Exploring the Relationship between ICTs and Public Health at Country Level: A Health Analytics Approach

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ABSTRACT

The authors use a health analytics approach to investigate the relationship between information and communication technology (ICT) and public health at a country level. The research uses the ICT factors of accessibility, usage, quality, affordability, trade, and applications, as well as the public delivery indicators of adolescent fertility rate, child immunization for DPT, child immunization for measles, tuberculosis detection rate, life expectancy, adult female mortality rate, and adult male mortality rate. ICT data was collected from the International Telecommunication Union ICT Indicator database. The public health data was collected from the World Bank website. Results of the analytics indicate that ICT factors are positively associated with some public health indicators. Nearly all of the ICT factors are positively associated with the public health indicators of immunization rates, TB detection rates, and life expectancy. The association with adult mortality is negative, which is also favorable. However, the association of ICT with fertility rate is negative, which is an unfavorable effect. These results offer insight into the importance of understanding the positive and adverse impacts of ICT on public health so as to guide national policy decisions in the future.

Keywords: Country Level, Health Analytics, Immunization, Information and Communication Technologies (ICT), Public Health

1. INTRODUCTION

Health analytics is a collection of decision support technologies that enables physicians, nurses, health officials, health policy makers, pharmacists and other knowledge-based workers to make better and faster health decisions (Kearney, 2013). Over the past few years, the availability and adoption of these applications and services by the healthcare industry has risen tremendously (Caban & Gotz, 2012; Ghosh & Scott, 2011; Raghupathi & Tan, 2008). Enabling this enhancement to health care is the declining cost of acquiring and storing large amounts of health data from a variety of sources, including electronic patient records, public health databases, health care providers, web-based applications, RFID tags, and social media applications. The healthcare industry is collecting data at an exponential rate and with a

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high degree of granularity due in part to raised compliance and liability priorities.

As more data is created digitally, healthcare providers strive to leverage this abundance of rich data using sophisticated analytics techniques to help make better decisions and deliver new functionality, such as personalized and evidence-based medicine (Taylor, 2010). Traditional medicine focused on reactive diagnosis and treatment of existing conditions, but the current healthcare trend is proactivity: predicting outcomes and reducing errors (IBM, 2010). Analytics offers benefits to healthcare organizations in a variety of ways, including the creation of longitudinal patient records from multiple disparate systems, quality reporting, clinical decision support, and health/condition management.

In the sphere of public health, analytics can improve surveillance and response. Data from integrated patient and treatment databases helps health officials ensure the rapid detection of infectious diseases and develop a comprehensive disease or outbreak surveillance and response program. In addition, the provision of timely health advisories and information based on analytics can serve to improve public awareness of the health risks related to infections and diseases, thereby increasing good public health (Accenture, 2011).

There is a need for detection and tracking of global threats to public health, and integrating local health providers and health officials with national data systems (e.g., Centers for Disease Control and Prevention) addresses that need (Tang, 2002). Sophisticated tools that facilitate management of patient populations using vital statistics, population health risks, prompt notifications, and disease registries are necessary for promoting and protecting public health (Detmer, 2003). Such improvements can have a significant effect on the public and even the economic health of a country. Disease control, in particular, influences the economic well-being and growth of a country given its impact on life expectancy, infant/child mortality, and education (Raghupathi & Wu, 2011).

Analytics can contribute to the public health domain in several ways. By using sophisticated business intelligence tools, statistical analysis, quantitative methods and mathematical-based models (Evans, 2013) and visualization, analytics offers healthcare professionals insight to make informed health decisions on diseases and treatments. Some of the tools that support health analytics include advanced spreadsheet models, statistical software packages, and

2. PUBLIC HEALTH

Public health is the practice of preventing disease and promoting good health of small groups of people from small communities to entire countries (American Public Health Association, 2001). Overall, public health is concerned with protecting the health of populations which can be as small as a local neighborhood or as large as an entire country. At the national level, public health concerns include bioterrorism, antibiotic resistant organisms, infectious diseases, mortality, malnutrition, and poor sanitation (World Bank, 1993; World Health Organization, 2001). The potential to collect, organize, integrate and disseminate relevant information from a multitude of sources enables analytics to improve the current health status of communities. In short, efficient health analytics can alleviate challenges within the public health sector (Koo et al., 2001; Yasnoff et al., 2001).

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more complex business intelligence analytics software such as Cognos, Hyperion, Business Objects, MicroStrategy, and Teradata.

In addition, by offering effective data utilization techniques, analytics facilitates and augments health promotion measures, timely diagnosis, and proper management of diseases (Tomasi et al., 2004). It can also improve public health activities, including promoting population health, predicting conditions that pose a risk to diseases, preventing diseases by altering these causal risk factors, and focusing on the governmental context in which public health is practiced (Yasnoff et al., 2000).

3. HEALTH ANALYTICS

Health analytics is the infrastructure for warehousing, reporting and analyzing health data. It allows for integrating data from disparate health information streams into one enterprise-wide dataset and for using statistical analysis tools (SPSS, SAS, regression, correlation, etc.) and/or business intelligence/data mining tools to make better and faster healthcare decisions (Evans, 2013; IBM, 2012; SAS, 2011).

Health analytics is used extensively in healthcare (Raghupathi, 2010). SAS data mining and analytic tools can help, for instance, determine whether certain patterns of physician prescribing optimize outcomes for patients undergoing heart surgery (taking patient risk factors into account). Analytics is used to improve overall quality of patient care (SAS, 2011) by exploring clinical outcomes (IBM, 2010) and risk tolerances. It is used for tracking the long-term care and rehabilitation of special surgery patients. Analytics can help determine whether certain clinical pathways optimize patient outcomes so as to achieve best practices; it can help assess patient mental states, optimize operating room use by specialty; and analytics can help health care professionals examine outcomes relative to the use of certain drugs, medical devices and protocols.

Tools such as SAS analytics can analyze structured and unstructured (free form) data. For example, structured analysis can help evaluate reimbursement trends for a specific diagnostic code or the length of stay for a particular condition. Unstructured analysis helps detect hidden patterns in data without any pre-determined notion or hypotheses on what those patterns should be, predicting, for example, the response to change in treatment protocols for ventilator patients.

Today, predictive analytics (Evans, 2013; SAIC, 2011) is changing the healthcare model in terms of preventive and proactive care, as illustrated by three trends. Protocol-based medicine focuses on evolution of best practices based on continuous assessment of patient population. Personalized medicine focuses on the individual patient and offers treatment customization for each patient. This approach combines genotypic data, medical images, environmental data, genetic profiles, molecular and, genetic research efforts and targeted pharmaceuticals’ data, to personalize diagnosis and treatment. Evidence-based medicine focuses on how medicine is practiced, identifying the best evidence for decision making and integrating clinical expertise with research results (Taylor, 2010).

There are several front-end applications through which users perform health analytics tasks, such as spreadsheets for basic data analysis, health enterprise portals for information search, management applications for tracking the performance of patient/healthcare provider through dashboards, querying tools for responding to questions, business intelligence tools, and data mining tools (McAullay et al., 2005; Raghupathi, 2010). Other technologies, such as web analytics, enable an understanding of how visitors interact with a health website and how best to utilize this knowledge in presenting information that encourages visitors (patients) to seek medical care. For example, understanding how visitors interact with an HMO page (i.e., which pages they go to most often) offers insight into what information they seek/value the most. This knowledge can be incorporated into clarifying redesigns of the pages so as to
encourage visitors to seek medical care and, importantly, to facilitate that process.

Vertical packaged applications such as customer relationship management systems or patient relationship management (PRM) systems focus on how care is provided and how information is shared with patients and the community. These applications can have built-in analytic capabilities and functionality to segment patients on the basis of how favorably they may react to a new drug.

Mobile health analytics is another nascent but integral area that presents tremendous potential. In this domain, in some areas, the mobile technologies are mature but challenging research problems still remain, such as data storage, OLAP servers, RDBMs and ETL tools. In other areas, the technology is relatively new with open research challenges such as Map Reduce engines, near real time health analytics, health analytics search, data mining (McAulley, 2005; Raghupathi, 2010), text analytics, and cloud data services.

While electronic medical records (EMR) and electronic health records (EHR) and other current technologies hold great promise for improving the efficiency and quality of patient care, their usefulness is limited. EMR, EHR, and the like do not address which treatment regimens yield the best outcomes for patients with certain genetic profiles, or what drug interactions are likely in a patient with certain risk factors, or how a combination of therapies helps patients undergoing a certain procedure, or what protocol produces the best results for a target population, and so on (SAS, 2011). Analytics help healthcare professionals effectively address exactly these sorts of questions. The challenge for the healthcare provider is not in the availability of data but in the gathering, cleansing and analyzing of diverse streams of data without a degree in computer science. Clinical managers, public health officials, pharmaceuticals, and the general public have varying requirements of the available data. Clinical managers need confidence that research reports present complete and accurate research so as to be assured of the implications when they modify treatment plans based on these reports. Clinical investigators and research administrators need to track outcomes with more reliability and thoroughness than general clinical practice while satisfying institutional review boards’ requirements and the NHII framework. Public health officials and pharmaceutical companies need to know how clinical research results relate to large populations. The public needs to know that the decisions on medical care are based on the best possible evidence.

The information lies in the labyrinth of data found in disparate systems and databases. The challenge of health analytics is in integrating and utilizing these sources. Data that may, for instance, be formatted for routine billing must be formatted for analysis. Some data is episodic and patient-focused, while some is cumulative and population-focused. Additional elements of the mix are the various coding and representation strategies that must be applied to the range of data components, such as Med DRA (Medical Dictionary for Regulatory Activities) for recording and classifying adverse events and ICD-9CM for coding diagnoses for reimbursement. Analytics can reconcile and cleanse these apparently incompatible data elements for study.

The current suite of operations in healthcare organizations either does not offer effective solutions or offers them at high costs and with questionable accuracy. Missing is a holistic approach and the capabilities to combine EMR with a variety of data types (operational research, financial, etc.) and then analyze the data to reveal hidden patterns and trends. Health analytics fills this gap.

4. CONCEPTUAL MODEL OF HEALTH ANALYTICS

In this section we develop a conceptual model of general health analytics by incorporating the typical components in the healthcare domain (Figure 1). The model is based on generic business intelligence and data warehousing framework in the literature (for example, see Chaudhury et al., 2011; Watson, 2009). Our
model is generic enough to be applied in any healthcare context in which analytics can be utilized.

The health data over which analytics tasks are performed often come from diverse health sources, such as multiple clinical laboratories, radiologists, insurances & HMOs, patient databases, and public health systems (e.g. CDC, HHS, WHO) (Laudon & Laudon, 2011). Also, the quality of the data and the way it’s represented and coded varies significantly—all of which have to be reconciled. The assorted data must be integrated, cleansed and standardized to be ready for analytics because efficient data loading is imperative. Adding to the complexity of health analytics tasks is that they typically are executed incrementally, as new data arrives (e.g., patients are discharged, cases are closed).

The group of back-end technologies for preparing the data for analytics is called Extract-Transfer-Load (ETL) tools. ETL tools help discover and correct data quality issues and efficiently load large volumes of data into the data warehouse. ETL tools perform the functions of integrating, cleansing and standardization on raw data to readying it for analytics. Once data is prepared for analytics, it is loaded into a repository called a data warehouse, which is managed by one of more warehouse servers. One such server is the relational database management system (RDBMS), which stores and executes complex queries on warehouse data using query structures, optimizations, and query processing techniques. Large data warehouses sometimes have parallel RDBMS engines so that SQL queries can be executed over large volumes at high speeds. These data warehouses have multidimensional data and online analytical processing (OLAP) servers that enable analytic operations such as filtering, aggregation, drill down and pivoting. Reporting servers enable defining, executing and rendering of efficient reports to healthcare professionals. Some of the health data is collected in an unstructured format (free form). For analyzing unstructured data, health enterprise search engines support text-based keyword search paradigms. For example, keyword searches can be applied to email or other web messages, lab results, medication lists, phone calls for a particular patient, and other similarly unstructured data. In addition to the analyzing and reporting servers mentioned above, data mining engines enable in-depth analyses of health data that is more extensive than that offered by OLAP or the reporting servers. Multidimensional data in the data warehouse are supported by Multidimensional OLAP (MOLAP) servers, which design and publish data cubes that allow for faster and more sophisticated processing. As noted, healthcare stakeholders use the outputs from the analytics implementation for decision-making.
5. RESEARCH METHODOLOGY

In this section, we apply the conceptual model shown in Figure 1 to the examination of the relationship between ICTs and public health delivery at a country level (Table 1).

5.1. Health Data Sources

We extracted the data for ICT variables from the World Communication /ICT Indicator database (http://www.itu.int/publ/D-IND-WTID.OL-2012/en for the years 2001 to 2010 because the data for those years is complete. The World

Table 1. Research methodology

<table>
<thead>
<tr>
<th>Health Data Sources:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT Variables: World Communications/ICT Database</td>
<td>PHI Variables: World Bank website</td>
</tr>
<tr>
<td>Variable Selection:</td>
<td></td>
</tr>
<tr>
<td>Independent variables: ICT variables (19 variables - 6 factors)</td>
<td>Dependent variables: PHI variable (7 variables)</td>
</tr>
<tr>
<td>Control variables: Income, Region</td>
<td></td>
</tr>
</tbody>
</table>

| ETL |  |
| Extract: Data extracted from World Communication/ICT database/World Bank website, in csv format; | Transform: Data transformed and prepared for loading, with Framework Manager; |
| Load: Prepared data loaded into IBM’s DB2 database and IBM’s Cognos-8 |  |

| Analytics Platform/Tools Selection |  |
| DBMS: IBM DB2 | Analytics: IBM Cognos |
| Analysis: Cognos Analysis and Report Studio |  |

| Analytics Implementation |  |
| Analysis and reports implementation using Cognos |  |

Table 2. Measurement items for ICT variables

<table>
<thead>
<tr>
<th>ICT Factors</th>
<th>Measurement Variables</th>
</tr>
</thead>
</table>
| Accessibility | 1. Fixed-telephone subscriptions (per 100 people)  
2. Mobile cellular subscriptions (per 100 people)  
3. Fixed (wired) internet subscriptions (per 100 people)  
4. Percentage of individuals using a computer (%)  
5. Percentage of households with TV (%) |  |
| Usage | 6. Total international incoming telephone traffic, in minutes  
7. Total international outgoing telephone traffic, in minutes  
8. Internet users(per 100 people) |  |
| Quality | 9. Percentage of the population covered by a mobile-cellular network  
10. Fixed(wired)-broadband subscriptions.  
11. International internet bandwidth(bit/s) per internet user |  |
| Affordability | 12. Monthly subscription for residential telephone service, in USD  
13. Mobile cellular prepaid-price of local call per minute (peak, on-net) in USD  
14. Fixed (Wired) broadband monthly subscription charge, in USD |  |
| Trade | 15. ICT goods exports (% of total goods exports)  
16. ICT goods imports (% of total goods imports)  
17. ICT service exports (% of total service exports) |  |
| Applications | 18. Annual investment telecommunication service, in USD  
19. Secure Internet servers (per 1 million people) |  |

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Telecommunication/ICT Indicators Database contains time series data for the years 1960, 1965, 1970, and annual data from 1975 to 2011 for approximately 140 telecommunication/ICT statistics. The 19 measurement variable items are shown in Table 2. Based on this database, the ICT variables were categorized into six factors: accessibility, usage, quality, affordability, trade, and applications (Table 2).

The data for public health delivery indicators (PHI) was downloaded from the World Bank website (http://data.worldbank.org/). A total of 214 countries were selected based on the country list from the PHI dataset. The country income data was obtained from the World Development Indicators (WDI) database, and the classifications (low, lower middle, upper middle, high) were obtained from the World Bank (http://go.worldbank.org/CWTURY-IPS0). The seven PHIs that were analyzed in this research include adolescent fertility rate, child immunization for DPT, child immunization for measles, tuberculosis detection rate, life expectancy, adult female mortality rate, and adult male mortality rate (Table 3).

The dataset of ICT factors and PHIs were merged based on the unique identification information of country name (or code). The control variable was country classification according to income: low income, lower middle income, upper middle income, and high income. In high income, countries were categorized on the basis of whether they were members of the Organization for Economic Cooperation and Development (OECD). The OECD promotes the economic and social well being of people around the world. An additional control variable was region: Europe, Australia and Oceania, Sub-Saharan Africa, Central America and the Caribbean, South America, Asia, North Africa and Greater Arabia, and Middle East.

Using analytics, we identified relationships between the ICT variables and the PHI variables and between income per capital and PHI variables (Raghupathi & Wu, 2011). Specifically, analytics was used to describe the following relationships:

- Accessibility of ICT and public health delivery indicators
- Usage of ICT and public health delivery indicators
- Quality of ICT and public health delivery indicators
- Affordability of ICT and public health delivery indicators

### Table 3. Measurement items for PHI variables

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Measurement variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adolescent fertility rate</td>
<td>The number of births per 1,000 women ages 15-19</td>
</tr>
<tr>
<td>Child immunization DPT</td>
<td>The percentage of children ages 12-23 months who received vaccination against diphtheria, pertussis, and tetanus (DPT).</td>
</tr>
<tr>
<td>Child immunization Measles</td>
<td>The percentage of children ages 12-23 months who received vaccination against measles.</td>
</tr>
<tr>
<td>Tuberculosis case detection rate</td>
<td>The ratio of newly notified tuberculosis cases (including relapses) to estimated incident cases (case detection, all forms).</td>
</tr>
<tr>
<td>Life expectancy</td>
<td>The number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.</td>
</tr>
<tr>
<td>Adult female mortality rate</td>
<td>The probability of dying between the ages of 15 and 60 (per 1000 female adults) – that is, the probability of 15-year-old dying before reaching age 60, if subject to current age-specific mortality rates between those ages.</td>
</tr>
<tr>
<td>Adult male mortality rate</td>
<td>The probability of dying between the ages of 15 and 60 (per 1000 male adults) – that is, the probability of 15-year-old dying before reaching age 60, if subject to current age-specific mortality rates between those ages.</td>
</tr>
</tbody>
</table>
• Trade of ICT and public health delivery indicators
• Applications of ICT and public health delivery indicators

In addition, analytics was also used to describe the relationship between income and the public health delivery indicators.

5.2. Extract-Transform-Load (ETL)

There are two ways in which the raw data from the public databases can be prepared and migrated into Cognos for analytics implementation. The first method is to extract the raw data from the public databases as .csv files and upload it into Cognos Transformer for transformation into cubes. A cube is an aggregation of different subsets of data across various dimensions and measures. We then load the published cube into Cognos for analytics implementation. Another way is to extract the raw data into traditional DB2 databases, connect to Cognos Framework Manager to transform the data into cubes, publish the package, and then load the published package into Cognos for analytics implementation. Figure 2 shows both methods.

For our research, we used the second method. The data was extracted from the ICT database and the World Bank website as raw data and downloaded into Framework Manager, which transformed the raw data by building cubes and publishing a package. The package cube was then loaded into Cognos for analytics implementation.

5.3. Analytics Platform and Tools Selection

Once the data was ready for analytics, we selected Cognos Studio as the platform and tool for analytics implementation. Cognos Studio has the report and query studios that allow for versatile querying and reporting of data. The Cognos Studios platform is very effective in time series analysis of ICT and PHI data. In order to generate effective query reports for analysis, some calculation functions were performed on the data and some titles of variables were modified for accuracy and clarity.

5.4. Analytics Implementation

Using Cognos Studio, analytic tasks were implemented through the query and report tools. Cognos offers the functionality to display the results of the analytics in a dual format of chart and table. We illustrate this feature of dual display (chart and table) in the results in Figures 3 and 4. In public health, tables are routinely used for monitoring health compliance, regulation, performance, and outcomes. We display the remainder of the results using the only the chart format. The results of our analysis help us gain insight into the trends and relationships between individual ICT factors and public health delivery indicators so as to make more accurate evaluations of public health.

6. RESULTS AND DISCUSSION

Table 4 shows a summary of the associations between the ICT factors and public health de-
livery indicators using the built-in algorithmic calculations and visualization techniques of analytics. The positive, negative and lack of associations between the two sets of variables are indicated.

We now discuss in detail the results of the analyses for each set of variables.

### 6.1. Accessibility and Public Health Delivery Indicators

The associations for the ICT factor of accessibility with the public health delivery indicators are shown in Figures 3 and 4.

In the analysis for the association between accessibility and public health delivery indicators (Figures 3 and 4), the output shows that overall accessibility to ICT is associated with...
a decrease over time in adult male and female mortality rates and adolescent fertility rate. Accessibility, however, is associated with an increase in life expectancy, child immunization of measles and DPT, and Tuberculosis case detection rate. Excepting the decrease in fertility rates, these are positive results for public health. The analysis also shows that from 2001 to 2010, overall accessibility of ICTs increased. All of the public health indicators have increased

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Table 4. Associations between ICT factors and public health delivery indicators

<table>
<thead>
<tr>
<th>ICT factors</th>
<th>Adolescent fertility rate</th>
<th>Child immunization</th>
<th>Tuberculosis detection</th>
<th>Life expectancy Female</th>
<th>Adult Mortality Rate</th>
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<td>Accessibility</td>
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<tr>
<td>High Income Non-OECD Countries</td>
<td>-</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>O</td>
</tr>
</tbody>
</table>

+ ICTs is associated with an increase in Public Health Delivery Indicators
- ICTs is associated with a decrease in Public Health Delivery Indicators
O ICTs has no/very limited association with Public Health Delivery Indicators
or decreased individually. From 2007 to 2008, the percentage of individuals using a computer increased from 10.794% to 14.112%. At the same time, adult mortality rates of males and females have decreased significantly from 202 to 197 (per 1000) for males and from 145 to 142 (per 1000) females. We also noted that mobile phone usage leads to a minor decrease in landline subscriptions.

6.2. Usage and Public Health Delivery Indicators

The result of the analysis for usage and public health delivery indicators is shown in Figure 5.

The output reveals that, similar to accessibility, usage of ICTs is also associated with a decrease over time in adult male and female mortality rates and adolescent fertility rate and an increase in life expectancy, immunization for measles and DPT, and tuberculosis case detection rate. Between the years 2001 to 2010, the percentage of internet users increased by 235% while the extent of telephone traffic (incoming and outgoing) increased by about 40 times.

6.3. Quality and Public Health Delivery Indicators

Figure 6 shows the association between quality as a factor of ICT and public health delivery indicators.

The analysis for quality of ICT shows that it is associated with a decrease in the adult male and female mortality rates and adolescent fertility rate over time. Meanwhile, it is associated with an increase in life expectancy, immunization for measles and for DPT, and tuberculosis...
case detection rate. Between the years 2000 to 2010, the percentage of population covered by a mobile network increased by 11%.

6.4. Affordability and Public Health Delivery Indicators

The output for the association between affordability and public health delivery indicators is shown in Figure 7.

Affordability is defined as the ability to purchase a monthly subscription, prepaid cellular phone and a monthly broadband subscription. The results show that monthly subscriptions for residential telephones are associated with a decrease over time in the adult male and female mortality rates and adolescent fertility rate. The results also show a positive association with life expectancy, immunization for measles and DPT, and tuberculosis case detection rate, which is consistent with the results of the other ICT factors. However, mobile cellular prepaid (as a variable for affordability) showed no association with public health indicators.

6.5. Trade and Public Health Delivery Indicators

The results of the association between trade (export/import) of ICT goods and services and public health delivery indicators is displayed in Figure 8.

Figure 8 shows that export of ICT services is associated with a decrease in the adult male and female mortality rates and the adolescent fertility rate, over time, and an increase in life expectancy, immunization for measles and DPT, and tuberculosis case detection rate. However, the export and import of ICT goods show very limited association with public health indica-

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*Figure 6. Quality and public health delivery indicators*
Figure 7. Affordability and public health delivery indicators

Figure 8. Trade and public health delivery indicators
tors. This implies that public health is impacted more by ICT services than by ICT goods. ICT services include computer and communications services (telecommunications) and information services (computer data and news-related service transactions). ICT goods include computer and peripheral equipment, telephone apparatus, radio and television broadcasting equipment, audio and video equipment, and so on. In public health, the dissemination of health-related preventive and diagnostic information can by itself lead to increased care in terms of immunizations and treatments. Therefore it is logical for ICT services to be associated with public health delivery indicators.

6.6. Applications and Public Health Delivery Indicators

The association between ICT applications and public health delivery indicators is shown in Figure 9.

Applications of ICT include secure internet servers and annual investment in telecommunications service. The output in Figure 9 shows that secure internet servers of ICTs is associated with a decrease in the adult male and female mortality rates, and adolescent fertility rate, over time. On the other hand, it is associated with an increase in life expectancy, immunization for measles and for DPT, and with the tuberculosis case detection rate. But the annual investment in telecommunication has limited association with public health indicators.

Figure 9. Applications and public health delivery indicators
6.7. Income and Public Health Delivery Indicators

In addition to the ICT factors, we also analyzed the association between the different income levels of countries and public health delivery indicators. The income levels were categorized as low, middle, lower middle, upper middle, and high. In addition, a dichotomy of high-income countries was established, separating those belonging to the Organization for Economic Cooperation and Development (OECD) and those that did not. Below are the excerpts for the analyses for different categories of income.

6.7.1. Low Income

Figure 10 shows the association between per capita income of low-income countries and public health indicators.

The per capita income of low-income countries is associated with a decrease in the adult male and female mortality rates and adolescent fertility rate, but with an increase in life expectancy, immunization for measles and for DPT, and the tuberculosis case detection rate.

6.7.2. Lower Middle Income

Figure 11 shows the association between per capita income of lower-middle-income countries and public health indicators.

Figure 11 shows that, similar to the low-income countries, the income per capita of
lower-middle-income countries is associated with a decrease in the adult male and female mortality rates and adolescent fertility rate, but with an increase in life expectancy, immunization for measles and DPT and the tuberculosis case detection rate.

6.7.3. Upper Middle Income

The association between per capita income of upper-middle-income countries and public health delivery indicators is shown in Figure 12. The results in Figure 12 indicate that the per capita income of upper-middle-income countries is associated with a decrease in the adult mortality rates of males and females and the adolescent fertility rate, but with an increase in life expectancy, immunization of measles and DPT, and the tuberculosis case detection rate.

6.7.4. High-Income OECD Countries

The association between high-income countries that are members of OECD and public health delivery indicators is shown in Figure 13. The analysis (Figure 13) shows that per capita income of high-income OECD countries is associated with a decrease in the adult male and female mortality rates and the adolescent fertility rate over time, but an increase in life expectancy, immunization for measles and for DPT, and the tuberculosis case detection rate.

6.7.5. High-Income Non-OECD Countries

The association between high-income countries that are not members of OEC, and public health delivery indicators is shown in Figure 14. The results indicate that the per capita income of high-income countries that are not
Figure 12. Upper middle income and public health delivery indicators

Figure 13. High income OECD countries and public health delivery indicators
members of the OECD is associated with a decrease in the adult male and female mortality rates and the adolescent fertility rate over time and with an increase in tuberculosis case detection rate. Surprisingly, there is no or very limited association with life expectancy, immunization for measles and for DPT. This runs contrary to the expectation that high-income countries would have more resources allocated to healthcare, which may result in an increase in the immunization rates for diseases. A possible explanation is that since these are non-OECD countries, the focus is not on public and social issues, and therefore the impact is not significant.

7. SCOPE AND LIMITATIONS

There are some limitations to our study. First, although our study looks at the data from 2001 until 2010, a reasonable time span, future researchers can cover a greater span and conduct a detailed longitudinal study that may throw light on more trends and patterns. Second, we do not investigate the causality in the relationship between ICT factors and public health. We only analyze the association between the ICT factors and public health delivery indicators. Future longitudinal studies can be undertaken to test the potential for causal relationships between sets of variables. Third, we considered only a segment of ICT variables and of PHI variables. There may be other intervening variables at the country level that offer additional insight or whose discovery may change the perspectives. Also, the data we extracted from the World Bank dataset is secondary in nature. The ICT and public health indicators are aggregated from multiple models and sources. Moreover, due to the fact that many of the country characteristics are interrelated (as also in ICT and public health delivery), it is likely our analyses are affected by correlated variables that have been omitted.

We used a health analytics approach on the relationship between ICTs and public health delivery. Future research on the relationship between ICT and public health delivery may profit by incorporating more complete theories and databases. Our conceptual model is an

Figure 14. High income non-OECD and public health delivery indicators
exploratory one, offering initial insight into the application of analytics in healthcare arena. Future research will no doubt enhance the model by adding more modules and components that are based on sound theoretical foundations.

8. CONTRIBUTIONS AND POLICY IMPLICATIONS

In spite of its limitations, our study makes several important contributions to the literature in the two primary areas of ICT & public health and public policy, at a national level.

Our research is an inter-disciplinary study in the areas of information technology use and public health, and contributes to the literature of both domains. Most prior studies on ICT and health care literature are conceptual (Connell & Young, 2007; Raghupathi and Tan, 2002; 2008) or are case studies of specific countries (Braa et al., 2004; Braa et al., 2007; Madon et al., 2007; Sahay & Walsham, 2006; Tomasi et al., 2004) or across selective countries (Protti, 2007; Tomasi et al., 2004). Conceptual and case studies, while insightful, are limited in their generalizability to the national level, a major limitation. In addition, they cannot offer a holistic view of how ICTs positively impact the delivery of overall public health.

The level of analysis of most studies in ICT and public health is either at the individual (patient) or the organizational (healthcare institution) level. Our country-level study of the relationship between ICT factors and public health indicators begins to address the role of ICTs at a national and global level, where it is needed (Melville et al., 2004).

We also make an important contribution in terms of the methodology of health analytics that we use in the study. It is an emerging technique that holds immense potential in the field of healthcare. Our study adds to the literature of empirical ones that deploy an analytic approach. Currently, there is a dearth of research in ICT and public health that deploys health analytic techniques.

We show how, in addition to ICT factors, a country’s income level plays a role in delivering public health through its impact on economic growth and investment. Countries with high income can afford to invest more in healthcare ICT so as to control and prevent diseases and their outcomes. High incidence of diseases such as malaria and HIV/AIDS adversely impact economic growth rates (World Bank, 1993; World Health Organization, 2001). Our findings can help global policy makers strategize on health resource allocation and investments so as to achieve maximum benefit for the population. It can also be used as guidance for receiving financial aid from other countries or organizations for improving the status of healthcare.

Our results contribute to policy making, especially in developing countries in the fields of healthcare and technology. Also, the findings are generalizable enough to be applied at a country level where there are large investments to be made in public health.

In terms of future research, many possibilities exist. The emerging concept of big data can be incorporated into health analytics to search through large volumes of rich data. In addition, future macro-level studies can combine some social indicators of healthcare along with the economic ones so as to offer a deeper understanding of the field. Our finding of the adverse impact of ICT on the adolescent fertility rate can inform future studies that explore the dark side of technology in public health terms. Calibrating investments in technology by studying its pros and cons vis-à-vis public health may well become an important indicator—made discoverable through health analytics tools—in the not-so-distant future.

REFERENCES


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