The County-Level Impact of Telemedicine: A Difference-in-Differences Analysis of the University of Mississippi Medical Center's Telemedicine Initiatives

by
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ABSTRACT

MEGAN ELISE MCLEOD: The County-Level Impact of Telemedicine: A Difference-in-Differences Analysis of the University of Mississippi Medical Center's Telemedicine Initiatives
(Under the direction of Dr. Mark Van Boening)

Mississippi has the fewest active physicians per capita of any state, consistently struggles with high rates of acute and chronic illness, and over half of its residents live in rural areas lacking specialty medical care. In an effort to bridge the state's geographical gap in access to healthcare, the University of Mississippi Medical Center (UMMC) has introduced telemedicine. This study conducts an analysis of some of the societal benefits of UMMC's telemedicine initiatives using a difference-in-differences identification strategy. This model attempts to obtain the county-level causal effects of implementing telemedicine by evaluating the resulting changes in length of life, quality of life, and other relevant health outcomes. Though this study does not find any statistically significant results, many of the estimates of these changes do indicate movement in the direction of improved county health. This is encouraging given that telemedicine's widespread use is relatively recent and the analysis may be suffering from a low incidence rate. Some of the estimates are also large with large standard errors, indicating that some telemedicine programs may have a great impact though this model is not able to accurately estimate that impact. These results provide hope that as the use of telemedicine continues to expand in the state of Mississippi collection of related data will enable further and more accurate analysis.

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I. Introduction

The "Digital Revolution" has affected nearly every human activity, including healthcare. One of the first notions of using electronic technology to assist in providing medical care came about in the 1960s when Larry Weed suggested using electronic means to keep track of patient information (Budniak, 2017). This innovation would come to be known as the Electronic Medical Record or EMR. Others soon began exploring applications of technology in healthcare. Dr. Michael DeBakey was the first to make use of video, transmitting real-time footage of an open-heart surgery overseas by satellite in 1965. Medical staff at a hospital in Geneva, Switzerland, were able to view the aortic valve replacement procedure DeBakey was performing in Houston (U.S. Department of Veterans Affairs, 2005). This concept of treating patients remotely by technological means became known as telemedicine.

It is important to distinguish between *telehealth* and *telemedicine*. While often used interchangeably, they do have distinct definitions. Telemedicine refers to the purely clinical actions of providing "curative medical treatment for established disease" over a spatial distance using technological means (Darkins and Cary, 2005,). Telehealth, on the other hand, encompasses "education for health, public and community health, health systems development and epidemiology," and any other means of promoting health via technology. In other words, telemedicine is the clinical subset of the broader entity telehealth (Darkins and Cary, 2005).

This thesis focuses on the use of telemedicine. There is a growing body of research on the clinical efficacy and cost reduction benefits of utilizing telemedicine, particularly in rural medicine. This study aims to contribute to that research by conducting an analysis of some of the societal benefits of the University of Mississippi Medical Center's recent telemedicine initiatives. The analysis utilizes a difference-in-differences regression framework on county-level data from the period of 2010-2017.

Section II explores the background of telehealth and telemedicine. Section III details the current state of health and use of telemedicine in the state of Mississippi. Section IV explains the data and research methodology used in this study. Section V presents the regression analysis. Section VI discusses the implications of the results.

II. Background

The history of telehealth and telemedicine is detailed below, but a key turning point came about with the advent of the smartphone. Its popularization has been likened to the development of the printing press as its effects have been of a similar magnitude (Topol, 2015). Perhaps the greatest effect of the smartphone in the healthcare sector has been what Dr. Eric Topol (2015) refers to as the "democratization of medicine." In essence, the smartphone has empowered patients to be more active participants in their well-being, to seek out and evaluate physicians, and to improve the accessibility and usability of their healthcare information. Smartphone users now have the capability to record details almost anytime and anywhere – everything from pictures to their own heart rate – and then send them to another user, save them for later, or conduct their own analysis. This newfound ability has catalyzed the adoption of telemedicine. Over the past few decades, several leaders in the medical and political sectors have realized the potential for the cross-pollination of technology and healthcare, leading to the formation of the American Telemedicine Association in 1993 and the establishment of the Office of the National Coordinator for Health Information Technology (ONC) in 2004.

The promise of telehealth and telemedicine has become evident in recent years with the emergence of numerous independent telehealth companies like Teladoc as well as the exploration of telemedicine initiatives by large healthcare organizations and academic medical centers. In their book *Telemedicine and Telehealth - Principles, Policies, Performance, and Pitfalls*, Dr. Adam Darkins and Dr. Margaret Cary pronounce, "Telehealth has the ability to improve the quality of healthcare, provide equity of access to healthcare services, and reduce the cost of delivering healthcare" (2005). This is certainly proving to be true. Telemedicine and telehealth are in their infancy, though. While studies on the cost effectiveness and clinical efficacy of utilizing telehealth have been conducted, further exploration is necessary, especially with regard to the socioeconomic impact of expanding access to care.

In order to more fully understand the current state of telemedicine and place this study into context, the following subsections detail the history of telehealth and telemedicine, the types of telemedicine, some prominent benefits of utilizing telemedicine, current policies pertaining to telemedicine, and existing obstacles to increased adoption.

a. History of Telehealth and Telemedicine

The prefix "tele" in telemedicine and telehealth comes from the Greek word meaning distant. If the literal definition of telehealth – providing health care services at a distance – is considered, then it is not a revolutionary idea. Primitive communication technologies were used to support public health. For example, villages and ships infected with communicable diseases warned travelers to keep away with devices like signs, flags, and bells, thus controlling the spread of infectious disease (Darkins and Cary, 2005).

The first major milestone in what is defined as telemedicine—providing clinical care at a distance—came about with the invention of the telephone in 1876. A patient could now call his or her doctor to receive remote medical advice or to summon help. The telephone is currently used extensively in the delivery of healthcare. A patient can schedule an appointment by phone, a mother can call a nurse hotline for advice after-hours, a physician might contact a colleague for a second opinion, or an attending clinician who has already left the hospital could be updated on the status of a patient. All these common occurrences are instances of telehealth provided via telephone.

What is now thought of as telemedicine—using *advanced* technology to provide clinical care—grew as technology rapidly progressed and became more readily available to the public. Modern telemedicine had its beginnings in the late 1960s and early 1970s. Routine teleconsultations took place over a closed-circuit television system that linked the Nebraska Psychiatric Institute to a remote state mental hospital during this time, Dr. Michael DeBakey's experimental telesurgery described above in Section I took place in 1965, and the first national conference/workshop on telemedicine took place in 1973 in Ann Arbor, Michigan (Darkins and Cary, 2005).

Despite these early successes, most initial telemedicine projects folded due to various combinations of the high costs of the technology, poor quality of the imagery, lack of demand for the service, and/or the inability to integrate with mainstream provision of healthcare (Darkins and Cary, 2005). NASA, remote research stations, offshore oil rigs, and the military were virtually the only parties that continued to support the development of telemedicine from the late 1970s to the mid-1990s. Interest in using telemedicine to provide care for the general public resurfaced in Norway in the early 1990s. The Norwegian government-funded healthcare system along with Norway's numerous remote regions lacking specialist physicians provided a unique opportunity for the implementation of telemedicine (Darkins and Cary, 2005). Upon seeing Norway's success, the United States regained interest in telemedicine for more than just extreme situations. By 1995, the US reported the highest number of annual teleconsultations of any country (Darkins and Cary, 2005). This resurgence of use in the United States was primarily focused on prison and rural telemedicine and was mostly funded by government grants (Darkins and Cary, 2005). Commercial telemedicine activity first began to take hold in radiology and has progressed into dermatology, psychiatry, cardiology, and other specialties (Darkins and Cary, 2005).

b. Types of Telemedicine

There are three types of telemedicine: 1) store-and-forward, 2) real-time, and 3) remote monitoring (Lyuboslavsky, 2015). Store-and-forward refers to the secure electronic transmission of medical information, such as digital images, documents, and pre-recorded videos. An example is a patient taking a picture of a rash and forwarding it to a dermatologist for diagnosis. The clinician is then able to review the transmission and send back a diagnosis and treatment plan. This significantly increases efficiency, but might not provide the same "healing touch" as in-person or real-time consultations. Real-time telemedicine occurs when a patient and provider are in separate physical locations, but communicating via telephone, video, or radio with one another in real time. This is a close proxy to a traditional face-to-face visit, but does not provide as many efficiency benefits as store-and-forward. Remote monitoring involves the use of sensors to track patients' body function and behavior. One example is a cardiologist stationed in another location in the hospital keeping tabs on his or her patient's heartrate in the ICU. Another example is an endocrinologist analyzing data from a patient's internet-connected blood-glucose monitoring device. Remote monitoring faces the most challenges with reimbursement, but is increasingly coming into use with the popularity of wearable devices and the Internet of Things (Lyuboslavsky, 2015).

c. Benefits of Utilizing Telemedicine

The benefits of telemedicine include improved convenience of and expanded access to care, cost reduction, and improved outcomes.

Improved Convenience of and Expanded Access to Medical Care

Modern technology has enhanced interpersonal connectedness and increased access to information. A colleague who lives across the world is now just an email or phone call away and everything from definitions to directions is now readily retrieved by a quick internet search. It is only logical that such convenience would extend to the healthcare field.

There are at least three improved conveniences from telemedicine. First, telehealth gives patients expanded access to information. This might be informative webpages about specific diseases and/or treatments on the Mayo Clinic's website or a platform like Epic System's for accessing one's personal health record. Second, telehealth increases patients' connectedness. Examples include online support communities such as PatientsLikeMe (Topol, 2015). Third, telemedicine reduces time cost. The average wait time for an appointment with a primary care physician in the United States is 2.5 weeks (Topol, 2015). Patients who elect to have a store-and-forward teleconsultation instead of an in-person consultation need not schedule an appointment, drive to their physician's office, or wait to be seen. Even a real-time teleconsultation that does require the alignment of schedules eliminates the need for travel.

Additionally, new telemedicine groups are cropping up with 24/7 operating hours and initiation to treatment plan timeframes of 24 hours or less (Topol, 2015).

Physicians realize an increase in efficiency with these tools, too. With store-and-forward, clinicians are able to set aside a block of time to review multiple stored patient transmissions without interruption. While one in-person consultation with a physician can last from 10-30 minutes, “reviewing a store-and-forward visit takes as little as two minutes” (Lyuboslavsky, 2015). Based on these numbers, a physician could complete 15 virtual visits in the time it might take to complete one in-person consultation.

Telemedicine also provides the benefit of greater access to care. “In most of the one-quarter of the United States that is considered rural, there is less than one doctor per thirty-five hundred people” (Topol, 2015). In these rural communities, individuals requiring care might be subject to even longer wait times for an appointment with that one local doctor. If they need a specialist, they will likely have to travel significant distances to a regional hospital or academic medical center, a luxury in time and expense that some might not be able to afford. Telemedicine can connect people in rural communities to a local hospital or to a specialist across the world and simultaneously eliminate the need to travel. Whether a personal smartphone or a computer at their local clinic is the means, this “flattening of the world” with technology can reduce the geographical gap related to healthcare access.

Cost Reduction

Telemedicine can also reduce cost. In some cases, such cost reduction can also improve access. Health Partners, an insurer based in Minnesota, conducted a study that showed an $88 average cost reduction per visit when using virtual visits in place of in-person visits (Anderson, 2013). Those without insurance can benefit, too. A basic visit with a physician through Teladoc costs only $38, no insurance required (though many telemedicine sites do accept insurance). Similarly, Dermatologist on Call only charges $59 for a dermatologist review of a rash. These examples contrast with an average cost of $160 for an uninsured patient's in-person visit with a primary care physician (Saloner et al., 2015). Telehealth also garners cost savings in the management of chronic conditions. In the Liu et al. (2016) study on heart failure telehealth programs, savings ranging from $2,832 to $5,499 (dependent upon the severity of the case) were realized per patient over a one-year period.

Improved Clinical Outcomes

Improved convenience, expanded access, and cost reduction would mean nothing, though, if the standard of care was comprised. Numerous studies have shown that patients prefer virtual visits and that their clinical efficacy is on par with, if not better than, typical in-person visits (Topol, 2015). For example, Topol's 2015 study of teleconsultation with genetic counselors demonstrated that these teleconsultations were just as effective as in-person consultations. The Bashshur et al. (2015) study on telemedicine intervention in diabetes management pointed to positive effects of telemonitoring and telescreening in terms of glycemic control, reduced body weight, and increased physical exercise. They found strong and consistent evidence of improved glycemic control among persons with Type 2 and gestational diabetes along with effective screening and monitoring of diabetic retinopathy.

d. Policies Pertaining to Telemedicine

The Health Information Technology for Economic and Clinical Health (HITECH) incentive program was created in 2008 to address the sluggish adoption of digital technologies by the healthcare industry. This program was funded by $30 billion out of the $700 billion stimulus package initiated by the Obama administration to combat the 2008 recession. A significant portion of this $30 billion went to promoting the adoption of electronic health records (EHRs), a component of telehealth (Wachter, 2015). The Office of the National Coordinator for Health Information Technology (ONC), created in 2004, was tasked with overseeing the program and was successful in increasing the use of EHRs in clinical hospitals from 10% to about 70% by 2014 (Wachter, 2015).

The ONC instituted the Meaningful Use policy to ensure that providers receiving the incentives were actually utilizing the subsidized technology. Stage 1 of the policy was instituted in 2011 and was generally thought to be reasonable and helpful. It included clauses like "providing clinical summaries to patients within three days of hospitalization and transmitting a decent proportion of prescriptions electronically" (Wachter, 2015). Stage 2 was rolled out in 2014 and evoked disdain in the healthcare community. It required hospitals and clinics to meet 17 aggressive core objectives, many of which were not entirely feasible or practical in the existing healthcare ecosystem. One of the requirements, for example, was that more than 5% of patients "view, download, and transmit" their electronic medical information to a "third party," like a subspecialist using a different EHR (Wachter, 2015). While written with good intent, this requirement was not practical. Patient portals and EHRs had to be reengineered to make that act possible and physicians were now responsible for ensuring their patients did something with their newly accessible information. Great in theory; difficult to enact when the demand and culture are not quite present. Meaningful Use Stage 1 did encourage the implementation of practical technology in the clinical space, but Meaningful Use Stage 2 has done more to stifle innovation with its impractical stipulations than it has to improve health information technology (Wachter, 2015). Common critiques of ONC policies like those discussed above include the lack of focus on the interoperability between EHRs and the usability of health information technology (Wachter, 2015). Looking forward, instituting policies to encourage different EHRs to interact seamlessly and incentivizing improved usability of health information technology for the provider and patient might prove useful.

The 1996 Health Insurance Portability and Accountability Act (HIPAA) is another policy that has impacted the field of telehealth. This law was enacted in part to protect patient privacy. Before HIPAA, there were no generally accepted security measures or true requirements for protecting confidential patient information in the healthcare industry. However, the need for such standards became apparent as the industry began to implement information technology systems for a variety of functions, both clinical and administrative, that had previously been documented on paper. While this switch increased efficiency, it also created new potential security risks (U.S. Department of Health and Human Services, 2013). HIPAA's Privacy and Security Rules delineate what constitutes protected health information (PHI) and outline the standards for securing such information. In January 2013, a modification to the original HIPAA called the "Final Rule" was released by the U.S. Department of Health and Human Services. It expanded the requirement of HIPAA compliance to include any entity that "creates, receives, maintains or transmits PHI" where it had initially only applied to "covered entities" such as health care providers, health care clearinghouses, and health plans and it also increased penalties for violations (U.S. Department of Health and Human Services, 2013). These updates are particularly troublesome "…for mobile health companies in a rapidly expanding health information technology (HIT) industry. Although there is much interest in potential partnerships between innovative companies and health care organizations to leverage new mobile technologies (e.g., smartphones, tablets, mobile monitors), the final rule may impose an unfunded mandate for organizations, which ironically may impede adoption of innovation in mobile health" (Wang and Huang, 2013). While evidently necessary and well-intentioned, HIPAA's stringent requirements surrounding the use, storage, and sharing of PHI may be holding back innovation. Hospitals and clinics must focus their energies on preventing a HIPAA violation at all costs, and small healthcare companies may be less able to compete with larger, established firms that have more resources to bear the burden of these additional regulations. These and other critiques of HIPAA have prompted some to argue that the "Department of Health and Human Services may need to reevaluate and adapt its regulations to keep up with the advent of new mobile technologies and take a more progressive and innovation-friendly approach to privacy and security" (Wang and Huang, 2013).

e. Obstacles to Adoption

If the case for adopting telemedicine is so compelling, then why is it not ubiquitous? There are at least three major reasons: 1) physician reluctance, 2) licensing issues, and 3) insurance reimbursement.

Physician reluctance is a notable barrier. Healthcare is somewhat notorious for being slow to change, e.g., even the stethoscope was balked at when it was first introduced. Topol (2015) attributes much of this attitude to the paternalistic culture that exists in medicine, noting that "the doctor knows best" is more than just a colloquial saying. Hippocrates himself, the founding father of medicine, was not exactly an advocate for informed consent: he wrote and taught that a physician ought to decide what information the patient could handle being told. This sort of medicine, of course, is not taught (and hopefully practiced) anymore. However, the culture has been passed down, thus creating the sentiment among many clinicians that additional technology tends to frustrate rather than augment their practice. Physicians are also very busy individuals. Experimenting with or updating constantly-evolving tools and technology may not be a top priority to a doctor whose system already works, even if the doctor is technologically-savvy. Implementing telemedicine can therefore appear to involve substantial frustration and significant time loss.

Current licensing regulations also stand as an obstacle to the proliferation of telemedicine. Despite all clinicians being board certified on a national level (every physician takes the same national certification exam), they are licensed at the state level. A dermatologist licensed to practice in California – though he or she has the same board certification as a dermatologist anywhere else in the country – could not provide teleconsultation services to a patient in Mississippi. The Interstate Medical Licensure Compact (IMLC) has been created in an effort combat this problem. “The IMLC is an agreement between 22 states and the 29 Medical and Osteopathic Boards in those states. Under this agreement licensed physicians can qualify to practice medicine across state lines within the Compact if they meet the agreed upon eligibility requirements” (Interstate Medical Licensure Compact, 2018). However, if a national licensing framework was established, or even if all the states agreed to honor each other’s medical licenses as they do with drivers’ licenses, this obstacle could effectively be eliminated.

The ambiguity surrounding insurance reimbursement for telehealth services is another hindrance. “In a poll of 1,500 family physicians, only 15% had used it (telehealth) in their practices—but 90% said they would if it were appropriately reimbursed” (Beck, 2016). Insurance companies have been grappling with how to reimburse for teleconsultations practically since telemedicine’s inception. Thankfully, many have begun to reimburse for real-time virtual visits if they would reimburse for the same service in-person (Beck, 2016). Medicare lags behind, though. “The federal health plan for the elderly covers a small number of telemedicine services—only for beneficiaries in rural areas and only when the services are received in a hospital, doctor's office or clinic" (Beck, 2016).

The reimbursement situation is particularly problematic when it comes to store-and-forward, remote monitoring, and physician-physician consults. There is currently no nationally-accepted framework for insurance reimbursement for these types of services ("State Telehealth Laws and Reimbursement Policies Report," 2017). As reimbursement moves from a fee-for-service schedule to an outcomes-based one, these issues may be less prevalent. In a fee-for-service model, a hospital charges an insurer a fee for each test and procedure performed. Whereas, in an outcomes-based model, an insurer pays a pre-determined fee (according to a patient's diagnosis) to a hospital to provide care for a patient. The hospital keeps any savings or is responsible for any additional costs above the actual cost to treat that patient. This model is meant to incentivize efficient and quality care. Telemedicine may take hold more quickly in this outcomes-based model because providing a teleconsultation or tele-second-opinion is less costly than an in-person consultation and provides a comparable outcome, allowing a hospital to profit more from the set fee (Beck, 2016).

Despite these obstacles, there is much to be explored when it comes to the impact of and use of technology in healthcare. In particular, a review of the socioeconomic impact of telehealth found significant benefit in areas like enhanced access to and quality of care, but cited the limited generalizability of studies due to inconsistent use of socioeconomic indicators (Jennett et al., 2003). A limited number of specific studies on management of chronic conditions have been conducted, but there is certainly need for more in order to develop a generalizable framework for widespread implementation of effective programs.

III. Mississippi

Demographics, policies, and telemedicine programs can vary widely by state. As this study focuses specifically on telemedicine programs instituted in the state of Mississippi, it is useful to explore the current demographics, policies, and telemedicine initiatives therein.

a. Current Demographics and Health in Mississippi

Pertinent demographic and health information provided by Rural Health Information Hub (2017) about Mississippi includes:

- Mississippi has an estimated population of 2,988,726 people.
- Nearly 54% of these residents live in what is considered a rural area.
- The U.S. Census Bureau reports that 59.3% of the state's population is white, 37.7% is Black/African-American, and 3.1% is of Hispanic/Latino origin.
- Of the 95 hospitals in the state, 31 are identified as Critical Access Hospitals.
- Mississippi has 177 Rural Health Clinics and 21 Federally Qualified Health Centers that provide services at 188 sites in the state.
- There is only one academic medical center and one children's hospital.
- 12% of Mississippi residents lack health insurance.
- The average per-capita income for Mississippi residents in 2015 was $34,771 although rural per-capita income lagged at $32,432.
- The poverty rate in rural Mississippi is 24.3%, compared with 16.8% in urban areas of the state.
- 20.8% of the rural population has not completed high school, while 13.8% of the urban population lacks a high school diploma.

- The unemployment rate in rural Mississippi is 6.4%, while in urban Mississippi, it is 5.2%.

When it comes to health and access to care, Mississippi has long lagged behind the national average. According to America's Health Rankings, the state's core measures of health have collectively placed it in the bottom three states in the nation for overall health since 1990 ("2017 Annual Report – Mississippi"). In other words, Mississippi has not been ranked higher than 47th for overall core measures of health for more than 25 years. In 2015, Mississippi had the highest rates of preterm birth, low birthweight, and death from cardiovascular disease, stroke, diabetes, and septicemia in the nation ("Stats of the State of Mississippi," 2017). It also had one of the highest rates of obesity and led the nation in physical inactivity ("2017 Annual Report – Mississippi"). Sadly, Mississippi also has the fewest active physicians and active primary care physicians per capita of any state ("Mississippi Physician Workforce Profile", 2017). Though the state does not possess substantial disparities in health status by education level, the geographic disparities are notable ("2017 Annual Report – Mississippi"). In 2017, the counties in the northwestern part of the state that comprise the Mississippi Delta (De Soto, Tate, Tunica, Panola, Coahoma, Quitman, Tallahatchie, Bolivar, Leflore, Grenada, Sunflower, Carroll, Holmes, Humphreys, Washington, Sharkey, Issaquena, Yazoo, and Warren) all ranked in the bottom quartile of health factors for the state. These health factors include health behaviors, quality and availability of clinical care, social and economic factors, and physical environment ("Mississippi Health Factors Rankings").

Given the state's struggles with debilitating chronic diseases, shortage of healthcare providers, and significantly rural population, Mississippi seems an excellent candidate for implementing telemedicine in an attempt to increase access to care and efficiency.

b. Telemedicine in Mississippi

According to the American Telemedicine Association, Mississippi receives an overall grade of "A" for their policies on coverage and reimbursement of telemedicine based on health plan parity and Medicaid conditions of payment. Only nine states in the nation received that designation in 2017. Of the thirteen indicators analyzed, Mississippi had "A's" for ten. For "eligible technologies" and "informed consent" under Medicaid Service Coverage and Conditions of Payment, Mississippi received "B's"—due to stringent rules for eligible technologies and requirement of an "unspecified method of obtaining consent"—and did not receive a grade for rehabilitation services as they are not currently offered in the state. Mississippi was also lauded by the report for its innovative payment/service delivery models for correctional facilities ("State Telemedicine Gaps Analysis," 2017).

Why is Mississippi considered one of the top states for telemedicine policy? In 2013, Mississippi enacted a parity law that required private insurers, state employee health plans, and public assistance to consider services provided via telemedicine equivalent to services they cover when provided through in-person consultation. The code further requires that deductibles, co-payments, and coinsurance must not be greater for the provision of a specific service via telemedicine than that same service provided via in-person consultation (Miss. Code Ann., 2013). This true parity in status and payment is rare even among states who have enacted parity laws.

Additionally, though the code initially stipulated that the telemedicine consultation had to be in real-time (i.e., not audio-only, telephone, email, or facsimile), the code was amended in 2014 to include parity in reimbursement for store-and-forward and remote patient monitoring services (Miss. Code Ann., 2014). This section of the code also outlines the appropriate value of reimbursement of remote patient monitoring as it can be difficult to compare this type of service to an in-person consultation.

Mississippi also has no geographic restrictions on where service can be provided—other than that the patient must reside within the state—and honors a wide range of specialties, even going so far as to allow a non-Mississippi-based provider (who is licensed to practice in Mississippi) to be reimbursed for store-and-forward services not available in Mississippi (Miss. Code Ann., 2014). The University of Mississippi Medical Center's (UMMC's) Center for Telehealth has worked and continues to work closely with state and national legislators to advocate for telehealth and develop sound policies to facilitate its adoption.

One obstacle to the provision of telehealth in rural areas is the lack of accessibility to high speed internet connection. Per 2016 data compiled by the Federal Communications Commission, "79 percent of Mississippi households are not connected to internet at speeds defined as broadband — 25 megabits per second downstream and three megabits per second upstream" (Wolfe, 2017). UMMC works with the rural clinics where it provides telemedicine services to ensure they have high-speed internet capabilities. For remote patient monitoring programs, patients are provided a tablet with a data plan and their cell service is checked to ensure their connection will be supported (Wolfe, 2017).

Overall, Mississippi is a national leader in telemedicine, thanks in large part to UMMC's Center for Telehealth. There remains potential for growth in several areas, which should be bolstered by UMMC's recent recognition as a National Telehealth Center of Excellence and the associated grant to support research and development (University of Mississippi Medical Center, 2017).

c. Telemedicine at the University of Mississippi Medical Center

In Mississippi, residents in 53 of the state's 82 counties are more than a 40-minute drive from specialty care (Michael Adcock, FACHE, e-mail correspondence, May 2017). This causes a troublesome delay in the receipt of necessary care and increases health risks, especially for emergency situations that require quick intervention. The resulting burden on local hospitals is also problematic due to the number of patients that have to be transferred to a higher level of care. Local hospitals consequently lose desperately needed reimbursement to larger medical centers which possess the specialty care that local hospitals lack.

The University of Mississippi Medical Center (UMMC)—the only academic medical center in the state—recognized this geographical disparity in access to care and sought to "shrink the gap" by utilizing technology. In 2003, UMMC began offering specialty emergency care via live tele-consults with rural hospitals and clinics. In 2008, UMMC added a TelePsychiatry program. In 2011, a full-time staff was dedicated to telehealth. Then, in 2013, the UMMC Center for Telehealth was officially formed with a 24/7 Telehealth Call Center. "More than 500,000 patient visits in 69 of the state's 82 counties have been recorded since the center began (in 2003) with just three sites, expanding to more than 200 sites today, not including the homes of patients" (University of Mississippi Medical Center, 2017). In 2017, the Center was named a national Telehealth Center of Excellence by the Health Resources and Services Administration, an agency of the U.S. Dept. of Health and Human Services. This national honor comes with over $2 million in grant funding to promote research on telehealth and to aid the center's support of other telehealth programs that seek their assistance (University of Mississippi Medical Center, 2017). The Center provides remote access to practitioners in more than 35 specialties. Additionally, telehealth nurse practitioners work as part of a multidisciplinary team that includes a certified emergency medicine physician on the UMMC campus to treat patients in the emergency departments of 17 rural Mississippi hospitals. The Center also recently debuted its "UMMC 2 You" program offered online throughout Mississippi to individuals and families on the state employee insurance plan and through select schools and companies for the treatment of minor medical issues (University of Mississippi Medical Center, 2017).

IV. Data

Data related to health outcomes, health factors, and demographics were obtained from the County Health Rankings and Roadmaps website (http://www.countyhealthrankings.org/ rankings/data/ MS). Specific outcome variables—such as deaths related to the circulatory system—were sourced from the CDC Wonder Online Database website (https://wonder.cdc. gov). This database compiles information on the number of deaths and causes of death according to the International Classification of Diseases, Tenth Revision (ICD10) codes. These data cover all 82 counties in the state of Mississippi from the period of 2010-2017. Additionally, UMMC's Center for Telehealth provided information regarding the start date of each service line in the 64 counties where they had contracts and were operating as of November 2017 (Megan Duet, MS, e-mail communication, November 2017).

These data are used to test whether the implementation of telemedicine programs (both generally and two specific service lines) affected health outcomes in the counties they served. The general effects of the programs are evaluated via improvements in length of life and quality of life occurring after implementation of telemedicine programs. Length of life is evaluated in terms of years of potential life lost (YPLL) which is defined in this dataset as the age-adjusted years of potential life lost before age 75 per 100,000 population. The CDC explains that “YPLL is calculated by subtracting the age at death from the standard year, and then summing the individual YPLL across each cause of death. For example, if three people died from a certain cause who were ages 2, 37, and 74, the YPLL-65 for that cause of death would be (65-2) + (65-37) = 63 + 28 = 91. Note that the YPLL calculation does not include people who died at the benchmark age or older. For instance, choosing 65 as the benchmark age excludes people who died at age 65 or older from the calculation of YPLL-65” (“Definitions for Years of Potential Life Lost,” 2014). Quality of life is evaluated in terms of poor physical health days (PPHD) per person per year. In this dataset, PPHD are defined as the average number of physically unhealthy days reported in the past 30 days (age-adjusted) from the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a system of telephone surveys that collect data about U.S. residents’ health-related risk behaviors, chronic health conditions, and use of preventive services. These length of life and quality of life outcome variables are used to evaluate the effects of the general presence of telemedicine in a county depending on whether the county had one or more service lines versus no service lines.

Additionally, the impact of two specific telemedicine service lines—tele-cardiology and tele-primary care (with a nurse practitioner)—are investigated based on one or more specific health outcome variables related to the given service line. The impact of tele-cardiology is evaluated based on the number of circulatory system-related deaths (per 100,000 population; CSD). The impact of tele-primary care is evaluated based on two outcome measures: the preventable hospitalization rate (PHR) and the percentage of diabetic Medicare enrollees age 65-75 that receive HbA1c monitoring (PctDM). Preventable hospitalizations are admissions to a hospital for certain acute illnesses like dehydration or for worsening chronic conditions that might not have required hospitalization had they been successfully managed in outpatient settings. In this dataset, PHR is defined as the number of hospital stays for ambulatory-care sensitive conditions per 1,000 Medicare enrollees. PctDM measures the general health of elderly diabetics. HbA1c tests indicate how high a person's blood sugar has been on average for the past 8-12 weeks. Monitoring HbA1c is thought to be one of the best ways to see if a person's diabetes is well-managed. Due to expected non-normality in the distribution of these variables, the log of each outcome variable is used in the regressions.

To account for any potentially confounding factors from different demographic and socioeconomic compositions of counties, control variables are included in the regressions. The same control variables are used in all regressions. These include the percentage of the county that is younger than 18, percentage of the county that is older than 65, racial make-up of the county, percentage considered rural, median income, percentage unemployed, percentage with only a high school education, percentage of children in poverty, and percentage who do not speak English. These variables capture differences in health outcomes attributable to age, race, education, and socioeconomic status.

Table 1 provides descriptive statistics on the outcome variables and the control variables. Both weighted (by county population) and unweighted means for each of the variables are reported. Standard deviations are given in parentheses. As shown in Table 1, per 100,000 people, there are an (weighted) average of 10,453.02 years of potential life lost each year per county for the period of 2010-2017. This means that, on average, premature deaths (before age 75) due to accident, disease, mismanagement of a chronic condition, or some other cause resulted in 0.10 years (or 1.25 months) of potential life lost per person each year. Likewise, across all counties, each person experienced an (weighted) average of 4.093 days of poor physical health each month.

Table 1: *Descriptive Statistics*

Dependent Variables	Weighted Mean (std. err.)	Unweighted Mean (std. err.)
Years of Potential Life Lost (YPLL)	10453.02	11245.87
	(262.4341)	(203.9679)
Poor Physical Health Days (PPHD)	4.093	4.3767
	(.0888)	(.05797)
Deaths Related to Circulatory System (per 100,000 Population; CSD)	229.6379	122.5378
	(42.9707)	(11.0635)
Preventable Hospitalization Rate (PHR)	85.518	96.0832
	(2.7748)	(2.3884)
Diabetic Medicare Enrollees Age 65-75 Receiving hbA1c Monitoring (%*100; PctDM)	80.89511	80.471
	(.71181)	(.5499)
Control Variables		
County Population	84277.28	36303.92
	(16743.41)	(4634.134)
Percentage Younger Than 18	25.0745	24.7023
	(.2642)	(.25986)
Percentage 65 and Older	13.5786	14.6436
	(.3059)	(.2396)
Percentage African American	37.1237	40.8185
	(3.4703)	(2.2584)
Percentage American Indian or Alaska Native	0.5662	0.6411
	(.1685)	(0.2106)
Percentage Asian	0.9565	0.5289
	(.1608)	(0.0637)
Percentage Native Hawaiian or Pacific Islander	0.0459	0.0289
	(0.0081)	(0.0055)
Percentage Hispanic	2.8134	2.3099
	(0.2741)	(0.1845)
Percentage Female	51.4571	51.1584
	(0.1941)	(0.2350)
Percentage Rural	50.5332	70.2359
	(4.4623)	(2.8157)
Median Income	39235.43	34498.92
	(1687.292)	(776.1693)
High School Graduation Rate	71.9427	71.3297
	(1.0042)	(0.6691)
Percentage Unemployed	8.8678	10.1521
	(0.3152)	(0.2596)
Number Children in Poverty	32.78	35.6189
	(0.9916)	(0.7840)
Percentage Non-English Speaking	1.0902	0.8563
	(0.1139)	(0.0965)

V. Identification Strategy

In order to distinguish the effects of telemedicine on health outcomes from confounding causes (more public funds allocated to healthcare, a push for enrollment in Medicare, etc.), the variation across counties resulting from the rolling implementation of UMMC telemedicine programs from 2010-2017 is exploited using a difference-in-differences research design. The difference-in-differences model is a statistical technique used to, in a sense, mimic a randomized experiment using available observational data. The model elicits the causal outcome of a treatment by comparing the outcome changes before and after the treatment is administered in the treatment group to those in the control group. The control group does not receive the treatment at any point and data are observed for the same period of time as the treatment group. The treatment group is observed prior to the start of treatment and after treatment has been administered. Difference-in-differences is useful in observational experiments where delivery of the treatment cannot be completely randomized. In order for the model to be valid, the control group must be similar in trend to the treatment group prior to the treatment being delivered. This design removes any bias that may have existed from the prior trend in an estimate that simply compares the outcomes before and after treatment. If the assumption holds, then the difference-in-differences model can be used to find the change in outcome that directly resulted from the treatment.

The general regression format used is:

$$y_{it} = \alpha + \beta_1 Treat_i + \beta_2 Post_t + \beta_3 Treat_i \times Post_t + \beta_4 X_{it} + u_{it} \qquad (1)$$

Dependent variable y_{it} is the outcome in unit *i* in time period t. The independent variables $Treat_i$ and $Post_t$ are dummy variables. $Treat_i = 1$ if observation y_{it} is from a unit in the treatment group and $= 0$ if it is from a unit in the control group, and $Post_t = 1$ if y_{it} is observed after the time period in which the treatment was administered and $= 0$ if y_{it} is observed prior to that time. Thus, coefficient β_1 captures the differences between treatment and control groups that do not vary with time (e.g., differing climate types) and coefficient β_2 accounts for shocks that occur simultaneously for both treatment and control groups (e.g., a change in the federal tax code). The variable $Treat_i{\times}Post_t$ captures the interaction between $Treat_i$ and $Post_t$. Notice that $Treat_i{\times}Post_t$ = 1 only if unit *i* is in the control group and period *t* occurs after treatments was administered, and = 0 otherwise. Therefore, coefficient β_3 is the main parameter of interest because it represents the pre/post difference for the treatment group minus the pre/post difference for the control group. In simpler terms, β_3 is the estimated causal effect of treatment after accounting for time-invariant and time-specific differences. Variable X_{it} represents the vector of control variables. The random error term u_{it} represents the difference between the outcome predicted by the model and that which is actually observed.

For the purposes of this study, the format of the regression used is Model 1 (M1):

$$Outcome_{it} = \alpha + \beta_1 HadTelemed_{it} + County_i + Year_t + \beta_2 X_{it} + u_{it} \quad (2)$$

$Outcome_{it}$ is one of the health outcomes for county *i* in year *t* (YPLL, CSD, PHD, PHR, or PctDM; see Table 1 above). $HadTelemed_{it}$ is essentially the $Treat_i{\times}Post_t$ variable from the general specification shown above in equation (1): it = 1 in any year *t* when county *i* has an active telemedicine program and = 0 in any year in which there was no active program. $County_i$ and $Year_t$ are county and fixed effects, respectively, that take the place of $Treat_i$ and $Post_t$ in equation (1). These variables do not have coefficients because they are fixed effects, not random variables. The fixed effects model is used here because unobservable, time-invariant effects (e.g., culture) are tied to the observable independent variables (e.g., implementation of telemedicine). X_{it} again represents the collection of control variables and u_{it} is the error term. Robust standard errors clustered at the county level are used to avoid overstating the significance of estimates due to serial error correlations within groups (Bertrand, Duflo, and Mullainathan, 2004).

In this case, the identifying assumption is that had implementation of telemedicine not occurred anywhere, the treatment-group counties would have followed a similar trend in health outcomes to control-group counties during the period of evaluation. Below in Section VI, this assumption is tested with both regressions and graphics. The format of the regressions used to test the assumption is Model 2 (M2):

$$Outcome_{it} = \alpha + \beta_1 HadTelemed_{it} + \beta_2 lead^p_{it} + County_i + Year_t + \beta_3 X_{it} + u_{it} \tag{3}$$

Equation (3) is identical to equation (2) except for the inclusion of variable $lead^p_{it}$, which is a leading indicator that = 1 if the observation of $Outcome_{it}$ occurs within *p* periods before the implementation of a telemedicine program (e.g., p = 2 indicates a window of 0 to 2 years) for a county in the treatment group and = 0 otherwise. If the inclusion of this indicator yields a statistically-significant coefficient (β_2), then the identifying assumption may not be valid.

Graphically, evidence of divergence in the trends of treatment and control counties prior to implementation indicates a violation of the identifying assumption. This divergence in trends is shown visually by graphing the coefficient estimates for leading and lagging indicators specific to each year pre- and post-implementation. The regressions used to obtain these estimates follow the formats shown in equations (4) and (5):

$$Outcome_{it} = \alpha + \beta_1 HadTelemed_{it} + \beta_4 YrPre^p_{it} + County_i + Year_t + \beta_3 X_{it} + u_{it} \tag{4}$$

$$Outcome_{it} = \alpha + \beta_1 HadTelemed_{it} + \beta_5 YrPost^p_{it} + County_i + Year_t + \beta_3 X_{it} + u_{it} \tag{5}$$

Here, $YrPre^{p}_{it}$ = 1 when observation $Outcome_{it}$ occurs within *p* periods before implementation of the telemedicine program (e.g., if *p* = 1, $YrPre^{1}_{it}$ = 1 when $Year_t$ = 2013 and if the telemedicine program was implemented in 2014 for that county) and = 0 otherwise. Likewise, $YrPost^{p}_{it}$ = 1 when observation $Outcome_{it}$ occurs within *p* periods after implementation of the telemedicine program. Graphing these β_4 and β_5 coefficient estimates gives a visual representation of the difference in trends of a health outcome between treatment and control counties over time. If the identifying assumption holds, β_4 estimates from equation (4) will be close to zero—meaning the pre-implementation trends in $Outcome_{it}$ for treatment and control groups do not differ. Additionally, if the β_5 estimates from equation (5) trend in one direction or the other after implementation, this would indicate that implementation had an effect on $Outcome_{it}$ in the treatment group, but not the control group. The β_5 estimates capture the dynamic effects of the treatment whereas β_1 represents the overall average effect. These dynamic effects can be masked when only considering the overall effect, so visually representing the dynamic effects can be useful. For the five dependent variables considered here, lower values indicate better health. Thus, negative post-implementation β_5 estimates would indicate that (on average) telemedicine improved county health.

VI. Results

a. Length and Quality of Life

First, an examination is conducted on whether implementing any telemedicine program has an effect on length of life or quality of life using the broad-measure outcome variables YPLL (Years of Potential Life Lost) and PPHD (Poor Physical Health Days). If telemedicine has a positive effect, then YPLL and PPHD will decline after implementation. The results from estimating equation (2) are shown in Table 2. For the variable $lead^{p}_{it}$, the leading period is p = 2 years. The

Table 2: Impact of Telemedicine on Length and Quality of Life

	OLS - Weighted by County Pop.		OLS - Unweighted	
	M1	M2	M1	M2
Panel A: Length of Life	Log(YPLL)		Log(YPLL)	
$HadTelemed_{it}$	-0.00351	-0.0028	0.0093	0.0109
	(0.0136)	(0.0137)	(0.0159)	(0.0162)
	p = 0.797	p = 0.839	p = 0.560	p = 0.505
0 to 2 Years Before Implementation of Telemedicine		0.0058		0.0122
		(0.0125)		(0.0207)
		p = 0.642		p = 0.557
Observations	649	649	649	649
Panel B: Quality of Life	Log(PPHD)		Log(PPHD)	
$HadTelemed_{it}$	-0.0152	-0.0183	0.0324	0.0283
	(0.0249)	(0.0247)	(0.0263)	(0.0258)
	p = 0.543	p = 0.460	p = 0.222	p = 0.276
0 to 2 Years Before Implementation of Telemedicine		-0.0252**		-0.032
		(0.012)		(0.0233)
		p = 0.039		p = 0.173
Observations	650	650	650	650

* = significant at the 10% level, **= significant at the 5% level

Note: standard errors shown in parentheses, county and year fixed effects and control variables (Table 1) included in all regressions

results for YPLL are in the upper panel, and those for PPHD are in the lower panel. The first two columns contain estimates from Ordinary Least Squares (OLS) regressions with the outcome variable weighted by county population and the last two columns contain estimates from the unweighted versions of the dependent variable. While none of these coefficient estimates are statistically significant, the estimates for $HadTelemed_{it}$ are negative in both the YPLL and PPHD population-weighted regressions. This is consistent with telemedicine lowering YPLL and PPHD, i.e., the presence of telemedicine improving general health. However, in addition to not being statistically significant, these estimates were not robust to the inclusion of $lead^2_{it}$, a two-year leading indicator that accounts for prior trends. A statistically significant coefficient for the leading indicator $lead^{p}_{it}$ is found in the weighted regression for PPHD, indicating that there may have been a preexisting trend in this outcome. So, though it is promising that the initial estimates show decreases in YPLL and PPHD, the fact that these coefficient estimates are statistically insignificant and not robust to inclusion of a leading indicator precludes drawing any conclusions about the impact of simply having a telemedicine program on length and quality of life.

Table 3 presents regressions designed to see if specific service lines have a clearer impact on length and quality of life. Outcomes YPLL and PPHD are regressed on treatment variables related to whether or not a county had a tele-primary care program (panel A) or a tele-cardiology program (panel B). Specifically, $HadTelemed_{it}$ = 1 is limited to the presence of the respective service-specific tele-med program. While some of the coefficient estimates again have the expected sign (decreases in YPLL and PPHD indicated by negative coefficient estimates), they too are statistically insignificant and not robust to the inclusion of a leading indicator $lead^{2}_{it}$. In fact, the coefficient estimates for the PPHD regressions conducted on the impact of tele-primary care and tele-cardiology on PPHD both changed from positive to negative with the inclusion of the leading indicator (panel B).

Table 3: Impact of Selected Service Lines on Length and Quality of Life

	OLS - Weighted by County Pop.		OLS - Unweighted	
	M1	M2	M1	M2
Panel A: Length of Life	Log(YPLL)		Log(YPLL)	
Had Tele-Primary Care with Nurse Practitioner	-0.0026	-0.0007	0.0203	0.0402
	(0.0142)	(0.0195)	(0.0222)	(0.0293)
	p = 0.855	p = 0.971	p = 0.362	p = 0.174
0 to 2 Years Before Implementation of Telemedicine		0.0029		0.0302
		(0.0158)		(0.0293)
		p = 0.857		p = 0.252
Observations	565	565	565	565
Had Tele-Cardiology Program	0.0243	0.0326	0.0138	0.0176
	(0.0185)	(0.0279)	(0.0276)	(0.0404)
	p = 0.193	p = 0.246	p = 0.620	p = 0.665
0 to 2 Years Before Implementation of Telemedicine		0.0087		0.0041
		(0.0208)		(0.0303)
		p = 0.678		p = 0.893
Observations	565	565	565	565
Panel B: Quality of Life	Log(PPHD)		Log(PPHD)	
Had Tele-Primary Care with Nurse Practitioner	0.0092	-0.0084	0.0393	0.0174
	(0.0224)	(0.0344)	(0.0445)	(0.0545)
	p = 0.684	p = 0.808	p = 0.380	p = 0.750
0 to 2 Years Before Implementation of Telemedicine		-0.0266		-0.0333
		(0.0263)		(0.0299)
		p = 0.315		p = 0.269
Observations	565	565	565	565
Had Tele-Cardiology Program	0.0183	-0.0156	0.0125	-0.02923
	(0.0221)	(0.0353)	(0.0261)	(0.045)
	p = 0.3497	p = 0.659	p = 0.632	p = 0.518
0 to 2 Years Before Implementation of Telemedicine		-0.0353		-0.045
		(0.0254)		(0.0338)
		p = 0.168		p = 0.187
Observations	565	565	565	565

* = significant at the 10% level, **= significant at the 5% level

Note: standard errors shown in parentheses, county and year fixed effects and control variables (Table 1) included in all regressions

Figures 1-4 show the estimated β_4 and β_5 coefficients from equations (4) and (5) regressed on the outcomes YPLL and PPHD. The vertical line at zero represents the implementation year. The estimated β_4 values for $YrPre^{p}_{it}$ (p = 0 to 6) from equation (4) are plotted to the left of the vertical line, and estimated β_5 values for $YrPost^{p}_{it}$ (p = 0 to 3) from equation (5) are plotted to the right of it. These estimated values show the differences in trends for YPLL and PPHD between treatment and control counties prior to and after implementation of tele-primary care and tele-cardiology. These figures show a probable violation of the common trend assumption because the leading indicator estimates are not consistently close to zero. In Figure 1, for example, the difference in trends for YPLL before the implementation (i.e., β_4 coefficient estimates) of tele-primary care deviate from zero, especially for p = 4, 5, and 6 (–4, –5, and –6 on the figure), indicating that the identifying assumption may not hold in this case. Also, there is not a notable divergence away from zero after implementation (i.e., β_5 coefficient estimates), meaning that the implementation of tele-primary care did not have a significant effect on YPLL in treatment counties. Similar conclusions can be draw from graphs 2-4 about tele-cardiology's effect on YPLL and tele-primary care and tele-cardiology's effects on PPHD. The dynamic effects of Figures 3 and 4 will be discussed further in Section VII.

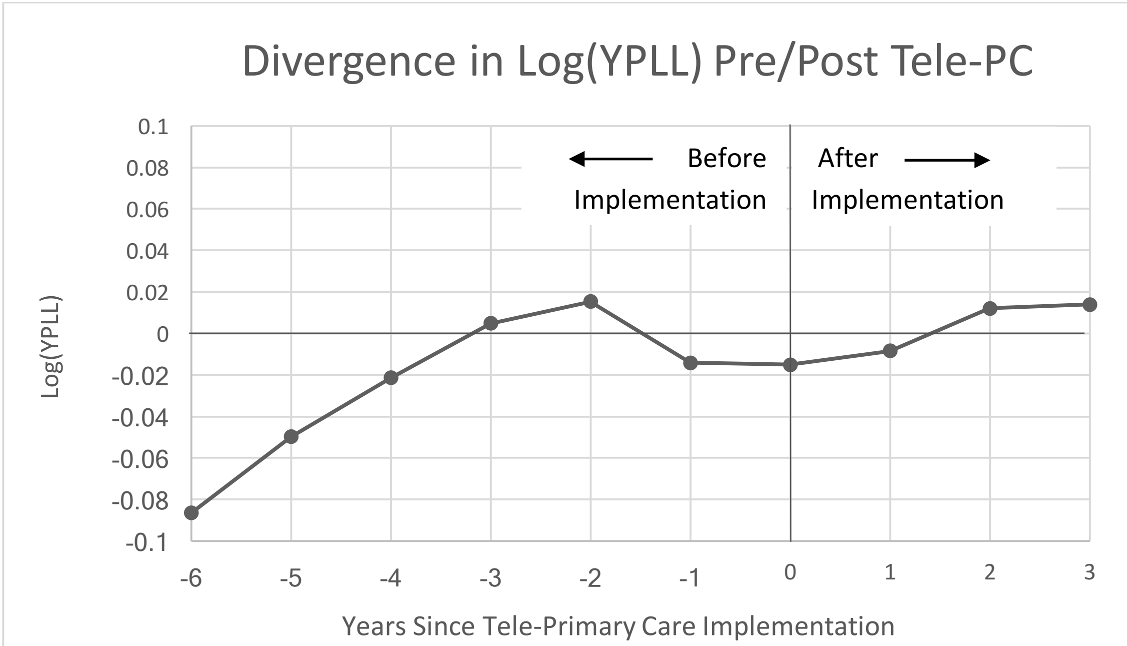

Figure 1: *Divergence in Log YPLL Before and After Adoption of Tele-Primary Care*

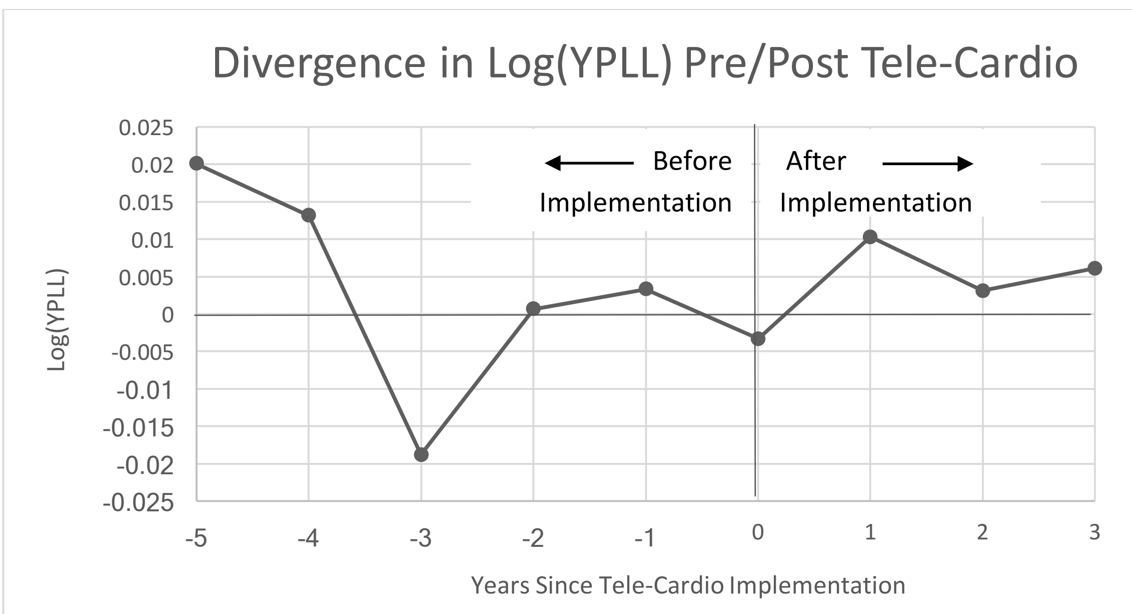

Figure 2: *Divergence in Log YPLL Before and After Adoption of Tele-Cardio*

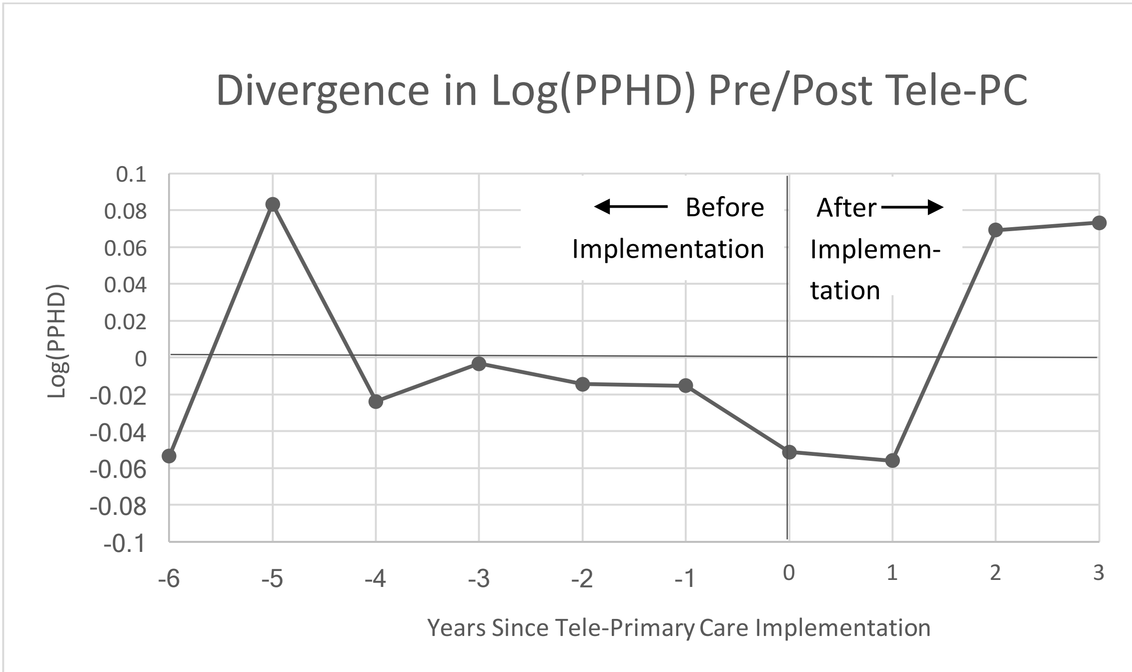

Figure 3: *Divergence in Log PPHD Before and After Adoption of Tele-Primary Care*

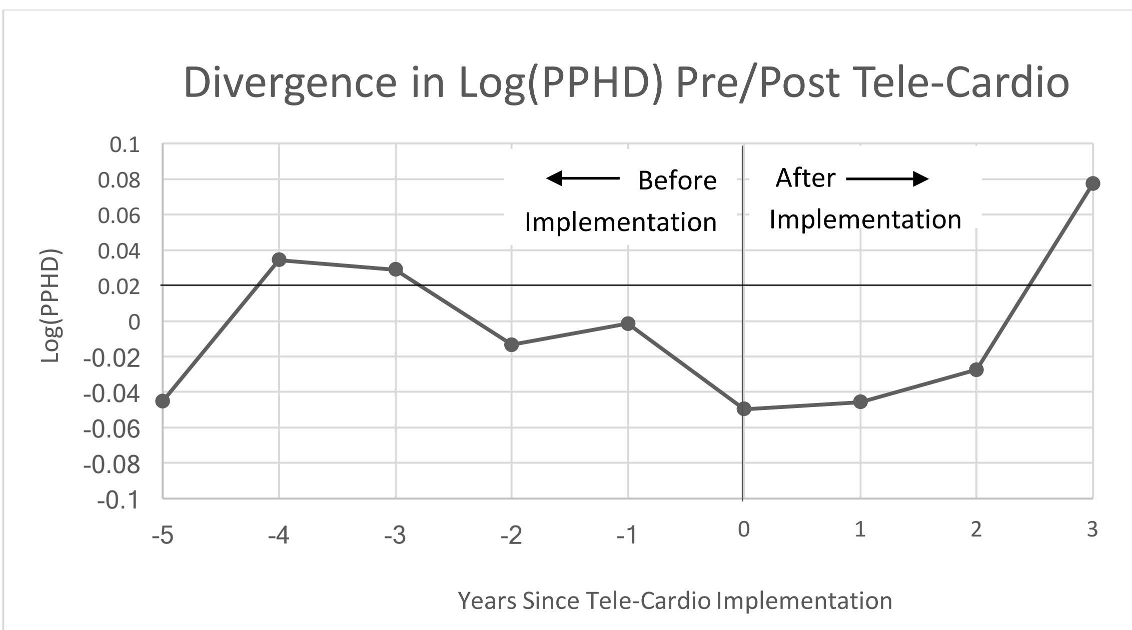

Figure 4: *Divergence in Log YPLL Before and After Adoption of Tele-Cardio*

b. Tele-Cardiology

Table 4 reports regression results with CSD as the health outcome variable. This regression is designed to investigate whether counties with tele-cardiology service lines saw a change in the number of circulatory system-related deaths. A decrease in deaths due to circulatory problems is expected to decline with the increased access to cardiology specialists that tele-cardiology provides. As in previous tables, the first two columns of Table 4 contain estimates from Ordinary Least Squares (OLS) regressions weighted by county population and the last two columns contain estimates from the unweighted versions of the same OLS regressions. These estimates, too, are negative (which indicates a positive effect of tele-cardiology) but not quite statistically significant or robust to the inclusion of a leading indicator. The graphical representation of prior trends in Figure 5 does nearly hold to the expectation that estimates prior to year zero are close to zero. However, the estimates after implementation do not show a steady decline, but rather increase, then decrease dramatically and rise again. So, while it does seem encouraging that estimates of the effect of tele-cardiology implementation are headed in the expected direction with a decrease in cardiac-related deaths, solid inferences cannot be drawn from the model.

Table 4: Impact of Tele-Adult Cardiology on Cardiac-Related Deaths

	OLS - Weighted by County Pop.		OLS - Unweighted	
	M1	M2	M1	M2
Panel A: Cardiac-Related Deaths	Log(CSD)		Log(CSD)	
Had Tele-Cardiology Program	-0.3081	0.0243	-0.1879	0.0145
	(0.2414)	(0.2982)	(0.1442)	(0.1981)
	p = 0.206	p = 0.935	p = 0.196	p = 0.942
0 to 2 Years Before Implementation of Telemedicine		0.3392**		0.2139*
		(0.1404)		(0.1161)
		p = 0.018		p = 0.069
Observations	486	486	486	486

* = significant at the 10% level, **= significant at the 5% level

Note: standard errors shown in parentheses, county and year fixed effects and control variables (Table 1) included in all regressions

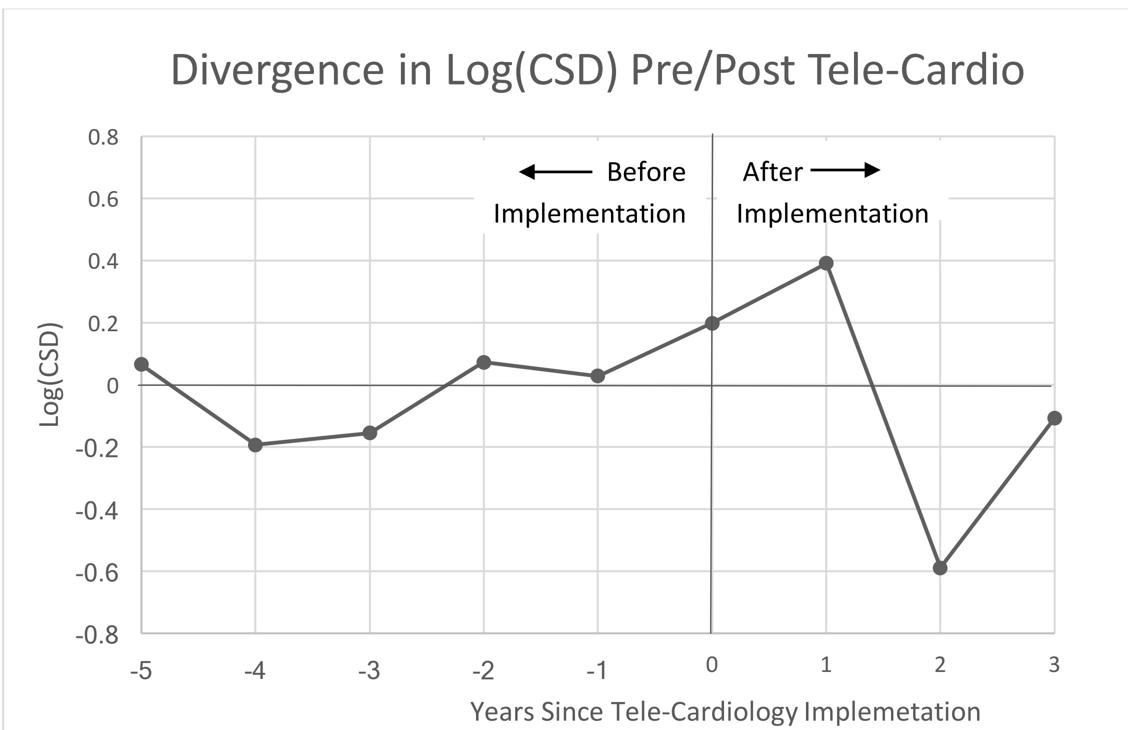

Figure 5: *Divergence in Log CSD Before and After Adoption of Tele-Cardio*

c. Tele-Primary Care

The same regression framework was used to elicit the effects of implementing a tele-primary care service line. Increased access to primary care providers should, in theory, reduce the number of preventable hospitalizations by providing essential care before a medical issue necessitates hospital-level treatment. It should also increase screenings for and consistent monitoring of chronic conditions like diabetes. Therefore, the model was used to estimate the effects of implementing a tele-primary care service line on preventable hospitalization rates (PHR) and on the percentage of diabetics enrolled in Medicare who are receiving blood sugar monitoring (PctDM). Here again, the first two columns in Table 5 contain estimates from Ordinary Least Squares (OLS) regressions weighted by county population and the last two columns contain estimates from the unweighted versions of the same OLS regressions. Neither of these estimates are significant and, in fact, both have the sign opposite that which was predicted. The leading estimates are also not close to zero prior to implementation as expected and vary rather than showing a steady trend post-implementation (Figures 6 and 7). So, no useful inferences can be drawn from these estimates either.

Table 5: Impact of Tele-Primary Care with Nurse Practitioner

	OLS - Weighted by County Pop.		OLS - Unweighted	
	M1	M2	M1	M2
Panel A: Preventable Hospitalizations	Log(PHR)		Log(PHR)	
Had Tele-Primary Care with Nurse Practitioner	0.0224	0.02417	0.0131	-0.0091
	(0.2086)	(0.0393)	(0.0286)	(0.0416)
	p = 0.286	p = 0.541	p = 0.649	p = 0.828
0 to 2 Years Before Implementation of Telemedicine		0.0027		-0.0337
		(0.0377)		(0.0347)
		p = 0.943		p =0.334
Observations	565	565	565	565
Panel B: Diabetes	Log(PctDM)		Log(PctDM)	
Had Tele-Primary Care with Nurse Practitioner	-0.0034	0.005	-0.0142	-0.011
	(0.007)	(0.0139)	(0.0086)	(0.0162)
	p = 0.630	p = 0.719	p = 0.104	p = 0.497
0 to 2 Years Before Implementation of Telemedicine		0.0128		0.0048
		(0.0131)		(0.0163)
		p = 0.334		p = 0.768
Observations	565	565	565	565

* = significant at the 10% level

Note: standard errors shown in parentheses, county and year fixed effects and control variables (Table 1) included in all regressions

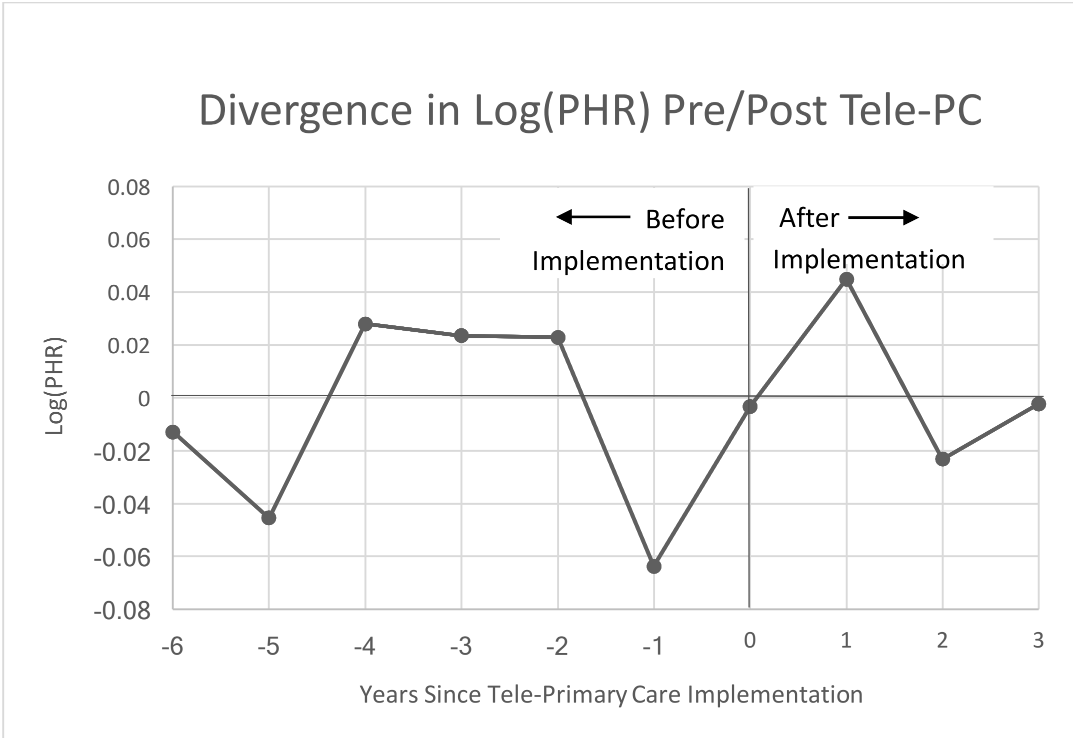

Figure 6: *Divergence in Log PHR Before and After Adoption of Tele-Primary Care*

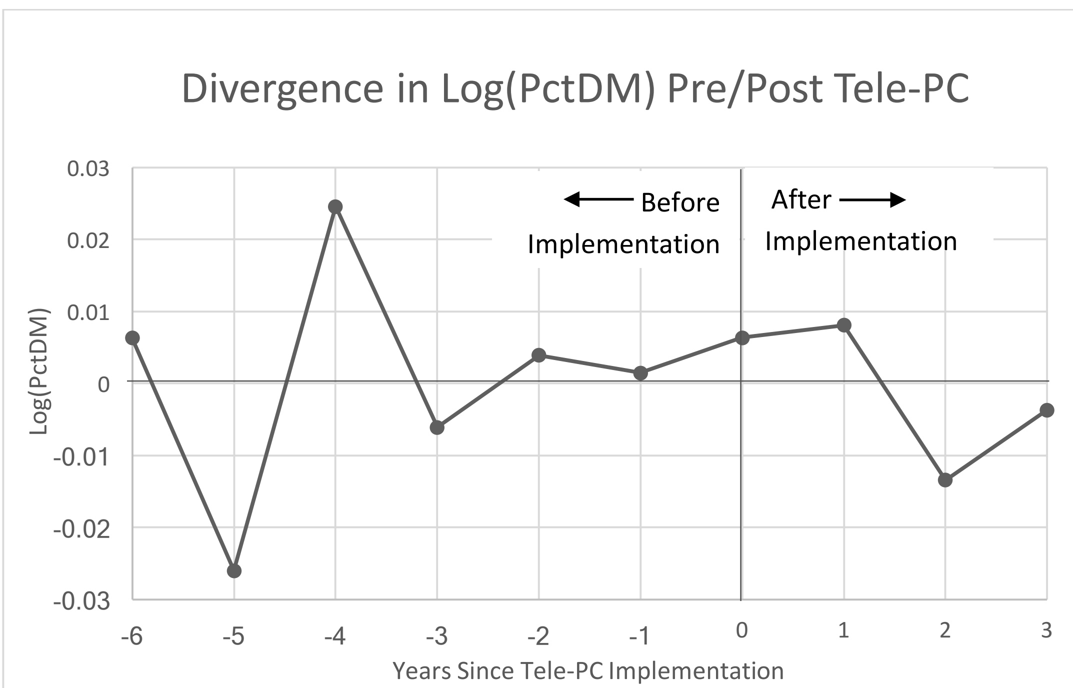

Figure 7: *Divergence in Log PctDM Before and After Adoption of Tele-Primary Care*

VII. Discussion

Though this study did not find any statistically significant results, many of the estimates at least had the predicted signs which is encouraging given that telemedicine has only recently come to be commonly used in medical practice. Some of these estimates were large with large standard errors, too, indicating that telemedicine may have a great impact, though this model is not able to accurately estimate that impact.

Because of the newness of telemedicine's widespread use, data on the number of patients using each service line, longitudinal patient outcomes, cost of provision of care, etc., are not readily available for study. As a result, it is possible that the number of individuals treated by telemedicine was not large enough for a county-level effect to be detected by this study. Ideally, a study would compare telemedicine users to others before and after the implementation of telemedicine. However, individual de-identified data was not available for analysis. Future studies may be able to elicit true causal outcomes if the data mentioned above do become available.

Additionally, measurable changes in health outcomes at the county level may not be realized immediately after implementation of a telemedicine program. At the time of this study, only 3 years of post-implementation data are available. That may be insufficient for statistical analysis if there is a time lag between implementation of a telemedicine program and changes in health outcomes. Future studies with more post-implementation data might be better suited to accurately evaluate the county-level change affected by these programs. A longer post-implementation observation period may also be useful in analyzing the extended dynamic effects of the programs. In Figures 3 and 4, for example, the estimates change sharply from negative to positive in the second or third year post-implementation, respectively, meaning the programs increased reported PPHD (the opposite of the intended effect). This may be due to an increased awareness of one's own health with the implementation of tele-primary care programs since the PPHD measure is self-reported. Further analysis of later observation periods might be able to examine if the increase in PPHD persists.

Lastly, there was evidence of probable violation of the common trend assumption that underlies the difference-in-differences methodology. Future studies should address this issue by better identifying the control (i.e., non-treatment) groups so as to obtain greater similarity between the control and treatment group trends prior to implementation.

UMMC is aware of the potential for growth in the area of data collection and analysis and intends to use some of the resources provided by the grant that accompanied their being named a National Telehealth Center of Excellence towards that end. Director of the Center for Telehealth Michael Adcock says, "While our center has been able to show some impressive outcomes, we have not had the staff to focus on researching telehealth delivery models and outcome comparisons. That is vital work that needs to be done, and we are well positioned to do it. This funding and designation will allow us to build on our comprehensive program and develop the research to support further changes in models of delivery" (UMMC, 2017).

The hope here is that telemedicine does continue to grow in the state of Mississippi and that collection and analysis of related data will add to the body of knowledge on the subject. Results of prior studies on patient outcomes from specific programs like UMMC's Diabetes Telehealth Network have shown promising results in both outcomes and cost reduction (UMMC, 2017). Perhaps as the adoption of telemedicine continues to spread and more and better data becomes available for examination, studies of similar design may be able to elicit causal links between telemedicine programs and public health outcomes at the county or even state level.

References

2017 Annual Report – Mississippi. America's Health Rankings. United Health Foundation. https://www.americashealthrankings.org/explore/2015-annualreport/measure/ Overall/state/MS. Accessed 2 Feb, 2018.

Anderson C. Online clinic shows cost savings. Healthcare IT News. http://www.healthcareitnews.com/news/online-clinic-shows-cost-savings. Published February 11, 2013. Accessed March 9, 2018.

Bashshur, R. L., Shannon, G. W., Smith, B. R., & Woodward, M. A. (2015). The Empirical Evidence for the Telemedicine Intervention in Diabetes Management. *Telemedicine and e-Health, 21*(5), 321-354. doi:10.1089/tmj.2015.0029

Beck, M. (2016, June 26). How Telemedicine Is Transforming Health Care. Retrieved from https://www.wsj.com/articles/how-telemedicine-is-transforming-health-care-1466993402

Bertrand, M., Duflo, E., and Mullainathan, S. 2004. "How Much Should We Trust Differences- in-Differences Estimates?" Quarterly Journal of Economics 119(1):249–75.

Budniak, A. "Remembering Dr. Lawrence 'Larry' Weed, Father of the First EMR." HITECH Answers: Meaningful Use, EHR, HIPAA News, 8 Aug. 2017, www.hitechanswers.net/remembering-dr-lawrence-larry-weed-father-of-the-first-emr/.

Darkins, A. W., & Cary, M. A. (2005). *Telemedicine and telehealth: principles, policies, performance, and pitfalls*. New York: Springer Publishing Company.

Definitions for Years of Potential Life Lost. Centers for Disease Control and Prevention. https://www.cdc.gov/injury/wisqars/fatal_help/definitions_ypll.html. Published September 2, 2014.

Interstate Medical Licensure Compact. http://www.imlcc.org/. Accessed March 20, 2018.

Jennett, P. A. et al., (2003). The socio-economic impact of telehealth: a systematic review. *Journal of Telemedicine and Telecare, 9*(6), 311-320. doi:10.1258/135763303771005207

Liu S.X., Xiang R., Lagor C., Liu N., Sullivan K. Economic Modeling of Heart Failure Telehealth Programs: When Do They Become Cost Saving? *International Journal of Telemedicine and Applications*. 2016;2016:1-9. doi:10.1155/2016/3289628.

Lyuboslavsky, V. (2015). *Telemedicine and telehealth 2.0: a practical guide for medical providers and patients*. United States: Victor Lyuboslavsky.

Miss. Code Ann. § 83-9-351 (2013).

Miss. Code Ann. § 83-9-353 (2014).

Mississippi Health Factors Rankings. County Health Rankings. http://www.countyhealthrankings.org/app/mississippi/2017/rankings/factors/overall.

Mississippi Physician Workforce Profile. Association of American Medical Colleges; 2017.

Rural health for Mississippi. Rural Health Information Hub. https://www.ruralhealthinfo.org/states/mississippi. Published November 9, 2017. Accessed February 2, 2018.

Saloner, B., et al. "Most Uninsured Adults Could Schedule Primary Care Appointments Before The ACA, But Average Price Was $160." *Health Affairs*, vol. 34, no. 5, Jan. 2015, pp. 773–780., doi:10.1377/hlthaff.2014.1258.

State Telehealth Laws and Reimbursement Policies Report. Center for Connected Health Policy. http://www.cchpca.org/state-telehealth-laws-and-reimbursement-policies-report. Published October 2017. Accessed February 2, 2018.

State Telemedicine Gaps Analysis. American Telemedicine Association; 2017.

Stats of the State of Mississippi. Centers for Disease Control and Prevention. https://www.cdc.gov/nchs/pressroom/states/mississippi/mississippi.htm. Published March 31, 2017.

The Office of the National Coordinator for Health Information Technology: Quick Stats. (2017, January 12). Retrieved May 10, 2017, from https://dashboard.healthit.gov/quickstats/quickstats.php

Topol, E. J. (2015). *The Patient Will See You Now: The Future of Medicine Is In Your Hands*. New York, NY: Basic Books.

University of Mississippi Medical Center. UMMC earns national Telehealth Center of Excellence designation. https://www.umc.edu/news/News_Articles/2017/October/ummc-designated-as-national-telehealth-center-of-excellence.html. October 2017.

U.S. Department of Health and Human Services. Modifications to the HIPAA Privacy, Security, Enforcement, and Breach Notification Rules Under the Health Information Technology for Economic and Clinical Health Act and the Genetic Information Nondiscrimination Act; Other Modifications to the HIPAA Rules. *Federal Register*. Vol 78.; 2013.

U.S. Department of Health and Human Services. Summary of the HIPAA Security Rule. HHS.gov. https://www.hhs.gov/hipaa/forprofessionals/security/laws-regulations/index.html. Published July 26, 2013. Accessed March 20, 2018.

U.S. Department of Veterans Affairs, Veterans Health Administration, Deputy Under Secretary for Operations and Management, Veterans Integrated Services Network 16, Houston VA Medical Center. (2005, January 01). Michael E. DeBakey VA Medical Center - Houston, Texas. Retrieved May 10, 2017, from https://www.houston.va.gov/debakey.asp

Vo, A., Shore, J., Waugh, M., Doarn, C. R., Richardson, J., Hathaway, O., . . . Thomas,

M. (2015). Meaningful Use: A National Framework for Integrated Telemedicine. *Telemedicine and e-Health, 21*(5), 355-363. doi:10.1089/tmj.2014.0142

Wachter, R. M. (2015). *The Digital Doctor: Hope, Hype, and Harm at the Dawn of Medicine's Computer Age*. New York: McGraw-Hill Education.

Wang C.J., & Huang D.J. The HIPAA Conundrum in the Era of Mobile Health and Communications. JAMA. 2013;310(11):1121–1122. doi:10.1001/jama.2013.219869.

Wolfe A. Where does a push toward telehealth leave the internetless? Clarion Ledger. October 22, 2017.