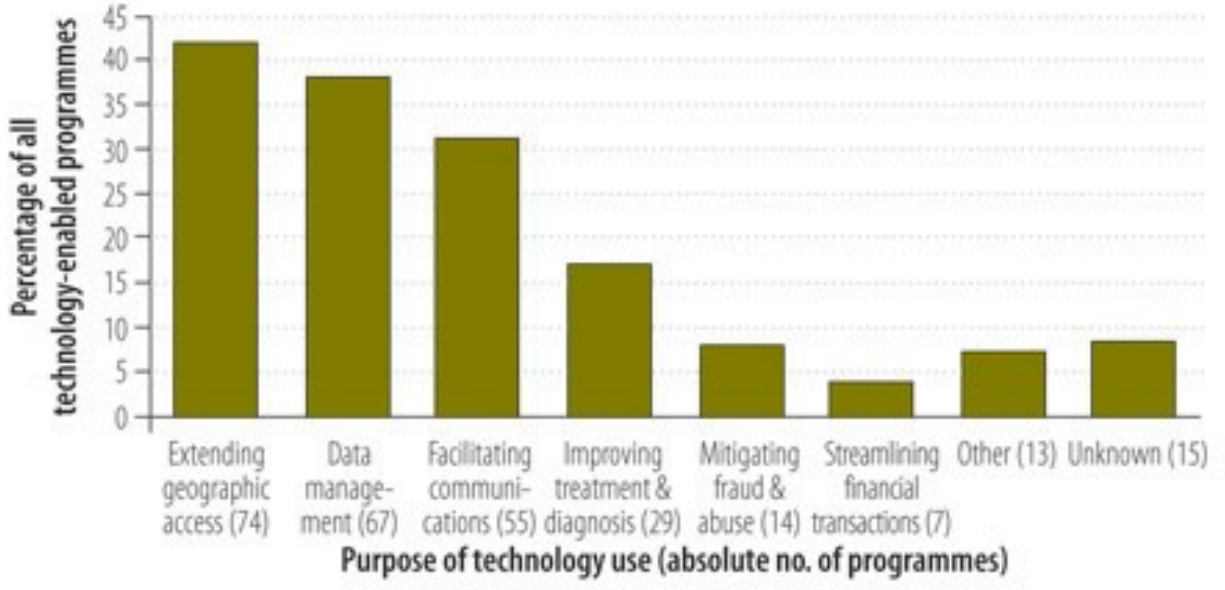
South Sudan - Historical Infant Mortality Rate Data		
Year	**Infant Mortality Rate**	**Growth Rate**
2020	62.050	-1.830%
2019	63.207	-1.800%
2018	64.363	-0.450%
2017	64.653	-0.450%
2016	64.943	-0.440%
2015	65.233	-0.440%
2014	65.523	-0.440%
2013	65.813	-3.730%
2012	68.364	-3.600%
2011	70.915	-3.470%
2010	73.466	-3.360%
2009	76.017	-3.250%

Source: United Nations World Population

2.6 Digital Health

World Health Organization defines Digital Health in the perspective of public or global health as "the use of information and communication technology in support of health and health-related fields". Following the Global Strategy on Digital Health 2020-2024, Digital Health provides new opportunities for promoting healthy lives and overall wellbeing of the society through functionalities of digital technologies.

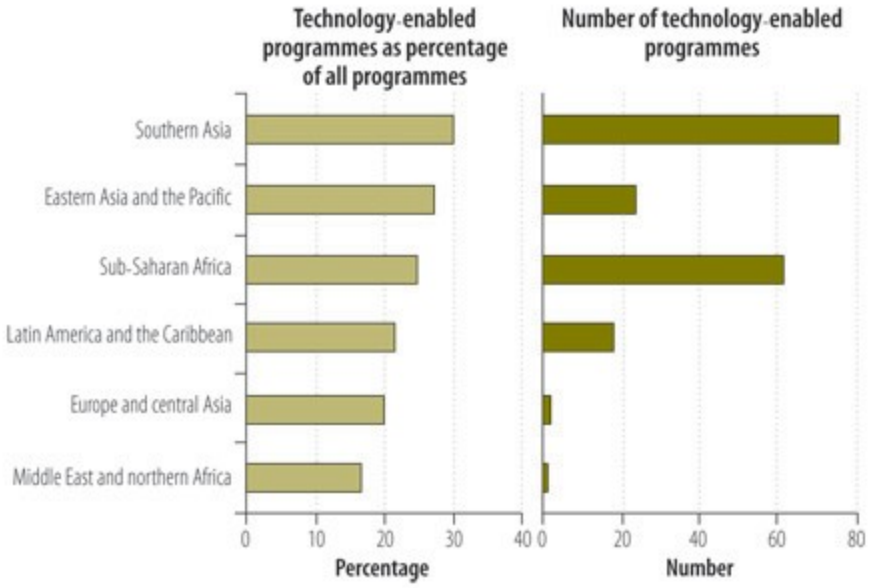
Graph 1: Technology-enabled programs, by purpose of use of technology



Source: E-health in low- and middle-income countries, 2012, pg.337

At the continental level, the free trade agreement (the African Continental free trade Agreement) supports investment in digital infrastructure in health sector and many countries have already developed digital platforms to improve health outcomes. In sub Saharan Africa, there is an increase in the evolution of technological infrastructure. Many programs such as banking, agribusiness, health and education now rely more on technology use than the previous method.

Graph 2: Technology-enabled programs, by region



Source: E-health in low- and middle-income countries, 2012, pg.335

The technological leapfrog in Africa is evident in many countries. In Uganda for example, the government initiated digital transfer of Health Management Information System data through mobile phones where surveillance reports covering disease outbreaks in communities. The platform is called "mTrac" which speeds up transfer of health data to the District health officials for immediate responses. As Uganda moves towards paperless health information system, Rwanda has launched "Drone Technology" in health sector.

The revolutionary medical technologies are used to deliver live saving medical supplies to distant rural hospitals where there is no blood bank and the initiative is to meet Rwanda's goal of connecting its people with essential medical supplies in 30 minutes. From magical technologies to deliver much needed health supplies to patients' connectivity, Africa continues to expand on digital technology. In South Africa, mobile phone technology called MomConnect is used to support maternal health and prevent deaths related to pregnancies. MomConnect is developed by

the South African National Department of Health to electronically record every pregnancy in the public health system as early as possible, provide pregnant women with interactive mechanism to feedbacks and provide health information to pregnant women to improve their health and that of their infants. The technical solution involves subscription by the pregnant women, registration with the health of nurses, weekly SMS text messaging to inform them of their pregnancy and baby health up to 1 year old. While in West Africa, digital technologies are being used in variety of dimensions such as saving mothers lives and checking authenticity of medical drugs for the safety of the consumers. For example, mPedigree which is a mobile and web technological platform uses SMS to verify drugs and combat fake medicine in the continent in West Africa and the continent at large. mPedigree plays fundamental roles in fighting counterfeiting system especially in pharmaceutical industries such that complications from wrong medications are avoided.

2.7 Electronic Health Record (EHR)

One of the powerful technologies for disease surveillance is electronic health record which is defined as an amalgam of data acquired and created during a patient's course through the health care system and stored in an electronic medium thus, a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting (Electronic Health Record, 2010). This technology is also referred to as real-time, patient-centered record keeping that avails patient data instantly and securely to the authorized users.

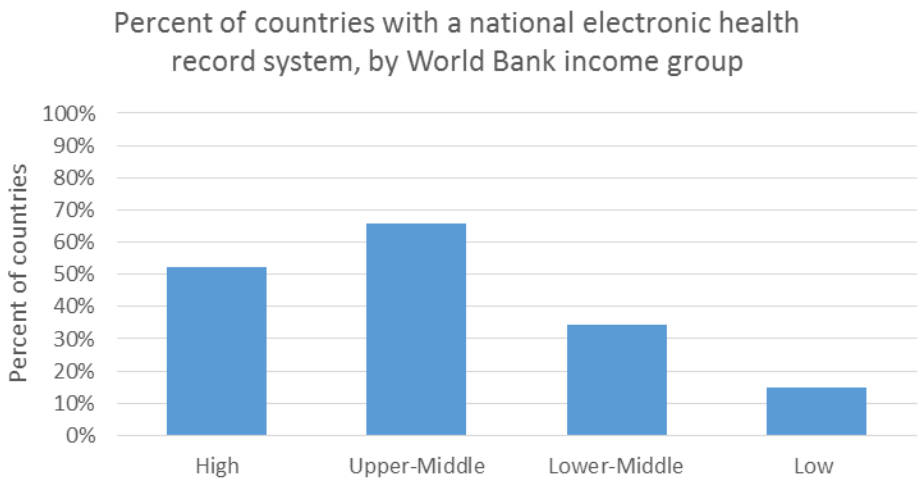
The integration of this technology revolution into health care system has been advocated by so many governments both in developed and developing countries. In January 31, 2006, President

George W. Bush said, “we will make wider use of electronic records and other health information technology to help control costs and reduce dangerous medical errors”.

A lot of research has been conducted to examine the benefits of this health technology and interestingly, it was found that EHRs apart from helping physicians, they are very useful in building strong professional relationships between staff members and patients. For example, a systematic review on EHR in US found positive or neutral relationship between patient satisfaction and the use of EHR by physicians to outpatients while in 2016, the Journal of Community Hospital Internal Medicine Perspectives published an article on the adoption of electronic health records and barriers stating that, EHR “further aims to increase the meaningful use of health information to engage in ongoing quality improvement initiatives directly at the point of care and in the exchange of information between providers”.

At global level, EHR has been adopted by a number of countries regardless of their income status. However, from global health survey, which was conducted in 2015, the use of EHR is high in Upper-Middle income countries with about 65 percent of countries having national health record system as indicated by the graph below.

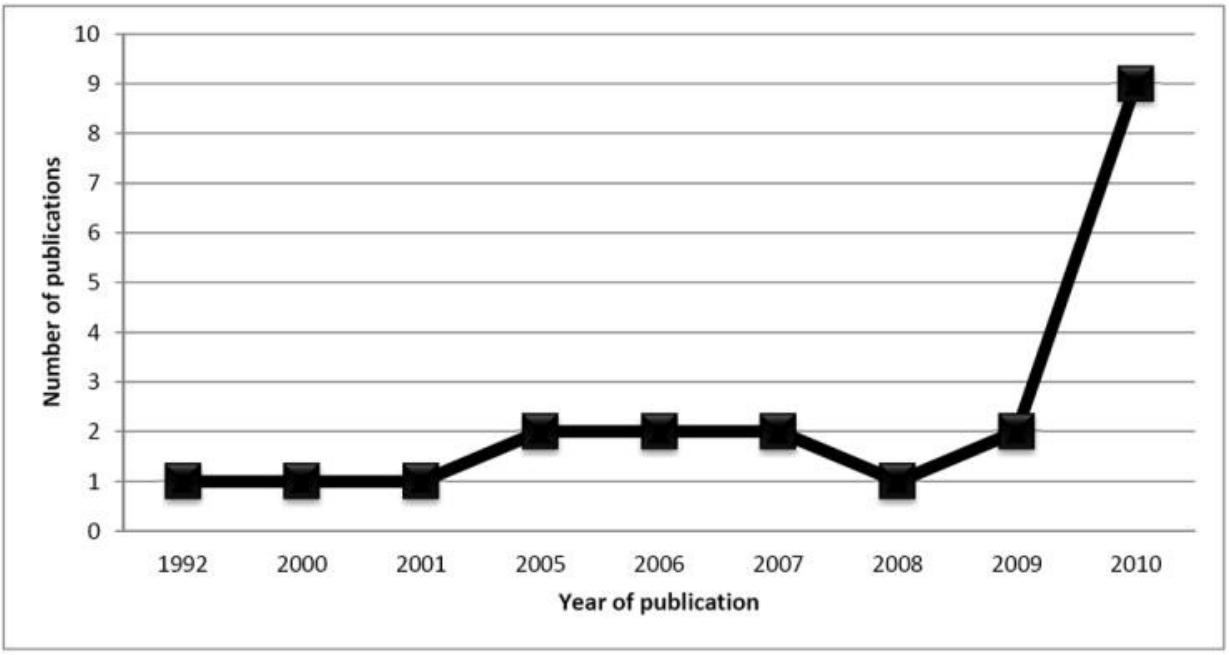
Graph 3: Percentage of countries with a national HER system



Source: Global Health Observatory data

Although public health facilities in South Sudan do not have EHR system, the technology has been adopted by some sub Saharan countries. For instance, Cameroon has implemented locally developed EHR known as "MEDCAB" for primary health care. Like in many other African countries, the existing data collection tools in Cameroon usually consist of non-standardized and incomplete paper-based registers showing considerable variation across facilities, providers and time. (Kamadjeu et al., 2005)

Publications on the use of electronic medical records in sub-Saharan Africa



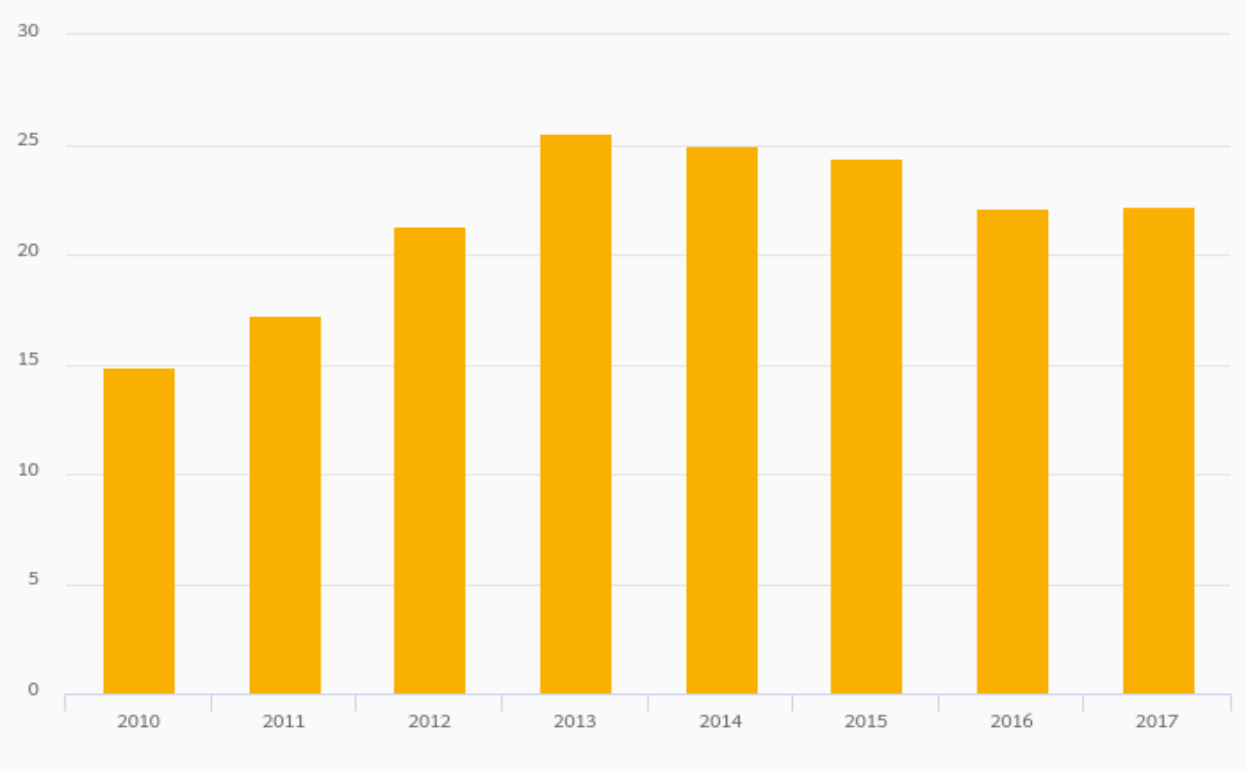
2.8 The penetration of Mobile Phone technology

From basic communication gadgets to money transfer devices, the versality of mobile phone technology has become the game changer by overcoming immense obstacles in various domains including health care industry. Over the last couple of decades, the penetration rate of mobile phone has been growing rapidly in Africa because the digital revolution has been embraced by many people in the continent as emphasized by the president of Rwanda in 2007. During the Connect Africa Summit in 2007, president Paul Kagame said that in ten short years, what was once an object of luxury and privilege, the mobile phone has become a basic necessity in Africa (Aker et al., 2010). Previous studies about mobile phone revolution stated that "existing empirical evidence on the effect of mobile phone coverage and services suggest that the mobile phone can potentially serve as a tool for economic development in Africa" (Aker et al., 2010)

The Global Mobile Penetration Growth reported that "despite the lull in GDP growth, the digital exodus to mobile phone ownership in sub Saharan Africa has surged. In fact, the growth in the digital space in the region is significantly exceeding GPD growth".

2.8.1. Mobile Phone Penetration (As % of Population) (%) in South Sudan

Graph 4: Mobile Phone Penetration as a percentage of population in South Sudan



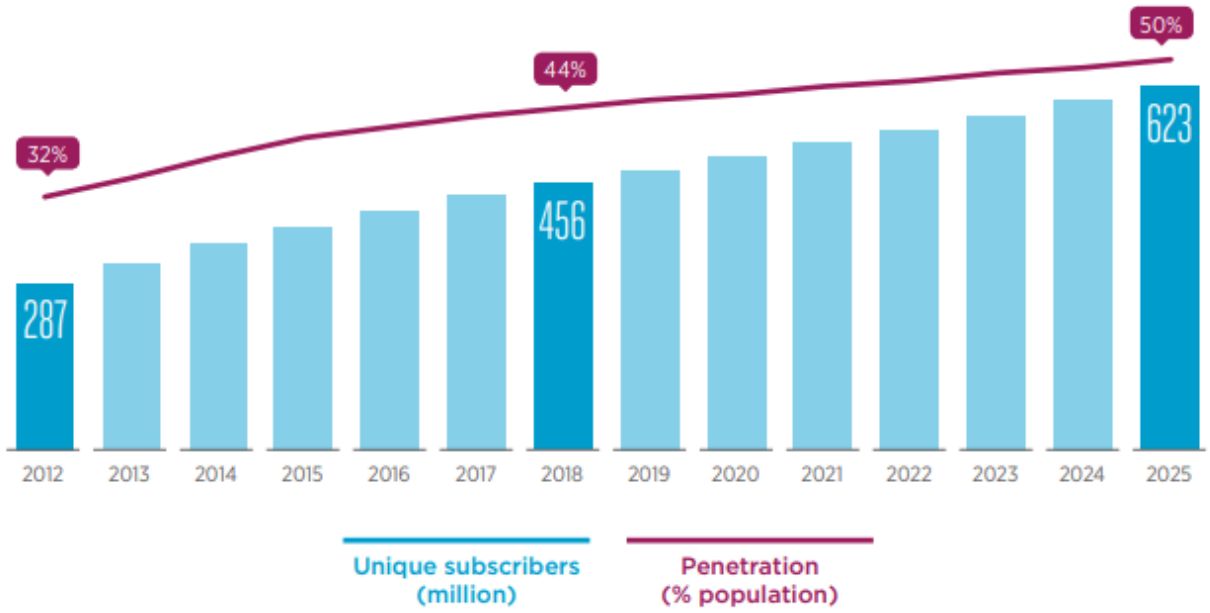
Source: World Bank

The World Bank estimated that South Sudan's mobile phone penetration as a percentage of population reached 22.2 % in 2017 indicating 0.46 % increase from the previous year. In the last ten years, South Sudan witnessed both the highest and lowest increase of mobile phone penetration as a percentage of population with the all-time high of 25.5 per cent recorded in 2013 and an all-time low of 14.9 per cent recorded in 2010 (World Bank). In comparison to its closest neighbors such as Central African Republic, Sudan, Ethiopia and Uganda south, South Sudan is

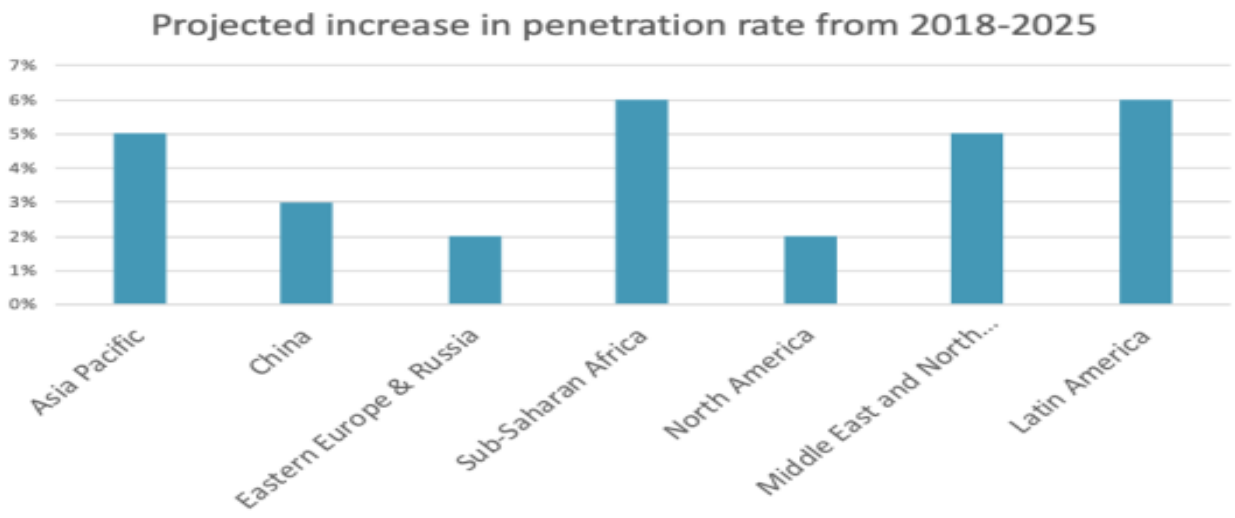
relatively behind its peers as of 2017 mobile phone penetration data. The figure indicates that Central African Republic had 25.2 per cent of mobile phone penetration as a percentage of population while Ethiopia, Sudan and Uganda all out margined South Sudan with 37.7 %, 70.7 % and 58.2 % respectively (World Bank). However, in sub Saharan Africa as a whole, the mobile penetration rate has been gradually rising since 2012, and total unique mobile subscribers are expected to be over 600 million by 2025 with penetration rate of 6% from 2018 to 2025.

2.8.2. Sub Saharan Africa Mobile Phone Penetration

Graph 5: Mobile Phone Penetration in Sub Saharan Africa



Graph 6: Projection of mobile phone penetration



Source: The Mobile Economy in Sub-Saharan Africa 2019. GSMA 2019

The mobile penetration will continue to grow due to the significant volume of mobile ecosystem contribution in the economy. The mobile economy sub Saharan Africa reported that "in 2018, mobile technologies and services generated 8.6% of GDP in Sub-Saharan Africa – a contribution that amounted to $144.1 billion of economic value added. The mobile ecosystem also supported almost 3.5 million jobs (directly and indirectly) and made a substantial contribution to the funding of the public sector, with almost $15.6 billion raised through taxation" (GSMA intelligent, 2019).

From medical standpoint, mobile phones are enhancing efficiency, reducing time and cost and thereby impacting the health care system in a positive way in all the regions. East Africa, for example, has become technology hub for innovation. Maternal and neonatal mortality incidents have been reduced in this region. Simple but useful algorithms that make biggest impacts in saving lives are developed and the installed into mobile phones for healthcare workers. The use

of mobile phone technology in health care has applauded by many world leaders to stop millions of needless deaths associated with pregnancy. In 2011, US Secretary of State Hillary Clinton launched a public/private partnership known as Mobile Alliance for Maternal Action (MAMA). The program sends SMS texts about health to mobile phones to educate pregnant women in rural areas in both Africa and South Asia.

Apart from using mobile phones for reducing maternal deaths and neonatal mortality across the world, mobile phones are widely used in health monitoring. On the 9th May 2019, the biomedical and life science journal literature at the U.S National Institutes of Health published and an article on the use of smartphone for monitoring health indicators. Sumit Majumder and M. Jamal Deen who wrote the article, studied the development in health monitoring systems using technology embedded in smartphones. The evolution of mobile phones especially the smartphones have been manufactured with sensors that are in-build. The article reported that these sensors were used for active and/or passive sensing of several health parameters and health conditions. The data captured by smartphones are suitable for gathering and analyzing valuable information related to physical and mental health status of an individual over a long period of time (Majumder et al., 2019). The various use of the smartphone sensors in health monitoring has turned these small devices to become a viable and cost-effective in health sector. The table below illustrates health issues monitored using smartphone sensors.

Figure 2: Smartphone sensors used for health monitoring

Monitored Health Issues	Typically Used Smartphone Sensors
Cardiovascular activity e.g., heart rate (HR) and HR variability (HRV)	Image sensor (camera), microphone
Eye health	Image sensor (camera)
Respiratory and lung health	Image sensor (camera), microphone
Skin health	Image sensor camera)
Daily activity and fall	Motion sensors (accelerometer, gyroscope, proximity sensor), Global positioning system (GPS)
Sleep	Motion sensors (accelerometer, gyroscope)
Ear health	Microphone
Cognitive function and mental health	Motion sensors (accelerometer, gyroscope), camera, light sensor, GPS

Source: Smartphone Sensors for Health Monitoring and Diagnosis 2019, pg. 3

CHAPTER 3: HEALTHCARE SYSTEM IN SOUTH SUDAN

3.1 Introduction

Chapter three discusses the public healthcare system in general then it covers healthcare system including health expenditure of South Sudan, East African region and the continent at large. The chapter also covers healthcare structure and the health facilities in the country.

After attaining independence from Sudan in July 2011, the government of South Sudan was expected to assume the responsibility of ensuring the welfare of the citizens through promotion of good health. The leaders including other stakeholders of the new nation were to streamline efforts in achieving public health programs in the country. Every government is expected to fulfill societal interest of healthy lives through campaigns about disease prevention and longevity of life. As stated by CEA Winslow, public health takes everybody on board thus, promoting health through the organized efforts and informed choices of the society, organizations, public and private communities, and individuals. South Sudan has both public and private healthcare services in the country with disparities of facility concentration.

3.2 The Public Healthcare System

The principal of social justice emphasizes that everyone has right to be healthy and live in conditions that support their health. The healthy condition of a population is one of the core factors of economic dividend of a country because active and long-term labor productivity is a direct result of strong and healthy individuals. The value of health in a community or society is understood by measuring various health outcomes such as maternal deaths and neonatal mortality. Public health plays an important role in maintaining healthy society by routinely

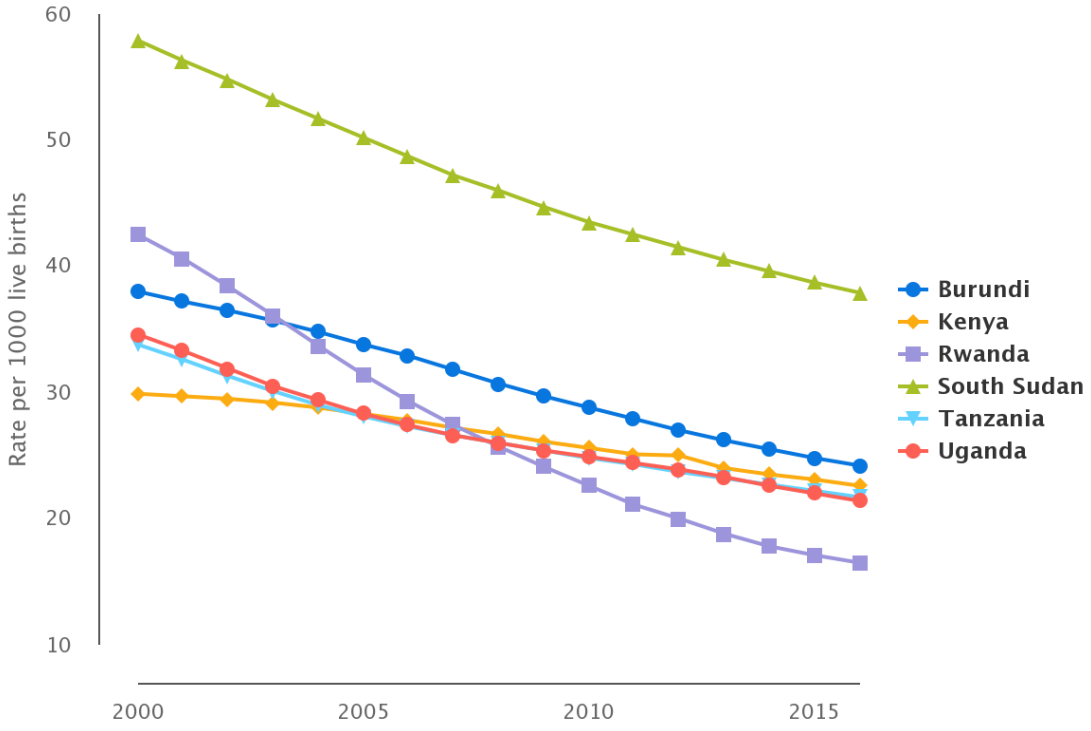
conducting disease surveillance to identify risk factors to certain group of people and localities that might be endangered.

3.3 Health status in the region

East Africa is rapidly becoming hub for mobile phone technology. The young and fast-growing demographics of the region require appropriate health policies at every level to overcome already existing health challenges such as child and maternal mortality. Such policies include harnessing the technological capacity and working in partnership to achieve health for all. The WHO Africa region reported that the rapid rise in use of cell phones has been one of the most dramatic changes in the Region. Surveillance systems, diagnostic support for remote health workers, training and support can all be provided by mobile phone. However, to be effective this requires identifying and dedicating people within the system to administer the system, respond to diagnostic images and data appropriately, support surveillance with data collection and feedback, and support community workers with regular training, evaluation and physical support– (WHO Regional Office for Africa, 2014).

The East African Health and Research Commission (EAHRC) a body established by the Heads of State of the East African Community to improve the health and well-being of citizens of the Community by generating, accessing, capturing, and disseminating health research reported some improvement in other health outcomes in the Community. However, South Sudan is trailing behind its neighbors as shown in the neonatal mortality graph below.

Graph 7: Neonatal mortality rate in East African Community

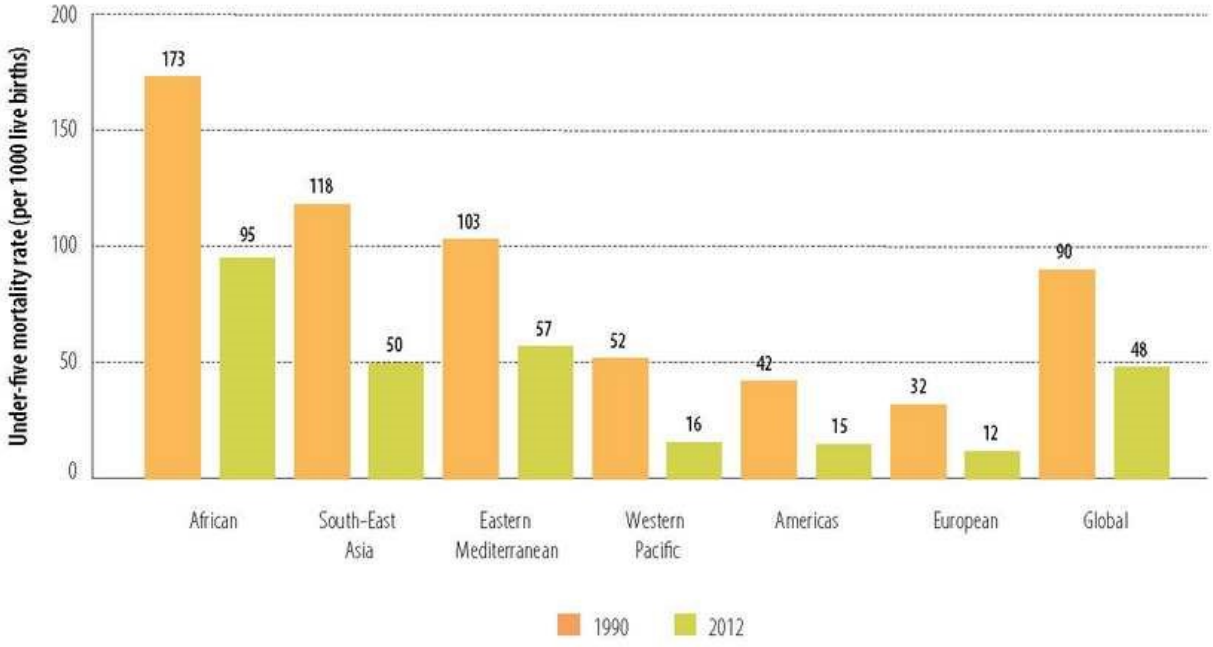


Source: EAHRC

At the continental level, Africa's health status especially in under-five mortality remains the highest in the world although some progress in cutting down the from 1990 to 2012. The united Nations Millennium Development Goals in reducing child mortality by two-third, effectively contributed in the drop of under-five mortality around the world. Although Africa had tremendous improvement in under-five mortality rate, there are disparities between individual countries and if demographic data were further disaggregated at every national level, most of the overall child mortality would be found in rural areas where the sparse health facilities are mostly distant apart from each other. For example, in Kenya, a study of 2008-2009 Demographic and Health Survey revealed that there was disparity of child mortality across the country where the highest incident of mortality rate occurs in rural compared with urban areas (Ettarh et al., 2012)–

This disparity could be the same in South Sudan where many health facilities were not operational.

Graph 8: Under-five mortality by regions



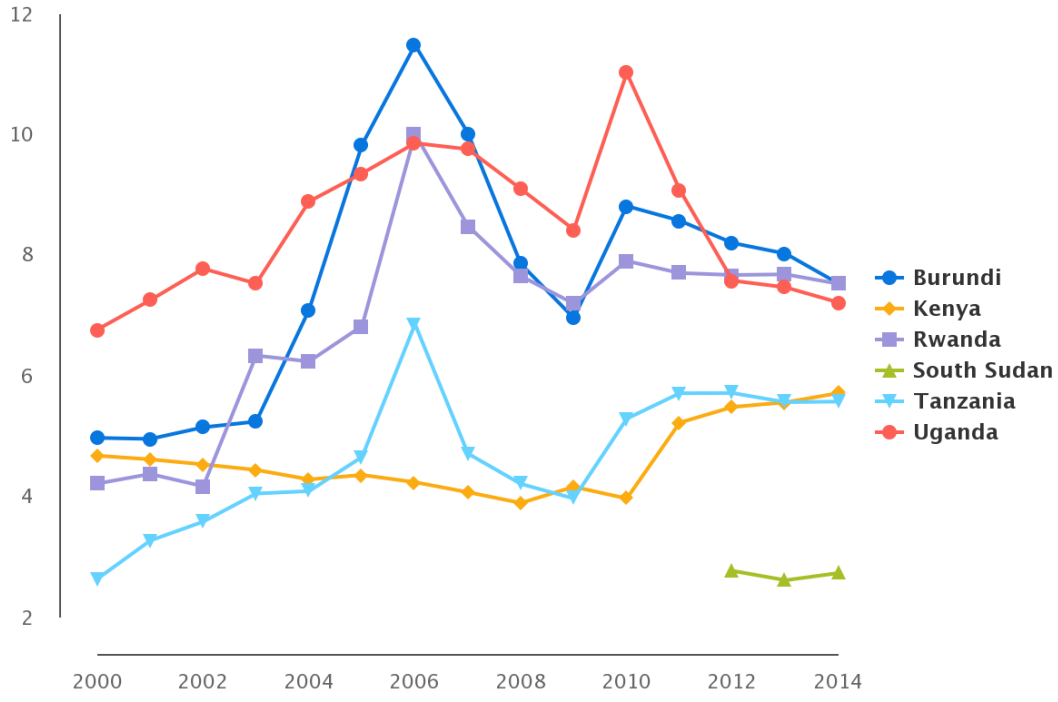
Source: EAHRC

3.4 Regional Health Expenditure

Health financing across the region and Africa at large had been changing remarkably because of ever growing health related costs. Countries have to meet the demands of healthcare in order to achieve the universal goal of proving health for all. As health has been recognized one of the fundamental pillars of human and economic development, emphasizes have been put for strong and efficient health financing system in Africa. In 2001, African Heads of States convened in

Abuja Nigeria and agreed to ensure health expenditure should be 15% of every country's GDP. The Abuja Declaration had significant impact in health system in the region although most countries fell short of meeting the target. Ten years after the Abuja Agreement in 2010, "the average total health expenditure in African countries stood at US$ 135 per capita, which was a small fraction of the US$3150 spent on health in an average high-income country" (WHO Regional Office for Africa, 2013). The graph below shows East African countries health expenditure over time.

Graph 9: Health Expenditure by countries of East African Community

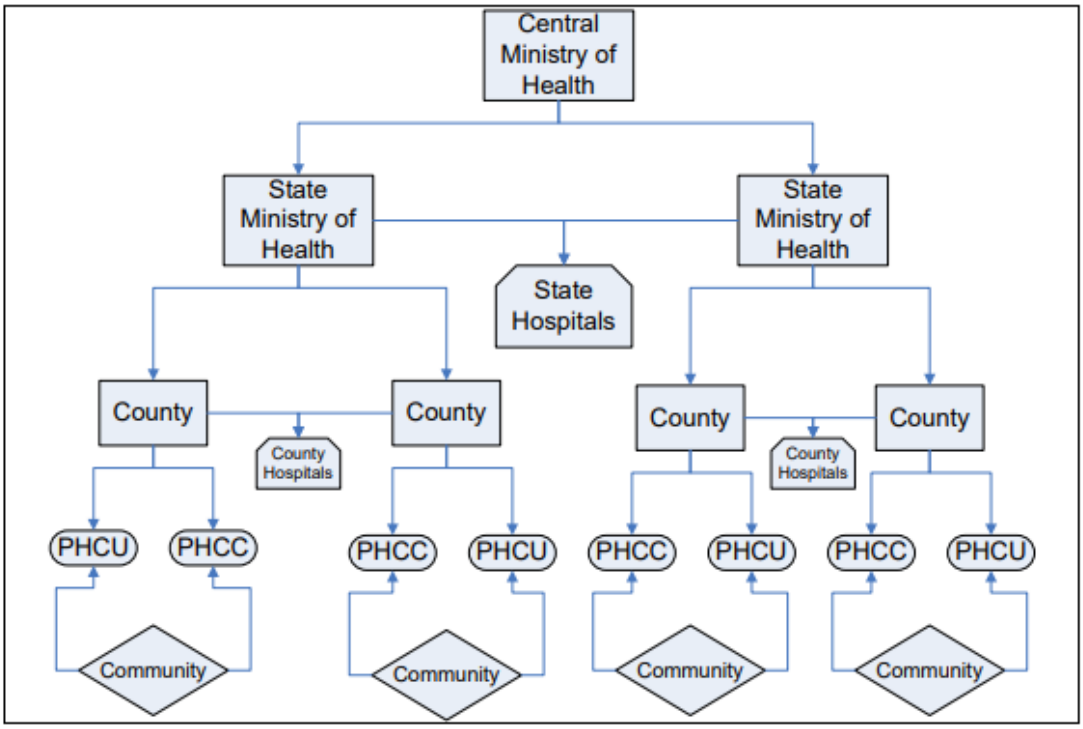


Source: EAHRC

3.5 Health status in South Sudan

The health system of South Sudan is a decentralized four-tier system – that's the central level, state level, country level and the community level as shown in the structure below.

Figure 3: Structure of Healthcare System in South Sudan



Source: Ministry of Health (2006e)

Despite having well established structure for delivery of health services to the people, the system is still the weakest in the region because of wars which vandalized all the health infrastructure in the country. The governance of the health system starts at the Central level; thus, the Central Ministry of Health where strategic, regulated and accountable systems are formulated. The Central Level is responsible for the stewardship of the national health care system. At the State Level, the State Ministry of Health is responsible for monitoring, evaluating, and auditing of

contracts with NGOs implementing health projects in the state. The State is also responsible for managing public funds and allocating resources equitably in different units. The State Ministry of Health also does strategic planning and coordination with the different actors within the health system.

At the County level, health activities take place such as the implementation of Basic Package of Health Strategy, etc. and the country authorities are responsible for "supervising, monitoring, and guiding health service delivery. They also serve as the main vehicle to identify local needs, both at the facility and community level, to feed into the strategic planning process at the state level" -(Southern Sudan Health Assessment, 2007). State authorities rely on the county offices in implementing and managing the daily activities of all the players of health in the state. These players comprise of Non-governmental organizations (NGOs), Faith-based organizations and different agencies working in health programs.

Community level is the last and the lowest hierarchy of the structure. It is usually made of "usually made up of community members, health facility representatives, and other stakeholders, often exist to provide voice and input into the functioning of PHCUs and PHCCs" -(Southern Sudan Health Assessment, 2007). The teams at the community level is extremely important because they maintain high-quality services to the local community.

3.6 South Sudan Health Care Facilities

The four tiers of the health care structures are; the Primary Health Care Units (PHCUs), The primary Health Care Centers (PHCCs), the County Hospitals (CHs) and the State Hospitals and the Teaching Hospitals. The PHCUs are the level of health service delivery where simple

treatments are carried out. The simple treatments include preventive and curative of certain illness. PHCUs are the "first level of the primary care and is expected to serve about 15000 population". The second level of health care service delivery is the PHCCs which are situated at the Payam Headquarters in rural areas. In urban areas, they found in Boma (Village). "PHCCs are the first level of the referral system, in addition provide laboratory services for diagnosis, maternity and in-patient care, and are expected to serve up to a population of 50,000" – (HSDP, 2011).

The County hospitals are found at the next upper level of government after Payam, thus County headquarters. These hospitals are the referral hospitals for PHCCs, and they perform emergency surgical operations and can serve up to 300,000 people. State Hospitals in South Sudan can serve population of up to 500,000 according to Basic Package for Health Services. Both County and State Hospitals "represent secondary care level where general medical specialists such as surgeons, obstetrician and pediatricians provide care, training and monitoring interns of Mid-level health personnel such as nurses, midwives and laboratory technicians"- (South Sudan National Strategic Plan for HRH, 2011). There are also Teaching Hospitals in the three biggest towns of South Sudan although one is not operational due to the recent conflict of 2013 and 2016. However, Teaching Hospitals are expected to provide tertiary care and carry trainings to technical staff in the field of medicine.

3.7 Health Care Facilities

The health facility mapping conducted in 2011 reported that there 1,487 health facilities in the country of which 1147 were functional while 340 remaining were not functioning. However, these number could be different now due to the last two wars 2013 and 2016 the country had which vandalized health facilities in the country especially those in the upcountry. At the time of the health facility mapping, there were three (3) functional Teaching Hospitals, seven (7) State Hospitals. The County Hospitals and Primary Health Care Centers that were functional were 27 and 284 respectively. The rest of the other health facilities based on their functionalities are shown in the below table.

Figure 4: Health Facilities 2011

Health Facility	Functioning	Non-functioning	Total
Teaching Hospital	3	-	3
State Hospital	7	2	9
County hospital	27	1	28
Specialized hospital	14	1	15
Private Hospital	10	4	14
Police/Military health Facility	10	-	10
PHC Centre	284	30	314
PHC Unit	792	302	1094
Total	1147	340 (23%)	1487

Source: South Sudan Health Facility Mapping 2011

CHAPTER 4- METHODOLOGY AND HYPOTHESIS

4.1 Methodology

From the Millennial Development Goals (MDGs) to the current Sustainable Development Goals (SDGs), nations around the globe have been urged to priorities policies aimed at reducing maternal death and child mortality rates. Some countries in Africa and elsewhere had adopted the use of health innovative technologies to achieve positive health outcomes. This research, after conducting Hausman Test and Breusch-Pagan Lagrange multiplier (LM), will use Random-Effects Regression to understand the causal effects of using digital technologies in controlling maternal and neonatal mortality rates and how these could benefit South Sudan in its attempt to scale down the high numbers of these two health indicators. The reason for opting for the random model is to extrapolate and infer the results to South Sudan. My control variables include current health expenditure per capita, Gross Domestic Product (GDP) per capita and the Out of Pocket expenditure on health; while my treatment variables are the maternal and neonatal mortality rates.

Below is the regression model with robust to control for heteroskedasticity

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \gamma K_{it} + \alpha_i + \varepsilon_{it}$$

Y_{it} = is the dependent variables (DV) thus, MMR and NMR

β_0= Overall intercept

X_{it}=Technology variable

β_1= Coefficient of the effect of technology

K_{it}= Control variables

γ= Coefficient of the independent variables

ε_{it}= Error term

My main variable is X_{it} (Technology) and I study the effects of technology in achieving the aforementioned health outcomes thus, maternal deaths and neonatal mortality. I will be adding one at a time the control variables (K_{it}) thus; GDP per capita, out-of-pocket expenditure and health expenditure per capita into the model to see how the effect of technology will change.

4.2 Hypothesis

In order to proof the potential benefits of health innovative technologies and subsequently show how South Sudan could have benefited from the revolution of digital technology, this research will test the following hypothesis test;

H_0: There is no effect of health innovative technology in the reduction of MMR and NMR

H_1: There is effect in the use of health innovative technology in the reduction of MMR and NMR

The measure of the casual effects of digital technologies on health outcomes (maternal mortality and neonatal mortality rates) would explain whether countries like South Sudan with little use of modern technologies should adopt digital in its health care system that has sparsely located health facilities.

4.3 Data Source

The datasets for the maternal and neonatal mortality rates were downloaded from the World Bank Database (https://databank.worldbank.org/source/world-development-indicators) from 2007 to 2017 while the control variables thus, the current health expenditure, out-of-pocket expenditure (OOP) per capita and GDP per capita were downloaded from the WHO Global Health Observatory data repository, in health financing section (https://apps.who.int/gho/data/node.main.HEALTHFINANCING?lang=en) for the same time frame (2007-2017). The countries that have adopted health technologies are; South Africa which rolled out the "MomConnect" technology, Kenya adopted "TotoHealth" technology, Rwanda launched rapid short message service for maternal and child health (RapidSMS-MCH), Uganda and Tanzania also use mobile phone technology to reduce maternal mortality and neonatal deaths.

4.4 Data Cleaning

The data from the World Bank database and WHO Global Health Observatory data repository do not have the same arrangement and or listing. I rearranged them and changed them in long shape in STATA.

4.5 Hausman Test

In order to avoid pseudo replication in my analysis, I first did Hausman test to check for the right model for my analysis because the above panel data is for five different countries and therefore, the studies to collect all the data might not be identical with the same assumptions across all the five countries. The Hausman test guides in choosing the appropriate statistical model. My two hypotheses for the Hausman test are; The Null hypothesis (Ho): - if the P-value is above 0.05, Random effect is suitable. The Alternative Hypothesis (H1): - Fixed Effect model is appropriate if the P-value is statistically significant. And the figure below shows the test result with P-value greater than 0.1200 thus, I accept the Null Hypothesis and reject the alternative hypothesis. Therefore, using STATA, Random effect is the appropriate model for the analysis of this research.

	Coefficients			
	(b) Fixed	(B) Random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
tech	1.726542	-30.07164	31.79818	.
GDP	-.019124	.0227877	-.0419117	.
Out_of_poc~t	-3.473026	.9434644	-4.41649	.7419562
HEALTH_EXP	.3577947	-.6854537	1.043248	.
2008bn.Year	-25.81785	-19.68984	-6.128006	.
2009.Year	-56.549	-28.27218	-28.27683	.
2010.Year	-86.7971	-41.4398	-45.3573	.
2011.Year	-102.5572	-59.23279	-43.32443	.
2012.Year	-124.2713	-70.14603	-54.12522	.
2013.Year	-140.4395	-63.90094	-76.53852	.
2014.Year	-155.9866	-63.16446	-92.82211	.
2015.Year	-169.0337	-69.42461	-99.60906	.
2016.Year	-182.2307	-78.22333	-104.0074	.
2017.Year	-187.1669	-87.42839	-99.73852	.

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(13) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 19.10
Prob>chi2 = 0.1200
(V_b-V_B is not positive definite)

CHAPTER 5- DATA ANALYSIS AND INTERPRETATION

5.1 Regression Results for Maternal Mortality Rate

The first part of my Random effect regression is to find the impact of health technology on Maternal Mortality Rate (MMR). MMR, the dependent variable is regressed with technology (tech) without any of the three control variables; thus, GDP, Out of pocket and Health expenditure. The figure below shows the results of the first regression.

```
Random-effects GLS regression                   Number of obs      =        55
Group variable: countryid                       Number of groups   =         5

R-sq:  within  = 0.5894                         Obs per group: min =        11
       between = 0.6327                                        avg =      11.0
       overall = 0.0421                                        max =        11

                                                Wald chi2(1)       =     64.64
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

MMR	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tech	-81.87533	10.18332	-8.04	0.000	-101.8343	-61.91639
_cons	420.4729	53.49166	7.86	0.000	315.6311	525.3146
sigma_u	113.98894					
sigma_e	35.882043					
rho	.90984378	(fraction of variance due to u_i)				

The result shows statistical significance with P-value less than 0.05 and indicating negative relationship between technology and maternal mortality rates. Thus, adoption of health technology reduces maternal mortality by 81 per 100000 births.

When I included variable GDP in the second regression below, the result shows statistical significance with p-value below 0.05. The use of health technologies and the level of GDP both

lead to the reduction of maternal deaths. The model indicates strong negative relationship between maternal deaths and the use of health technologies. This negative relationship supports every government's effort in the scaling down of maternal deaths.

```
Random-effects GLS regression                   Number of obs      =        55
Group variable: countryid                       Number of groups   =         5

R-sq:  within  = 0.6982                         Obs per group: min =        11
       between = 0.5646                                        avg =      11.0
       overall = 0.5669                                        max =        11

                                                Wald chi2(2)       =    111.27
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

MMR	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tech	-53.21334	10.75234	-4.95	0.000	-74.28754	-32.13914
GDP	-.0452344	.0102766	-4.40	0.000	-.0653762	-.0250926
_cons	592.827	68.01049	8.72	0.000	459.5289	726.1252
sigma_u	120.10678					
sigma_e	30.437285					
rho	.93965449	(fraction of variance due to u_i)				

In the next below regression, after adding variable GDP in the previous model, I now include out of pocket in the regression. Since most countries in the region do not have full coverage of health insurance for their citizens, out-of-pocket medical expenses are common across these countries and it is done in South Sudan healthcare system. The variables indicate statistical significance with positive relationship between out-of-pocket and maternal deaths. This is evidently true because most households in rural areas do not have financial resources to chatter for three maternal care services such as the ante natal, natal and post-natal care. This leads to increase in MMR across the countries. Therefore, out of pocket expenditure for maternal care from both

institutions thus, public and private health facilities is affecting the rural population more and contribute to increase in maternal deaths unlike introduction of digital technologies that are beneficial for achieving positive health outcomes.

```
Random-effects GLS regression                   Number of obs      =        55
Group variable: countryid                       Number of groups   =         5

R-sq:  within  = 0.7474                         Obs per group: min =        11
       between = 0.5439                                        avg =      11.0
       overall = 0.5521                                        max =        11

                                                Wald chi2(3)       =    143.30
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

MMR	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tech	-33.48121	11.6483	-2.87	0.004	-56.31145	-10.65097
GDP	-.0577164	.0113481	-5.09	0.000	-.0799581	-.0354746
Out_of_pocket	2.715914	.9195446	2.95	0.003	.9136396	4.518188
_cons	515.6235	94.22504	5.47	0.000	330.9458	700.3012
sigma_u	169.79679					
sigma_e	28.585854					
rho	.97243834	(fraction of variance due to u_i)				

Lastly when controlling with health expenditure per capita, the use of health technologies is still significant, reducing maternal mortality rate by 64 per 100000 live births. The coefficient of public health expenditure per capita is negative too, indicating reduction of percentage point in maternal death rate. The use of technology and increase in health expenditure per-capita may lead to drop in maternal deaths.

5.2 Robustness Checks

In order to examine how the coefficient of my variable of interest behaves, I run robustness test using corruption index of these countries as control variable. I understand that corruption might negatively affect the performance of health service delivery and would like to see the economic effect of technology when controlled with corruption index.

I will perform the robustness checks for the two main control variables thus; GDP per capita and health expenditure per capita following the hypothesis below.

Robustness test hypothesis

Null: The assumption made by the control variable (Health expenditure) is true.

Alt: The assumption made by the control variables (Health expenditure) is false.

Thus;

1. My analysis assumes that the variables I used are not related to the error term hence no omitted variable bias.
2. But if there is omitted variable bias, then the coefficient on technology might be biased up or down, depending on which variables are omitted.
3. However, I suspect that there might be omitted variable bias in my model because health delivery in most African countries are associated with corruption right from budgeting to the procurement of some technologies, and corruption affects health system, so corruption will be related to health outcomes and will be in the error term if not controlled for.

4. Adding corruption index as a control is an alternative analysis, I can run to see how much omitted variable due to corruption index is.
5. If it turns out that the coefficient on technology is indeed different with the new control, then I will include corruption index as a control variable instead of the first model.

Running the regression of MMR on tech, and health expenditure then adding corruption index as a control variable produced the following results.

```
Random-effects GLS regression                   Number of obs      =        55
Group variable: countryid                       Number of groups   =         5

R-sq:  within  = 0.5837                         Obs per group: min =        11
       between = 0.6577                                        avg =      11.0
       overall = 0.4219                                        max =        11

                                                Wald chi2(2)       =     67.70
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

MMR	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tech	-78.21452	10.49165	-7.45	0.000	-98.77778	-57.65126
HEALTH_EXP	-.0972655	.0780991	-1.25	0.213	-.250337	.055806
_cons	447.1215	59.23234	7.55	0.000	331.0283	563.2148
sigma_u	120.27253					
sigma_e	36.22745					
rho	.91681863	(fraction of variance due to u_i)				

In the above regression, my variable of interest is highly significant with the percent variation due to individual specific effect (rho) of about 92%. The overall R-square is 0.42 and the control variable health expenditure is not statistically significant. However, the robustness test has different result.

```
Random-effects GLS regression                   Number of obs      =        55
Group variable: countryid                       Number of groups   =         5

R-sq:  within  = 0.6247                         Obs per group: min =        11
       between = 0.6834                                        avg =      11.0
       overall = 0.6766                                        max =        11

                                                Wald chi2(3)       =     51.90
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

                                (Std. Err. adjusted for 5 clusters in countryid)
```

MMR	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
tech	-65.96421	17.41682	-3.79	0.000	-100.1006	-31.82787
HEALTH_EXP	-.2672102	.0380248	-7.03	0.000	-.3417374	-.192683
Corruption	5.108417	1.72913	2.95	0.003	1.719384	8.49745
_cons	225.9635	94.16457	2.40	0.016	41.40431	410.5226
sigma_u	42.876958					
sigma_e	33.317328					
rho	.62351953	(fraction of variance due to u_i)				

Here the overall model explanation (the R-square) has increased from just 42 per cent to about 68 percent. All the variables are now statistically significant including the health expenditure which has economic effects. Interestingly and as expected, the rho of the robustness check is less than 95% confidence level meaning there is higher level of uncertainty in the first model.

Therefore, I reject the null hypothesis and accept the alternative hypothesis of the robustness test and will therefore include corruption index in my model. The robustness checks also confirm health innovative technology reduces maternal mortality rates.

5.3 Regression Results for Neonatal Mortality Rate

Having tested technology use in reducing maternal deaths, I'm regressing to find its significance in one of the alarming health outcomes in the region, the neonatal mortality. As I explained in the literature review, technology has been adopted to ensure mothers are monitored regularly after delivery such that their babies do not develop and suffer from other preventable causes like appropriate nutrition and vaccinations. The figure below indicates statistically significant result of health technology on reduction of neonatal mortality rate. The use of technology reduces neonatal mortality rate by about 3.3 percentage point. This first regression is not controlled with other variables discussed above.

```
Random-effects GLS regression                   Number of obs      =        55
Group variable: countryid                       Number of groups   =         5

R-sq:  within  = 0.6099                         Obs per group: min =        11
       between = 0.9336                                        avg =      11.0
       overall = 0.0825                                        max =        11

                                                Wald chi2(1)       =     40.59
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

NMR	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tech	-3.279178	.5147105	-6.37	0.000	-4.287992	-2.270364
_cons	22.22182	.8717918	25.49	0.000	20.51314	23.9305
sigma_u	1.3290023					
sigma_e	1.3978317					
rho	.47477454	(fraction of variance due to u_i)				

In the second regression below, I controlled with the country's GDP per capita, both variables show statistical significance and negative relationship with neonatal mortality rate. The use of

health technology during and after delivery when controlled with GDP reduces neonatal mortality by about three percentage points. Thus, the use apps help in informing and reminding pregnant women on healthy behaviors during and after delivery so that babies do not die immediately. Like the MomConnect in South Africa, some health facilities send SMS texts to mothers and pregnant women about their next ante natal visits. The use of technology apps help to reduce complications during delivery and hence reducing neonatal deaths in the communities and the country at large.

```
Random-effects GLS regression                   Number of obs      =        55
Group variable: countryid                       Number of groups   =         5

R-sq:  within  = 0.6460                         Obs per group: min =        11
       between = 0.9064                                        avg =      11.0
       overall = 0.8534                                        max =        11

                                                Wald chi2(2)       =    118.09
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

NMR	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tech	-2.664644	.3784209	-7.04	0.000	-3.406336	-1.922953
GDP	-.0010524	.0001766	-5.96	0.000	-.0013985	-.0007063
_cons	26.25446	1.016867	25.82	0.000	24.26143	28.24748
sigma_u	1.6201378					
sigma_e	1.3374601					
rho	.59471161	(fraction of variance due to u_i)				

Like in maternal deaths, out of pocket has positive relationship with neonatal mortality rate. However, the use of technology is significant in reducing neonatal deaths. It reduces neonatal deaths by around two percentage points when controlled with two other variables; thus, GDP per capita and out of pocket health expenditure. Since out of pocket medical costs hurts poor

households most, many people especially in the rural areas could not afford to pay medical expenses to attend to specialists such as gynecologists. Hence out of pocket expenditure contributes to increase of neonatal deaths.

```
Random-effects GLS regression                   Number of obs      =        55
Group variable: countryid                       Number of groups   =         5

R-sq:  within  = 0.7420                         Obs per group: min =        11
       between = 0.8535                                        avg =      11.0
       overall = 0.8286                                        max =        11

                                                Wald chi2(3)       =    154.18
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

NMR	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tech	-1.763105	.404535	-4.36	0.000	-2.555979	-.9702309
GDP	-.0015815	.0002438	-6.49	0.000	-.0020593	-.0011036
Out_of_pocket	.1302758	.0323193	4.03	0.000	.0669312	.1936204
_cons	22.28614	1.596093	13.96	0.000	19.15785	25.41442
sigma_u	2.0274177					
sigma_e	1.1537365					
rho	.75537986	(fraction of variance due to u_i)				

CHAPTER 6- CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From the results above, in both maternal and neonatal mortality, the statistical significance of the model when controlled with the first two control variables shows that the NULL (H_0) hypothesis is rejected and the ALTERNATIVE (H_1) hypothesis is accepted meaning the use of health innovative technologies reduce maternal and neonatal deaths. For instance, when technology is controlled with health expenditure only, both variables are statistically significant, and negatively related to the dependent variable. With this control variable, the use of health technology reduces MMR by more than 78 per centage point.

However, starting with the maternal mortality outcome, technology remains overall statistically significant and negatively related with MMR when all the three control are added. Technology reduces MMR by about 64 per centage point but the other two control variables (GDP per capita and Out of pocket expenses) turned statistically insignificant although health expenditure per capita is significant with about 0.7 per centage point of MMR reduction. It is at this point (when all the three control variables are included in the model), I run Breusch-Pagan Lagrange multiplier (LM) to decide between random effects regression and simple Ordinary Least Square regression. My null hypothesis for the LM test is that, if the p-value is more than 5%, then random effects is not the appropriate because the three control variables do not have significant differences across the countries. Otherwise the alternative hypothesis is the p-value is less than 0.05 per centage point.

With the simple OLS regression, when technology is controlled with all the three variables, there is statistically significance and hence, it is good tool for achieving maternal and neonatal mortality drop in the country.

The next health outcome thus, neonatal mortality rate also has negative relationship with the use of health innovative technologies. The deaths of newborn babies drop or reduces with the use of the technology. This is supported by the various literature mention previously. Like in the MMR case, the subsequent results show statistically significance as I progressed with controlling my main variable with the control variables.

6.2 Policy Recommendation

Following the evidence of the various regression results including the robustness checks for the maternal mortality rate, it is therefore, reasonable to conclude that health innovative technologies are very vital in saving the lives of a mother and or her newborn baby. The adoption of technologies in health sector could be a game changer as far as maternal and neonatal mortality is concerned since the results indicate that technology is more valuable in achieving these two health outcomes than both GDP and health expenditure per capita. With technologies, numerous barriers and challenges to service deliveries affecting South Sudan could be avoided.

Therefore, with the economic constraints the country is currently facing, it would be appropriate for the ministry of health and other health policy makers to start adopting and using technologies in order to reduce MMR and NMR. The ministry of health could start the model of South Africa and Tanzania by launching the technology platforms for pregnant mothers. This system is viable since many health workers already own cellphones, updating information on safe health to

pregnant mothers would be easier. As the country struggles to recover from the economic collapse as a result of the most recent political crisis, large scale support to digital entrepreneurs like in Kenya, Rwanda and Uganda is not feasible now. However, focus timely health messages to pregnant women is essential and the innovative technologies like the apps would be of paramount benefit to support people where health facilities are far apart and commuting to these facilities might lead to complications resulting to loss of lives.

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