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The Impact of Supply Chain Logistics Performance Index on the Control of Neglected Tropical Diseases in Low- and Middle-Income Countries

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Abstract

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Dissertation Submitted in Partial Fulfillment

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Abstract

Neglected tropical diseases (NTD) in low- and middle-income countries are still not on target per the World Health Organization's (WHO) elimination goal of 2020. Mass drug administration (MDA) is one of the effective strategies supported by the WHO for the control and subsequent elimination of NTD. This quantitative study explored how supply chain logistic capacity may be hampering MDA coverage in countries in which the diseases are endemic. The study examined secondary data from WHO data bank for MDA coverage, to quantify the relationship between supply chain logistics capacity, as measured by the World Bank's logistics performance index (LPIs), and the control of NTD using MDA. The ecological theory of health behavior was the theoretical framework for this study. The research questions explored whether a low- and/or middle-income country's supply chain infrastructure, logistics services, customs and border procedures, and supply chain reliability, predict the coverage of MDA in controlling NTD. A multiple regression model determined the linear relations between each predictor: supply chain infrastructure (H_1), logistics services (H_2), custom and border procedures (H_3), and supply chain reliability (H_4) and the control of neglected diseases as determine by MDA. Results indicated that supply chain capacity, custom and border processes, and supply chain reliability are statistically significant in predictors of MDA coverage in the control of NTD in developing countries. This study may enhance social change by improving supply chain capacity for more effective distribution of PCT drugs, thus helping with the elimination of NTDs and improved health outcomes in low- and middle-income countries.

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Dedication

This work is dedicated to my family. My wife – Ayisha Issah-Umaru and my kids – Kalafakana, Abdul-Hakim, Majidatu, Abdul-Kabeer and Abdul-Razak, for their sacrifices and support during my study at Walden University. And to all those who are affected with NTD in resource-limited underserved communities worldwide.

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Chapter 1: Introduction to the Study

Introduction

Neglected tropical diseases (NTD) are a group of 17 parasitic, zoonotic, and helminthic diseases that affect “the bottom billion” people in mostly poor, developing countries (Hotez et al., 2009),. NTDs affect more than 1 billion people in low- and middle-income countries, accounting for an annual mortality of over 534,000 deaths (Hotez, Fenwick, Savioli, & Molyneux, 2009). Tropical disease control remains a challenge due to the limited capacity of low- and middle-income countries to implement the effective strategy of preventive chemotherapy and transmission control, PCT, (Zhang, MacArthur, Mubila, & Baker, 2010). In recent years however, due to the devastating effect of these diseases in endemic communities, international public health support, through the World Health Organization (WHO), is being received. The WHO is leading a consortium of international organizations, philanthropists, and private pharmaceutical companies that form private-public partnerships (PPP) to support research in the control and subsequent elimination of NTDs in developing countries (Addiss, 2010). Through this partnership, the Global Program for the Elimination of Neglected Tropical Diseases (GPENTD) initiative was created in 2000 with the aim of stopping the devastating effect of NTD through preventive chemotherapy by MDA (WHO, 2013).

Research in the control of NTDs shows that PCT, through mass drug administration (MDA), is effective in controlling vector transmission and potentially eliminating tropical diseases in endemic communities (Keenan et al., 2013). MDA, is the distribution and direct administration of PCT drugs to the affected communities, irrespective of disease condition, resulting in reduction in blood parasitic population that causes disability and mortality (Keenan et al., 2013). Therefore, annual MDA coverage is the indicator of successful control of tropical diseases in endemic communities (Smits, 2009). For this reason, exploring factors that may mitigate annual coverage of MDA in endemic communities may contribute to positive social change of reducing disabilities and improving population health in endemic communities.

Kentel et al., (2013) outlined factors responsible for low intake of MDA in endemic communities (Krentel, Fischer, & Weil, 2013), but failed to consider supply chain capacity as a possible predictor of NTD control (Lega, Marsilio, & Villa, 2012). Even though research has shown a positive correlation between supply chain and improved services in business and financial organizations (K. W. Green, Whitten, & Inman, 2008), and in manufacturing and food sectors (Infante & Santos, 2007), its relations to public health disease prevention received little attention (Lee, Lee, & Schniederjans, 2011; Lega et al., 2012). For instance, Lee et al., (2011) demonstrated that supply chain capacity diminishes hospitals' performance and quality of care (Lee et al., 2011). Others have shown that stronger supply chains enhance vaccine distribution (Lega et al., 2012), rapid response to emergency outbreaks, as well as humanitarian logistics (Mbohwa, 2010). Nonetheless, research is insufficient on the effect of supply chain structures in the control of tropical diseases with mass administration of PCT drugs in endemic communities (Lee et al., 2011).

This study was an attempt to fill the existing literature gap in disease prevention research, by exploring supply-chain capacity as predictors of NTD control, using mass administration of PCT drugs, in low- and middle-income countries. Because the elimination of NTDs depends on MDA coverage (Keenan et al., 2013), factors impacting successful MDA coverage may have rippling effects on eradication. Consequently, ecological structures that mitigate the effective distribution of chemotherapeutic drugs to affected communities needs to be strengthened (Baker et al., 2013). Because supply chain logistics is a set of activities linked to downstream distribution of products and to the upstream flow of information from manufacturers to end users (Lee et al., 2011), there is a potential association between supply chain capacity and NTD elimination. Therefore, exploring this association may help public health practitioners, policymakers, researchers, and developing country program managers craft appropriate strategies toward NTD elimination.

This study is expected to contribute to social change through interventions related the supply chain, which, when implemented, would strengthen ecological predictors impacting elimination of NTD in LMIC. Additionally, this study is expected to broaden scientific knowledge in disease prevention beyond the traditional scope of epidemiology, to fill the gap in crafting effective measures toward NTD elimination.

Background

Research in the application of supply chain to disease prevention has received limited attention by public health practitioners (Elmuti, Khoury, Omran, & Abou-Zaid, 2013; Lee et al., 2011). Reasons for insufficient attention are as follows: it consists of multidisciplinary subject matter (de Vries, & Huijsman, 2011), fragmented theories (Chen & Paulraj, 2004), limited data availability, and inadequate supply chain education among public health practitioners (Elmuti et al., 2013). In recent years however, supply chain research has received attention in the healthcare sector with respect to information technology, supply chain innovation, agile management processes and performance matrices (de Vries et al., 2011). Nonetheless, fragmented theoretical frameworks in supply-chain research make direct transfer of knowledge from business and economics to epidemiology, a complex undertaking (de Vries et al., 2011).

In a systematic literature review of 638 published supply chain articles, more than 181 theories were used to develop hypotheses, research questions, and models (Defee et al., 2010). Thus, the theoretical diversities in supply chain research, which are mostly outside traditional epidemiology, put a unique perspective on the application of supply chain principles to disease prevention. Furthermore, fragmented theories created upstream and downstream constraints in measuring the effectiveness of supply chain interventions to disease prevention (Chen & Paulraj, 2004). Therefore, innovative research methods are needed to define measurable constructs that relate supply chain to disease prevention, particularly for the elimination of tropical disease in low- and middle-income countries.

Building on the existing constructs of supply chain performance in business and economics, this research explored how supply chain capacities can predict NTD control in low- and middle-income countries. To assess worldwide supply chain capacities, the World Bank developed the logistics performance index (LPI), which is a series of indicators that measure national structures that impact the ease of products movements and logistics reliability in a country (Arvis, Mustra, Ojala, Shepherd, & Saslavsky, 2007).

Since 2007, the World Bank has collected LPI for more than 160 countries across the globe, including LMIC, to assess logistics capacities in the distribution of essential products to end-users (Martí, Puertas, & García, 2014).

Low- and middle-income countries account for 85% of the global burden of NTD responsible for 22 million disability-adjusted life years (DALY) annually (Hotez & Kamath, 2009). Control of NTDs in LMIC-endemic countries is measured by the successful implementation of PCT using MDA (Keenan et al., 2013). Repeated MDAs in endemic communities has been shown to substantially reduce blood microfilariae (24.5 to 2.7%), felarial antigen (53.3 to 19.6%), and antibodies to filarial antigen (78.9 to 27.5%) in the control of lymphatic filariasis in Tanzania (Simonsen et al., 2013). As a result, repeated administration of preventive chemotherapy significantly reduces infectious agents leading to the control and elimination of tropical diseases in some countries. Nonetheless, LMIC continue to record low MDA coverage as a result of inadequate ecological structures to successfully implement PCT interventions (Krentel et al., 2013).

This study explored the ecological relationship between supply-chain capacity and control of tropical diseases by MDA in developing countries. The study also reviewed gaps in the current literature on best approaches to eliminate NTD by examining supply chain logistics management in low- and middle-income countries (Spiegel et al., 2010).

Literature on supply chain research from industrial, economic, and the private sector was borrowed into public health to explore how supply chain structures predict control resource-limited environment of infectious diseases. The result of this study was expected to benefit policymakers, international organizations and academia in their quest to understand mitigating factors in the control of tropical diseases.

This study, therefore, delineated the importance of supply chain in disease prevention, which has been minimally explored in public health research. The social change implication of this research is as follows: strengthened supply chain infrastructure; improved border processes; reliable logistics services; and reduced disability and mortality of NTD in affected communities.

Problem Statement

Control of NTDs relative to the availability of chemotherapeutic drugs for MDA is a growing concern to public health practices in endemic communities (Aksoy, 2010). The Global Partnership for the Eradication of NTD has reached more than700 million people with PCT drugs by the end of 2013 (WHO, 2013). However, this represents only 35% of those in need of chemotherapy worldwide (WHO, 2013). Consequently, innovative approaches to policy and research are needed if the Millennium Development Goals (MDGs) for the eradication of “other diseases” is to be achieved (Spiegel et al., 2010). So far, PCT coverage is the indicator for successful control of NTDs in affected countries (Hotez & Kamath, 2009) because of the substantial reduction in blood microfilaria population thereby lowering disease-specific morbidity and mortality (Simonsen et al., 2010a; Smits, 2009). Nonetheless, most developing countries continue to fall behind the WHO’s benchmarked target of >65% PCT coverage because inadequate ecological structures impedes the implementation of the MDA strategy (Krentel et al., 2013). Hence, research into ecological structures mitigating the success of

MDA in endemic communities is necessary in order to develop systematic approaches towards elimination of tropical diseases in low- and middle-income economies.

Supply chain research has associated stronger logistics structures to a firm's profitability, higher return-on-investment, and customer satisfaction (Green et al., 2008). Conversely, the association between supply chain capacity and disease prevention has received limited attention in public health research (de Vries, et al., 2011). Although there is evidence of association between supply chain capacity and improved health care (Lee et al., 2011), availability of essential medicines (Harding et al., 2014) and response to disease outbreak (Mbohwa, 2010), the effect of supply chain capacities on the availability of preventive chemotherapy drugs in the control of NTDs has not been explored.

This exploratory study evaluated the association between supply chain capacity, measures by logistics performance indicators, and the control of NTDs, measured by MDA coverage of PCT drugs. The ecological model of health behavior (EMHB, Cohen et al., 2000) was the theoretical model used to explore the prediction of supply-chain capacity on MDA coverage of PCT drugs, to eliminate NTD in low- and middle-income tropical countries.

Purpose of the Study

The purpose of this study was to explore the quantitative association of supply chain capacity, and the control of tropical diseases, in tropical low- and middle-income endemic countries. The independent variable was supply chain capacity, which was measured withy the World Bank's logistics performance indicators. These indicators are:

(a) supply chain infrastructure (b) supply chain services (c) custom and border procedures, and (d) supply chain reliability (Arvis, Mustra, Ojala, Shepherd, & Saslavsky, 2014). The dependent variable was control of NTDs, which was measured by the annual MDA coverage of PCT drugs in endemic countries.

The study was expected to contribute to filling gaps in the current epidemiological literature on alternative approaches to disease prevention because it examined consistent supply chain logistics management in low- and middle-income countries (Spiegel et al., 2010). Furthermore, the study provided important evidence to support the need for supply chain infrastructure strengthening for the control of infectious tropical diseases and improved health outcomes in developing countries.

Research Questions and Hypothesis

RQ1: Is there a relationship between supply chain infrastructure and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

$H1_0$: There is no significant relationship between supply chain infrastructure and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

$H1_A$: There is a significant relationship between supply chain infrastructure and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

RQ2: Is there a relationship between logistics services and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

$H2_0$: There is no significant relationship between logistics services, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

$H2_A$: There is a significant relationship between logistics services, and NTD control in low and/or middle-income countries, as measured by MDA coverage of PCT drugs.

RQ3: Is there a relationship between customs and border procedures, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

$H3_0$: There is no significant relationship between customs and border procedures, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

$H3_A$: There is a significant relationship between customs and border procedures, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

RQ4: Is there a relationship between supply chain reliability, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

$H4_0$: There is no significant relationship between supply chain reliability, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

$H4_A$: There is a significant relationship between supply chain reliability, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

Theoretical Framework

The Theoretical Framework upon which this study was based, is the “ecological model of health behavior”, determined by structural mechanisms by which population-level factors effect change in individual health behaviors (Cohen, Scribner, & Farley, 2000). This theory posits that structural factors at the population level are important in improving nations’ health. The model identified four categories of structural factors that affect health: (a) availability of consumer products (b) physical structures (c) social structures and policies and (d) cultural messages (Cohen et al., 2000).

Building on existing ecological theories, Cohen’s model identified ecological-level structures that influence behavior and affect individual health outcomes. These ecological structures influences individual’s constraining or mitigating health behaviors, access to health enhancing chemotherapy and control of infectious diseases (Cohen et al., 2000). Nonetheless, supply chain ecological structures may constrain access to preventive care and improved wellbeing but it largely remains unexplored in epidemiological literature.

Interventions for the elimination of NTD are aimed at addressing ecological factors that influence health. NTD disproportionally affect the poor and marginalized in society due to limited access to environmental conditions that promotes health (Addiss, 2010). Accordingly, the global effort for the elimination of tropical diseases focuses on population level transmission control through mass administration of preventive drugs, improving community level access to health infrastructure and promoting social equity. Therefore, exploring ecological structures that promote quality of health in the control of tropical diseases is needed. The use of the Ecological Structure Theory in this study was to test the hypothesis that structures at the national level influence the availability of preventive drugs that are used for mass administration of preventive drugs.

Similarly, the Theoretical Framework for supply chain structure capacity was based on the ecological determinants of health using the logistics performance indicators. Ecological scores of logistics indicators are used to rank countries according to supply chain infrastructure, logistics services, customs and border procedure, and supply chain reliability to asses ease of trade facilitation and population wellbeing (Martí et al., 2014). Therefore, ecological evaluation of LPI relative to country's capacity to control vector transmission will enhance public health's understanding of disease prevention for improved health outcome.

Nature of the Study

This exploratory, quantitative, secondary data analysis explored relationships at the ecological level to determine the strength of supply chain logistics indicators in predicting MDA coverage of PCT drugs in the control of NTD. This is consistent with the theoretical framework of ecological structures in disease prevention and control. The independent construct were: (a) supply chain infrastructure (b) supply chain services (c) customs and border procedures, and (d) supply chain reliability (Arvis et al., 2014). These variables were measured through a survey of logistics professionals who assess their own country’s supply chain environments. The dependent variable was control of NTD, which was measured by annual MDA coverage for preventive chemotherapy and transmission drugs.

The study used archival public data collected by the World Bank for the period 2007, 2010, 2012 and 2014 as predictors (Arvis et al., 2007, 2014). Variations of predictors from 2007 to 2014 were analyzed for low- and middle-income endemic countries to evaluate improvements in each indicator over the period. Additionally, quantitative relationships between each predictor and MDA coverage of PCT drugs were explored using statistical regression analysis.

Archival data from the World Health Organization’s (WHO) data repository for MDA population was analyzed. Annual MDA coverage of PCT for five tropical diseases are reported to WHO’s Global Health Observatory by endemic countries worldwide: (a) lymphatic filariasis, (b) soil-transmitted helminthic, (c) schistosomiasis, (d) onchocerciasis and (e) trachoma (WHO, 2013). MDA coverage was calculated as the ratio of population who have received preventive treatment doses of chemotherapeutic drugs, to those requiring preventive chemotherapy in the country (WHO, 2014). Coverage data from 2000 to 2014 for lymphatic filariasis was used in this study. The WHO’s benchmark of >65% MDA coverage of PCT drugs was used as the standard for annual successful coverage of MDA.

Definitions of Terms and Variables

Terms

Supply chain management: define as the integrated activities of planning, sourcing, procurement and logistics between suppliers, intermediary and customers (Council for Supply Chain Management Professionals, 2014). This term was used in this study to indicate the management of activities at population level that coordinate the distribution and storage of preventive chemotherapy drugs for mass administration in endemic countries.

Logistics management: part of supply chain management that plans, implements and control the efficient downstream distribution of products and services and upstream transmission of related information from the point of origin to the point of consumption (Council for Supply Chain Management Professionals, 2014).

Healthcare supply chain or logistics management: this is the management, planning, implementation and efficient control of healthcare products and services from the manufacturer or service provider to the patients or population in need of the health products or services (de Vries, Huijsman, Meijboom, et al., 2011; Lega et al., 2012)

NTD: a group of bacteria, virus, helminthes and parasitic diseases that affect and cause substantial illness in more than one billion people globally (WHO, 2013). In this study, NTD describes helminthic and other parasitic tropical diseases in which preventive chemotherapy and transmission control (PCT) are the control/elimination intervention.

Mass drug administration (MDA): is the direct administration of preventive chemotherapeutic drugs to the entire population at risk in an endemic area in order to control, prevent and eliminate common or widespread disease irrespective of disease condition (WHO, 2013).

Logistics performance index (LPI): interactive benchmark on indicators that identifies challenges and opportunities in trade logistics capacity across countries (Arvis et al., 2014). National LPI comprises four logistics indicators: supply chain infrastructure, logistics services, customs and boarder procures, and supply chain reliability (Arvis et al., 2014).

Low-income and middle- income countries (LMIC): the World Bank's lending categorization of countries according to their gross national income (GNI) measured in 2005 United States dollars per capita. In the fiscal year 2015, low-income countries are those with GNI per capita of $1,045 or less and middle-income countries are those with GNI per capita less than $12,746 but more than $1,045 (World Bank, 2014).

Independent or predictor variables

- *Supply chain infrastructure*: evaluates the quality of trade and transport infrastructure including road, rail, airport and information technology in the country.
- *Custom and border procedures:* evaluates the efficiency of import/export clearance and transparency of customs and boarder agencies.
- *Supply chain services:* evaluates the quality of transportation services delivered by road, rail, air, maritime, warehousing and distribution.

- *Supply chain reliability:* evaluates sources of major delays in pre-shipment inspection, loss of products in transit, compulsory warehousing and solicitation of informal payment.

Dependent or outcome variable

The outcome variable was control of NTD defined by MDA coverage of PCT drugs. MDA coverage was calculated as the ratio of number of exposed people treated with preventive chemotherapy drug and the total population requiring preventive chemotherapy in the country. MDA coverage for the prevention of lymphatic filariasis was used as the dependent variable of interest. A successful MDA benchmark was 65% annual coverage per MDA event in the endemic country.

Assumptions

This study assumed that exploring the relationship between supply chain and disease prevention, using standardized tools, would reveal an association that could strengthen the supply chain in an effort to eliminate NTDs. It was also assumed that recommendations from this study might contribute to the field of supply chain epidemiology in exploring the role of supply chain structures in disease prevention in resource-limited economies.

The use of secondary archival data in this research was based on the assumption that reliability and validity of the original data reflected respondents' intention of supply performance in each country. Finally, the voluntary, annual MDA report to the WHO Global Disease Repository reflected the true coverage in each reported country and year.

Scope and Delimitations

This study was limited to the application of supply chain logistics capacities to disease prevention in resource-limited settings. The role of the supply chain in tropical disease prevention was explored in this study due to the potential effect of logistics capacity on the distribution of essential chemotherapy drugs for the elimination of tropical infectious diseases. By linking supply chain capacity to the epidemiology of disease prevention, public health interventions for the sustainable elimination of tropical diseases can be enhanced.

The population is defined as tropical diseases endemic to countries that have initiated mapping for preventive chemotherapy (WHO, 2013) eliminate lymphatic filariasis. Globally, there are about 1.2 billion people living in countries where preventive chemotherapy for tropical disease is required. Preventive treatment is required in 53 tropical countries but only those countries with complete reported data between 2007 and 2014 (41 countries) were used. Excluded in the study were countries that are outside the tropics, have a gross national income higher than $13,000 per capita, and have not initiated mapping for eliminating lymphatic filariasis.

Limitations of the Study

The study was limited to low- and middle-income economies where tropical disease is endemic. Another limitation of the study was the use of secondary archival data at the ecological level to measure independent and dependent constructs. This limited generalization of the study to developed countries and other low- and middle-income countries in which NTD was not endemic. Even with these limitations, the outcome of the study could be applied to other parasitic or viral diseases that are earmarked for elimination in infrastructural-limited developing countries.

Significance of the Study

The global fight to eliminate tropical diseases through MDA coverage of PCT drugs is under threat if factors affecting the distribution of preventive drugs are not explored (Krentel et al., 2013). This study explored the relationship between ecological structures and disease prevention in resource-limited, developing countries. With limited investments in disease prevention in developing countries, cost-effective alternatives to eradication of infectious diseases are needed in order to achieve MDGs (Parker & Allen, 2011). Recommendations from this study are expected to contribute to social change by strengthening supply chain structures in low- and middle-income countries towards the elimination of tropical infectious diseases. As such, strengthened ecological structures are necessary for improved health outcomes in developing countries as determined by the ecological framework theory of this study (Cohen et al., 2000).

Summary

This chapter introduced the study, highlighted the problems addressed, theoretical framework used and the overarching purpose. The independent variables were based on ecological structures that determines supply chain capacity in trade and disease elimination. Measurement of structural capacity at the ecological level was introduced by the World Bank in 2007 as a benchmark for exploring challenges and opportunities for developments.

Eradication of tropical diseases using mass administration of PCT drugs was to be achieved globally by 2020, with global pharmaceutical companies donating chemotherapy drugs to achieve these targets. However, inadequate ecological structures in most tropical disease endemic countries hampers attainment. Many factors may be attributable to this scenario but the current study explored quantitative prediction of supply chain capacity and control of tropical diseases with preventive chemotherapeutic drugs.

Chapter 2 presents literature on the application of the ecological theory of disease prevention. Further, literature on the role of supply-chain capacity in business and economics will be explored for disease prevention. The chapter will end with criticism of existing literature on the subject of supply chain epidemiology and how this study could contribute to addressing these gaps.

In chapter 3, methodologies of data collection, statistical analysis and hypothesis testing is presented, in addition to hypothesis testing. The chapter also explained the different predictors and outcomes, and how the use of bivariate and multivariate analysis model predicted relationship between variables.

Chapter 4, presents the findings in tabular and graphs formats as well as interpretation of statistical significance of the result. Using linear regression analysis, it was predicted that each logistics performance indicator is linearly correlated to the coverage of MDA in the control of NTD in low-and middle-income countries. Individually, logistic infrastructure, customs and border processes, and supply chain reliability were statistically significant in predicting the control of tropical diseases.

Chapter 5 discussed the findings and their significance contribution to social change. The chapter also addressed research limitation, recommendations for further studies and a call for action by the global communities in strengthening supply chain capacities in developing countries if the goal of NTD eradication by 2020 is to be achieved.

Chapter 2: Literature Review

Introduction

NTD elimination with MDA of preventive chemotherapy drugs is a growing concern to global public health research and practice in low- and middle-income endemic countries (Aksoy, 2010). The Global Partnership for the Elimination of NTD, a consortium of international public health practitioners, has treated more than700 million people with preventive chemotherapy drugs, but which is only 35% of those in need of treatment globally (WHO, 2014). As a result of the low coverage, innovative policies and research are needed to increase treatment coverage in order to achieve global elimination targeted by the year 2020 (Spiegel et al., 2010).

Supply chain capacity has been associated with firm's profitability, higher return on investment, and customer satisfaction (Green et al., 2008). Nonetheless, the application of supply-chain capacity in disease prevention interventions, especially for the distribution of preventive chemotherapy drugs in endemic communities, is largely unexplored (de Vries et al., 2011; Aksoy, 2010). This study explored the association between supply chain capacity, determined by LPI, and the control of NTD by MDA of PCT drugs in developing countries.

Empirical review of the preventive literature revealed significant gaps in innovative theories on the role of supply chain in disease prevention intervention. Whereas research on the effectiveness of preventive chemotherapy for NTD elimination has been explored (Hanson et al., 2012; Hotez, 2009; Parker & Allen, 2011), little is known on the impact of supply-chain capacities in developing economies on NTD elimination. Consequently, research on the impact of supply-chain capacity in disease prevention using epidemiological theories is expected to contribute to the body of knowledge of supply chain epidemiology.

This chapter reviews the relevant literature on the control of NTD using MDA of PCT in endemic countries relative to supply chain capacity in an effort to explore mitigating factors influencing tropical disease prevention in resource-limited settings. The chapter reviews relevant theories, discusses existing strategies of NTD control, supply chain capacity indicators, and the epidemiology of NTD to highlight existing literature gaps on supply-chain capacity in disease prevention.

Literature Search Strategy

The following databases were used for this review: Google Scholar, EBSCO, ProQuest, PubMed, Academic Search Premier, MEDLINE, CINAHL, Business Source Complete, ABI/INFORM Complete and SAGE Premier. The WHO Global Disease Observatory and the World Bank Open Knowledge Repository were also of particular use. To locate the relevant literature, these terms were searched: *supply chain, logistics, supply chain management, neglected tropical diseases, public health supply chain, healthcare supply chain, mass drugs administration, logistics performance measure, logistics performance index, control of neglected diseases, supply chain theories, and low-and middle-come countries*.

Theoretical Foundation

According to Berkman and Kawachi (2000), theoretical frameworks targeting health outcomes are derived at the intra-personal, inter-personal or ecological levels.

Interventions focusing on intra- and inter-personal levels are within individual's control, and those at the ecological level are external to personal control. Ecological interventions recognize the influence of environmental, social, and structural factors on health outcomes. Subsequently, manipulation of environmental, structure and social conditions in which people live can affect individual and population health, thereby reducing morbidity and mortality of infectious diseases.

The theoretical framework, upon which this study was based, is the "ecological model of health behavior", which determine structural mechanisms by which population-level factors effect change in individual health behaviors (Cohen, 2000). This theory posits that structural factors at the population level are important in improving individual and community health outcomes. The theory identifies four categories of structural factors that affect health outcomes: (a) availability of essential health products (b) physical structures that influence behavior (c) social structures that limit high-risk and encourages low-risk behaviors, and (d) cultural messages that influence health (Cohen et al., 2000).

Building on existing ecological theories, Cohen et al., (2000) identified ecological structures as safe roads, transportation and vector control, which are influencers of individual and population health status. Accordingly, ecological structural factors may mitigate access to health enhancing chemotherapy in the control of infectious diseases. However, ecological structures in low- and middle-income countries are inadequate, leading to prevalence of NTD.

Conversely, other researchers have argued that neighborhood socio-economic conditions, rather than ecological factors, are important determinants of individual and population health (Wen, Browning & Cagney, 2003). These researchers suggested that conceptual model theory, which correlates neighborhood poverty and affluent to health outcome, determines population health. Accordingly, conceptual model theory of economic structures should be the basis of population-based interventions.

Paradoxically, the conceptual model theory proposed by Wen et al., (2003) only explains differences in individual's socio-economic status and not ecological structures that determine population health outcome. For this reason, adopting the conceptual model theory of health behavior in this study may not adequately explains ecological influencers of preventive chemotherapy in the elimination of infectious diseases.

Even so, other researchers have adopted Cohen's ecological framework to evaluate organizational decision latitude, modeled adolescence health behaviors and predicted regimen adherence; pointing to the strength of this theory in disease prevention (Elovainio, Kivimaki, Steen & Vahtera, 2004). In the control of tropical diseases, delivering preventive chemotherapy to endemic communities is critical to successful disease control. Therefore, the use of the ecological model of health behavior which determine structural mechanisms in which population-level factors effect change in individual health behaviors in this research, is justified.

NTD

Infectious diseases are the leading cause of morbidity and mortality in developing countries, accounting for more than 73% of disease burden and 71% of deaths

(Engels & Savioli, 2006). NTD are a group of infectious diseases with two important shared characteristics; (a) predominates in the tropics and (b) largely neglected by governments, funders, researchers and policymakers (Feasey et al., 2010). Transmitted by vectors (protozoa, helminthes and bacteria), NTD affect bottom billion of the world's poorest population causing extensive suffering, disfiguration, long-term disability, social neglect, loss of income and premature deaths (Hotez, Savioli, & Molyneux, 2009). NTD disproportionately affect low- and middle-income countries due to inadequate health, social and economic structures to support effective control strategies. Consequently, strong health infrastructure and strengthened population-level capacities can lead to elimination of NTD in developing countries.

Epidemiology of NTD

In recent years, the devastating impact of NTD has received public health attention through the WHO collaborative partnership program to eliminate tropical infectious diseases (WHO, 2014). Thirteen high-prevalence tropical diseases, causing substantial disabilities and mortality, are earmarked for elimination in 2020 by the WHO partnership. Seven of the thirteen are to be eliminated with MDA of PCT drugs (Table 1).

Table 1

Epidemiology of seven NTDs targeted for elimination by PCT

Disease	*Causative agent*	*Transmission*	*Global burden*	*Estimated DALY*	*Control strategy*

Lymphatic Filariasis	*Filarial worms; (Wuchereria bancrofti, Brugia malayi or B. timori)*	*Bites of infected mosquitoes that deposits adult worm in lymphatic vessels*	*1.4 billion people in 73 countries are exposed; 120 million are infected; 40 million incapacitated*[a]	*5.8 million*	*Annual MDA (MDA) of multiple anti-helminthic drugs*
Trachoma	*Chlamydia trachomatis*	*Flies and human contacts with eye and nose discharge of infected people*	*229 million in 53 countries are exposed; 2.2 million visually impaired; 12 million irreversibly blind*	*2.3 million*	*Surgery, Antibiotics, Face cleanliness, and Environmental improvements (SAFE)*
Ascariasis (Roundworm)	*Ascaris lumbricoides*	*Through ingestion of eggs found in soil-contaminated faeces or uncooked food*[(a)]	*Approximately 10% of the developing countries' population are at risk; 60, 000 death in children annually*	*1.8 million*	*Periodic mass deworming of children with chemotherapy drugs*

Schistosomiasis	*Schistosoma genus; blood fluke trematode worm*	*Skin penetration of lava parasite released by freshwater snails.*	*249 million people in 78 countries are at risk.*	*1.7 million*	*Annual administration of Praziquntel, improved water access and snail control*
Trichuriasis (Whipworm)	*Trichuris trichiura*	*Ingestion of eggs*	*604 million people are at risk of infection globally mostly children*	*1 million*	*Periodic deworming of children with benzimedazole*
Onchocerciasis	*Onchocerca volvulus*	*Transmitted through repeated exposure to blackfly bites*	*Mainly in tropical sub-Sahara Africa with 99% of infected people; 37 million are infected*	*0.5 million*	*Annual mass drug administration of Ivemectine*
Dracunculiasis (Guinea-worm)	*Dracunculus medinensis*	*Swallowing infected water flea in contaminated water*	*At the edge of eradication; only 148 cases in Africa reported in 2013*[a]	*Unknown*	*Provision of clean water source, education and surveillance*

a. Adopted with permission from WHO (2013), Tropical Disease Repository website

Together, the seven tropical diseases accounted for more than 13 million disabilities in life-years lost among one-fifth of the world's population (Fenwick, 2012; Mathers, Ezzati, & Lopez, 2007). At the same time, most endemic countries suffer from multiple infections, hence requiring combination of preventive treatment packages.

As depicted in Table 1, the highest burden of preventable NTD is lymphatic filariasis which accounts for nearly 6 million disabilities in 1.4 billion of the world's poorest population. Subsequently, elimination of LF will have stronger public health impact in reducing social, economic and health burdens of NTD. Consequently, research into factors affecting the impact of, and subsequent elimination of LF will have significant social change contribution to endemic communities, donors, governments and policymakers. This research, therefore, focused on the ecological factors affecting the annual MDA coverage of PCT drugs distribution for the elimination of LF in developing countries.

NTD Control

Effort towards the elimination of NTD in endemic countries has received limited public health attention, until recently. The WHO's Millennium agenda (WHO, 2006), the London Declaration and the Global Plan to Eradicate Neglected Tropical Disease, 2008 – 2020 are among the global forum aimed at eradicating tropical diseases (WHO, 2007). The objectives of these programs were: (a) stop vector-transmission through the administration of PCT drugs; and (b) alleviate the suffering of affected populations through strengthened ecological structures (WHO, 2007).

The WHO guideline for NTDs elimination recommended MDA of PCT drugs, disease management, vector control, veterinary public health and provision of safe drinking water as five overarching interventions to eradicate NTD in endemic communities (WHO, 2006). So far, annual MDA coverage of PCT drugs, is the driver of success of these interventions partly due to large donation of drugs by pharmaceutical companies, international donors and governments (Hotez & Kamath, 2009). Thus far, over 700 million doses of PCT drugs combination of diethylcarbamazine, ivemectin, and albendazole have been delivered to affected communities (WHO, 2014), but this represent 35% of population in need of PCT drugs. Additionally, NTDs are co-endemic (e.g. lymphatic filariasis and onchocerciasis), as such PCT drugs combinations provide protection for multiple diseases, further reducing the burden on endemic communities (Hanson et al., 2012). For instance, repeated MDA of PCT drugs combinations in endemic communities was shown to substantially reduce the blood microfilariae levels from 24.5 to 2.7%, of felarial antigen from 53.3 to 19.6%, and antibodies to filarial antigen from 78.9 to 27.5% in the control of Lymphatic Filariasis in Tanzania (Simonsen et al., 2013). Hence, repeated administration of PCT drugs results in significant reduction in infections of tropical diseases.

However, gap remains in endemic countries' capacity to implement annual MDA of PCT drugs due to structure inefficiencies (WHO, 2014). Whiles large-scale donation of essential preventive medicines by pharmaceutical manufacturers and donors have improved availability, access to these medications in endemic communities is below 65% coverage benchmarked for successful elimination (Cohen, Dibner, & Wilson, 2010;

WHO, 2010). Reasons attributed to this trend include inadequate health infrastructure, limited resources to mobilize large-scale distribution of donated drugs, and ecological structures to sustain donor contributions (Krentel et al., 2013). Nevertheless, PCT drugs implementation remains the prioritized strategy to successfully eliminate NTD by 2020 (WHO, 2010).

On the other hand, some researchers have questioned the prioritization of PCT as the ultimate strategy for NTD elimination (Conteh, Engels, & Molyneux, 2010; Parker & Allen, 2011; Spiegel et al., 2010). Spiegel et al., (2010) argued against the "overmedication" of the population at the detriment of social determinants of health. Similarly, Conteh et al., (2010), argued on the "catastrophic" effect of NTD on household income, whiles Parker & Allen (2011) questioned the overall effectiveness of MDA as effective tool for tropical disease elimination. Even with these arguments, the overall benefit of PCT, which are: low cost-per-patients, population effect, and large reduction in disabilities annually (over 50 million in Table 1), makes it the preferred intervention strategy for eventual elimination (Fenwick, 2012). For this reason, the current research focused on annual MDA of PCT drugs as preferred intervention for global elimination of infectious tropical diseases in developing countries. This research, therefore, hypothesizes that ecological supply chain structures in developing countries is associated with the control of tropical diseases using the annual administration of PCT drugs in resource-limited developing countries.

Constructs of Supply Chain Logistics Capacity

The role of supply chain constructs in public health epidemiological research has received limited attention by researchers, governments and policymakers alike. Whereas supply chain theoretical principles are applied in private, business, manufacturing and retail services, its application to healthcare infrastructure, disease prevention, and elimination of preventable infectious diseases is still in infancy (Lee et al., 2011). Thus, a new research paradigm of supply chain epidemiology", where supply chain principles are used to inform public health interventions, strategies and policies, is necessitated. This research leveraged lessons learned in supply chain principles from other disciplines to disease prevention.

Diversity of Supply Chain Theoretical Principles

Theories of supply chain are complicated because of multi-disciplinary nature of the subject matter. Hence, underpinning a single theoretical construct that delineate the overall efficiency of supply chain performance in one field of study may lead to inconsistence literature gap (Chen & Paulraj, 2004b). In a systematic review of over one-hundred articles across several disciplines, Burgess et al., (2006) revealed inconsistencies in theoretical and methodological application of supply chain research in economic, business and healthcare (Burgess, Singh, & Koroglu, 2006). This inconsistency, further aggravated the need to streamline research constructs in understanding the influence of supply chain on disease prevention. Perhaps, this may be the reason why prevention research literature is limited in leveraging the experiences of the private sector systems to public health interventions.

In a similar meta-analysis of more than 638 articles related to supply chain, 181 different theoretical constructs were used to hypothesize the relationship between supply chain and outcome variables, further confirming the diversity of theoretical principles (Defee, Williams, Randall, & Thomas, 2010). All the same, with increasing globalization, coupled with non-barrier transmission of infectious diseases (e.g. Ebola, MERS, SARS etc.), there is the need for public health practitioners to learn from other research approaches.

There has been significant return-on-investment, improved firm's profitability, stronger competitiveness and client satisfaction, as a result of well-coordinated supply chain initiatives in developed countries. Nevertheless, this has not been applied in the public sector, particularly in the area of epidemiology for the control of infectious diseases in developing countries (Chen & Paulraj, 2004). For the field of Supply Chain Epidemiology to develop, theoretical principles in relation to ecological conditions that influence health, should be used to explore association between supply chain structures and disease prevention. Hence, this research leveraged on the ecological principles of health behavior to examine the association between supply chain capacity and control of infectious diseases in low-and middle-income countries.

The ecological model of health behavior theory posits that, structural factors at the population level are important to improving nation's health (Cohen et al., 2000). The model identifies four categories of structural factors: (a) availability of essential supplies, (b) physical capacity to distribute supplies to end-users (c) socio-economic structures and (d) cultural messages to the population (Cohen et al., 2000). On the basis of this theory, the current research employs structure constructs that measures supply chain efficiencies across nations and its relations to infectious disease elimination. Using the Logistics Performance Index (LPI), which is a measure of country's logistics capabilities, supply chain structures in low- and middle-income countries was assessed relative to the control of infectious tropical diseases.

Supply Chain Performance Evaluation

Evaluating the efficiency of supply chain logistics activities was the subject of business and economic research in the early 1990s. As mentioned earlier, the complexity of supply chain processes make it difficult for a single quantitative model of measurement. Attempt by Beamon (1999), revealed variations in evaluation criteria for qualitative and quantitative studies of supply chain (Beamon, 1999). As a result, supply chain efficiencies were measured by categorization of services into quality, timely, flexibility, reliability, and cost (Beamon, 1999). The author bemoaned the weaknesses in this type of measurement and, consequently proposed three measures; resources, output and flexibility, which were to be linked with strategic goals (Beamon, 1999). With Beamon's proposal, supply chain effectiveness were then measured with an index of return-on-investment, order fulfilment, customer satisfaction, product quality and demand variation (Beamon, 1999).

Expanding on Beamon (1999) strategic framework, Gunasekaran et al., (2001) asserted that supply chain performance measurement must represent a "balanced" with strategic, tactical, and operational levels of management to accommodate third-party providers. Hence, the balanced scorecard approach changed the measurement of supply chain performance by incorporating partnership, and coordination of financial and non-financial matrices (Gunasekran et al., 2001). Accordingly, it became imperative for organizations to utilize their supply chain capabilities, outsourced non-value added activities, and manage relationships to effectively bring products and services to end-users.

In comparing Beamon's strategic resource matrix with Gunasekran's balanced framework, both recognized the diversity of supply chain processes, aligning to strategic goal and interrelationship of matrices for supply chain efficiencies. In contrast, however, both works failed to incorporate environmental factors outside the organizations' business processes, which may be paralleled to socio-structural determinants of health in epidemiology.

Then, the "green supply chain" model, which depicted interaction of different organizations, processes and professionals in respond to firm's internal and external collaborations (Hervani, Helms, & Sarkis, 2005). This model has, as its principle, ecological structural alignment with operational and strategic practices in order to achieve clients' satisfaction (Hervani et al., 2005). Thereby recognizing internal capacity and ecological structural interface as interlocking mechanism of assessing performance (Hervani et al., 2005). This framework bears resemblance with the ecological structures of health behavior, which recognizes intra-personal, inter-personal and environmental factors that influence health outcome. Nonetheless, this resemblance has not been recognized by public health researchers, creating gaps in existing literature on the relationship between supply chain and disease prevention.

However, using single firm's supply chain matrix to relate population-level health outcomes may be inappropriate to measure national health status. For that matter, a national-level performance indicator is prerequisite to quantifying ecological structures that influence community health outcome. With that in mind, the LPI, is an excellent national-level indicator that evaluates countries' supply chain capacities in relation to trade, policy and potentially health outcome (Arvis et al., 2007).

Logistics Performance Index (LPI)

The LPI is a multidimensional assessment tool for measuring efficiency and reliability of supply chain structures in national and international trade capacities (Arvis et al., 2007). Developed by the World Bank, academics and logistics service providers, the LPI surveys logistics professionals, small and medium size freight forwarders, and global express carriers working in their own countries, to identify challenges and opportunities of trade efficiencies (Arvis et al., 2007). Since 2007, the LPI has been used to evaluate supply chain efficiencies of more than150 countries surveying over 1000 professionals in the countries they operate (Arvis et al., 2007). The LPI is structured along international and domestic capacities using quantitative benchmark to rank "logistics friendliness" of participating countries (Arvis, Mustra, Ojala, Shepherd, & Saslavsky, 2010).

The six international dimensions of LPI are: (a) customs processes, (b) logistics infrastructure, (c) international shipment, (d) quality of logistics services, (e) tracking and tracing and (f) timeliness (Arvis et al., 2010). Scores from each dimension are averaged and compared across countries to evaluate their competitiveness. A high score of 5 and a low score of 1 determines the level of infrastructure development, investments opportunities and diversification. (Arvis, Mustra, Ojala, Shepherd, & Saslavsky, 2012).

The four domestic dimensions of LPI, which looks at the logistics environment within national boundaries are: (a) logistics infrastructure, (b) quality of logistics services, (c) customs and border procedures and (d) supply chain reliability (Arvis et al., 2012). Again, each dimension is scored and aggregated to rank domestic supply chain reliability, economic growth and poverty in developing countries (Arvis et al., 2014). Table 2 demonstrates the interconnectedness of the two dimensions of LPI.

Table 2

International and domestic dimensions of LPI

LPI	International	Domestic	Related to
Customs process	yes	yes	border procedures
Logistics infrastructure	yes	yes	infrastructure
International shipment	yes	no	
Quality of logistics services	yes	yes	services
Tracking and tracing	yes	yes	supply chain reliability
Timeliness	yes	no	

Customs and border procedures (CUS). Measures the efficiency of border clearing agencies and processes including custom services (Arvis et al., 2007). This indicator is the same for international and domestic level measurements as it relates to border and custom processes within national boundaries.

Logistics infrastructure (INF). Measures the quality of telecommunication, information technology and transportation in the country (Arvis et al., 2010).

Infrastructure efficiencies determine the constraints or improvements in logistics activities resulting from road network, air and sea capacities in a country.

Quality of logistics services (SER). Measures the quality of, and competency of logistics services providers in the country (Arvis et al., 2012). It relates to the availability of freight forwarders, transport service providers and other private and public agencies that facilitates the movements of goods and services in a country.

Supply chain reliability (REL). Similar to track and tracing, the supply chain reliability measures the speed at which a specific product reached the end-user (Arvis et al., 2014). At the same time, it relates to the efficiencies of tracking a product once it is in the country; in case of products recall, damages, loss in transit and traceability (Arvis et al., 2014).

Unlike other supply chain measurements indices (Beamon, 1999; Gunasekaran, Patel, & Tirtiroglu, 2001; Hervani et al., 2005), the LPI defines national structures that influence trade, socioeconomic conditions and health determinants (Arvis et al., 2007, 2010, 2012, 2014). For this reason, application of LPI in epidemiological research may provide significant socioeconomic measures that may influence health behaviors. It is the hope of this researcher that by estimating the impact of these supply chain structures, opportunities may exist for improvement in order to eradicate poverty, better health conditions and eliminate infectious diseases.

LPI and Socioeconomic Conditions in Low- and middle-income Countries

The World Bank and other development partners have used the LPI to assess trade facilitation and economic conditions of more than 160 countries globally. The first

LPI survey in 2007 highlighted supply chain gaps in developing economies, which hinders their competitiveness in the global market (Arvis et al., 2007). Observed structural differences between developed and developing countries therefore highlighted the role of logistics indicators to economic growth. Consequently, the LPI became a benchmark for economic reforms in developing economies by identifying structural challenges and opportunities to improved national outcomes (Arvis et al., 2007). For instance, Singapore, Netherlands and Germany were the top three performers in 2007 whereas Rwanda, Timor-Leste and Afghanistan were the bottom performers, further highlighting the relationship between logistics performance and economic development (Arvis et al., 2007).

In the 2010 survey, LPI depicted the significant of efficient logistics performance to product diversity, direct development and economic growth (Arvis et al., 2010). More so, logistics performance was related to supply chain reliability, and predictability. Additionally, the level of logistics services available in higher performing countries more than doubles that of low performing countries (Arvis et al., 2010). Furthermore, the difference in LPI scores between low-performing and high-performing countries reflected the economic gaps in infrastructure developments. Therefore, developing countries were disadvantaged in providing health-enhancing environment for their population well-being as a result of low logistics performance (Arvis et al., 2010).

Other LPI surveys of 2012 (Arvis, et al., 2012) and 2014 (Arvis et al., 2014) supported the role of logistics performance in developing countries' structural and economic advancement. In 2012 for instance, Singapore and Burundi were the top and lowest performers respectively, whereas Germany and Somalia were the top and lowest performers for 2014. Consistently, developed countries with advanced structures have high ranking, whiles those with limited infrastructure are at the bottom. LPI rankings, therefore, represent the level of economic conditions that may relate to health-enhancing infrastructure. Subsequently, this research hypothesized that estimating logistics structures in developing countries provide evidence of strength or weaknesses of health-enhancing structures that may impact infectious disease elimination.

Other researchers have highlighted the relationship between LPI scores and social conditions (Gunner & Cookson, 2012). Using LPI scores, Gunner & Cookson (2012) performed regression analysis and found that social predictors relates to logistics performance similar to economic indicators (Guner & Coskun, 2012). Social predictors were risky behaviors, democracy, and human development, which are ecological determinants of socio-economic wellbeing of a country. Thus, the work of Guner & Coskun (2012) expanded on the application of LPI, beyond economic indicators, to social conditions that may influence health. Because of the interlocking relationship between social conditions and population health (Beckman & Kawachi, 2000), estimating LPI scores for developing countries may revealed social and structural conditions that mitigate the control of tropical diseases.

Notwithstanding Guner & Coskun' (2012) work, other researchers have used the LPI to analyze socioeconomic strengths of emerging economies (Marti, Puertas, & García, 2014). Using the gravity equation, the impact of logistics structures on emerging economies was visualized with LPI rankings, which led to the conclusion that social infrastructure in developing countries are related to their supply chain logistics capacity (Marti et al., 2014). Implying that emerging economies are exposed to varying logistics and supply chain challenges which may influence their trade competitiveness, poverty alleviation and wellbeing (Mart et al., 2014).

In summary, empirical studies have shown that logistics and supply chain contribute to country's socioeconomic conditions. Specifically, LPI has become a benchmark for comparing global logistics infrastructure across countries (Martí et al., 2014). At the same time, there is growing evidence associating socioeconomic conditions and health outcome (Adler & Rehkopf, 2008; Allotey, Reidpath, & Pokhrel, 2010; S. Cohen, 2004), further suggesting the possible association of supply chain logistics to disease prevention. In light of this evidence, I explored the association between logistics indicators and the control of infectious tropical diseases in low- and middle-income countries.

Supply Chain Capacity and Disease Prevention

Limited empirical research is available which relates supply chain to health service delivery, particularly for tropical infectious diseases prevention. In an earlier attempt, Samuel et al., (2010) alluded to the dynamics of health systems due to multiple stages of service-oriented supply chain (Samuel, Gonapa, Chaudhary, & Mishra, 2010). Using the bullwhip effect, the authors developed multistage model for hospital operations revealing that patients' experience is improved when stages are reduced (Samuel et al., 2010). However, this model did not address the interconnectedness of other players outside the hospital set-up for improved patients experience. If Samuel et al., (2010) had considered other players in the logistic industry, it could have revealed the dynamics of supply chain in the health sector.

Perhaps, a more comprehensive review of healthcare supply chain was the work of de Vries and Huijsman (2011), which draws parallel between industrial supply chain and the health services industry (de Vries, Huijsman, de Vries, et al., 2011). According to these authors, core to supply chain principles in health sector are performance improvements, waste reduction, coordination of processes, building relationships, collaboration, and patients care (de Vries, Huijsman, de Vries, et al., 2011).

Unlike supply chain in the industrial sector, which moves goods and services, that of health care industry goes beyond the movement of physical goods (pharmaceutical and medical devices), to include patients and information flow. Thereby making the healthcare sector supply chain unique compared to other sectors; as a result the health sector lags behind the industrial sector in measuring the impact of supply chain capacity to health interventions. Even with its uniqueness, concepts, models and practices of industrial sector supply chain may benefit health sector’s transformation (de Vries et al., 2011). Thus, lessons learned from other disciplines should underpin research assumptions of supply chain in disease prevention. In light of this, I used lessons learned from industrial sector to explore the relationship between supply chain capacity and control of tropical diseases in low- and middle-income countries.

Learning from previous healthcare research, supply chain innovation was found to correlate with hospital performance and patients care (Lee et al., 2011). Similarly, supply chain capacity was associated to effective management of life-saving blood-bank inventories (Nagurney, Masoumi, & Yu, 2012), vaccines (Haidari et al., 2013), essential medicines (Chandani et al., 2012), and disease outbreaks (Mbohwa, 2010). In responding to disease outbreak (e.g. cholera, Tsunami, Hurricane and Ebola), insufficient logistics infrastructure, including customs delays, poor road network and inadequate information and communication technology, delayed response time resulting in loss of lives and properties (Mbohwa, 2010).

Supply chain optimization model was used to develop cost-effective logistics systems for the distribution of human blood leading to improved availability of life-saving perishable inventory (Nagurney et al., 2012). Similarly, supply chain infrastructure capacity reduced the availability of critical maternal-and-child care commodities, thereby increasing childhood mortalities in low- and middle-income countries (Chandani et al., 2012). In both studies, community-level stock out of "indicator products"— blood product and oral rehydration salt, was used to evaluate the relationship of supply chain and health systems.

Using the highly extensible resource for modeling supply chain (HERMS) software, Haidari et al., (2013) modeled the efficient mix of transport and storage that resulted in more than 30% increase in vaccines availability in developing countries which reduced vaccine-preventable diseases mortalities in resource-limited countries (Haidari et al., 2014).

Interestingly, the application of supply chain principles to health care research resulted in fragmented theories and multiple measurement matrices. Clearly, existing literature focusses on the efficient performance of healthcare organizations, with limited attention to public health interventions. Hence, the existing gaps in the field of supply chain epidemiology can be addressed if public health intervention research employs epidemiological theories, and uses standard matrix to evaluate the impact of supply chain capacity to disease prevention. Particularly, exploring the effect of supply chain in low- and middle-income countries may allow policymakers and public health practitioners to strengthen ecological structure towards NTD elimination by the target year of 2020.

Summary and Conclusions

This chapter reviewed literature in the area of supply chain epidemiology. Specifically, the outcome variable, which is control of NTDs, was discussed in relation to mass administration of preventive chemotherapy and transmission drugs used for the elimination of infectious tropical diseases. The efficiency of MDA for the control of NTD was demonstrated using relevant literature. Implying that successive annual MDA of PCT drugs may lead to the control of multiple tropical diseases in low- and middle-income countries.

Additionally, the independent variables were discussed in relation to LPI, which is a standard matrix of indicators for measuring supply chain capacity in multiple countries. Developed by the World Bank, in collaboration with stakeholders and academia, the LPI has been used by other researchers to compare economic and social structures across nations. Categorized as domestic and international, four variables measure performance within national boundaries (domestics) and six variables measure performance between boundaries (international); relating it to public health intervention principles of ecological and interpersonal determinants of health.

Literature on supply chain research is multidisciplinary and fragmented, making it difficult to relate a single epidemiological construct to logistics performance. Whereas supply chain research is matured in industrial and economic field, gap still remains in public health supply chain literature. Even though hospital supply chain was found to relate to patients' care, there is limited application of the same principle to the control of NTD. Learning from the positive role of supply chain in industrial performance, there is the need for a paradigm shift in defining supply chain epidemiology using the concepts, theories and models of disease prevention.

This study contributes to the body of knowledge in defining ecological supply chain structures to disease prevention. Importantly, using ecological theory of disease prevention, which is rooted in epidemiology, supply chain capacity in developing countries can be used predict control of NTD in order to reduce disability-adjusted life years, morbidity and mortalities associated with these diseases.

In Chapter 3, research methodology and the relations between the dependent and independent variables, with statistical measurement will be discussed.

Chapter 3: Research Method

Introduction

Control of NTD, with mass administration of preventive chemotherapy and transmission drugs, relative to supply chain logistics capacity, remains a challenge in resource-limited endemic countries. There are likely many reasons for this; however, this area of study has received limited attention by public health professionals, particularly in the area of epidemiology of tropical diseases prevention (Burgess, et al., 2006).

This chapter presents research questions and hypotheses that forms the basis of this study. Methodology, data types, reliability, validity, statistical analysis and significance for predicting the association between supply chain capacity indicators and disease control are discussed.

Research Design and Rationale

This study used quantitative, secondary data analysis to predict relations between supply chain capacity and the control of neglected diseases in tropical countries. Quantitative correlational analysis at the ecological level of supply chain logistics capacity was evaluated using the following logistics indicators: supply chain infrastructure (H_1), logistics services (H_2), customs and border procedures (H_3), and supply chain reliability (H_4). This was consistent with the theoretical framework of ecological structures in disease prevention and control. Criterion construct was NTD control, measured by annual MDA of PCT drugs. The predictor variables include (H_1) supply chain infrastructure, (H_2) logistics services, (H_3) customs and border procedures, and (H_4) supply chain reliability, as measured with logistic performance index (Arvis et al., 2014); a survey of logistics professionals who assess their own country's logistics environments.

Research Hypothesis and Questions

The following research questions were used to explore relationships between criteria and predictor variables:

RQ1: Is there a relationship between supply chain infrastructure and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

$H1_0$: There is no significant relationship between supply chain infrastructure and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

$H1_A$: There is a significant relationship between supply chain infrastructure and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

RQ2: Is there a relationship between logistics services and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

$H2_0$: There is no significant relationship between logistics services, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

$H2_A$: There is a significant relationship between logistics services, and NTD control in low and/or middle-income countries, as measured by MDA coverage of PCT drugs.

RQ3: Is there a relationship between customs and border procedures, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

$H3_0$: There is no significant relationship between customs and border procedures, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

$H3_A$: There is a significant relationship between customs and border procedures, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

RQ4: Is there a relationship between supply chain reliability, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

$H4_0$: There is no significant relationship between supply chain reliability, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

$H4_A$: There is a significant relationship between supply chain reliability, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs.

Table 3 displays variables and statistical tests by hypothesis. The dependent variable in all four hypotheses is annual mass administration coverage of preventive chemotherapy drugs used to control transmission of NTDs, and the predictor variables are; supply chain infrastructure, logistics services, customs and border procedures, and supply chain reliability.

Table 3.

Theoretical model of statistical relations

Hypothesis	Criterion variable	Predictor variable	Statistical analysis
H_1	Mass Drug Administration (MDA) of Preventive Chemotherapy (PCT) for the control of NTDs	Supply Chain Infrastructure score	Multiple Least-squares regression
H_2	Mass Drug Administration (MDA) of Preventive Chemotherapy (PCT) for the control of NTDs	Logistics Services score	Multiple Least-squares regression
H_3	Mass Drug Administration (MDA) of Preventive Chemotherapy (PCT) for the control of NTDs	Customs and Border procedures score	Multiple Least-squares regression
H_4	Mass Drug Administration (MDA) of Preventive Chemotherapy (PCT) for the control of NTDs	Supply chain reliability score	Multiple Least-squares regression

Methodology

Population

Population was defined in this study for the criterion variable is tropical countries that are endemic with one or more tropical diseases that have either or not initiated mapping for preventive chemotherapy and transmission control and reported at least two successive mapping years to WHO. Globally, there are about 1.2 billion people living in

73 countries where preventive chemotherapy for tropical disease is required. Excluded from this population are countries that are outside the tropics, have gross national income higher than $13,000 per capita, and are not endemic for one or more NTDs.

On the other hand, population for the indicator variables is 150 countries that have participated in at least one of the World Bank's logistics capacity survey in 2007, 2010, 2012 and 2014 survey periods. Excluded in this population are countries that have not participated in any of the World Bank's survey periods.

Sampling and Sampling Procedures

A stratified random sample of 150 countries that participated in the LPI survey was used as sampling technique. Stratification will have allowed specific characteristics of individuals in a population to be reflected in the sampled stratum based on their true proportion in the population (Treiman, 2014). With this proposal, a minimum sample size required was 85 countries; that is, based on a formal power analysis shown in Table 4 using G*Power. A medium effect size of .15 and an alpha (α) error probability of .05 were estimated. Power was set at .80, meaning that an 80% chance of finding a relationship between variables with a less than a 5% chance of error if a true relationship exists in the population is expected.

Table 4.

A priori computed sample size - Linear multiple regression: Fixed model, R^2 deviation from zero

Analysis:	Power Parameters	Coefficient
Input:	Effect size f^2	0.15
	α error probability	0.05

	Power (1-β error probability)	0.80
	Number of predictors	4
Output:	Non-centrality parameter λ	12.75
	Critical F	2.49
	Numerator degrees of freedom	4
	Denominator degrees of freedom	80
	Total sample size	85
	Actual power	0.80

However, not all the 150 countries are classified as low and middle income countries with tropical disease burden. Hence stratifying the population was necessitated to achieve inclusion criteria of the defined population. After stratification, 73 countries satisfied the inclusion criteria for tropical disease endemic low- and middle-income countries as well as participated in at least one LPI survey period. Out of the 73 countries, 58 have not achieved eradication between 2007 and 2013. Hence these countries were regionally stratified and matched with their respective LPI survey period.

Having matched the predictor and the criterion variables by region and country, only 41 have complete scores for each of the supply chain indicators across the survey period as well as reported MDA coverage information corresponding to the LPI. Subsequently only 41 related pairs (Pallant, 2013) were used for analysis. This corresponds to purposeful sampling technics resulting in 164 cases (41*4) that is statistically reliable for SPSS analysis with four variables (Pallant, 2013). For a statistically significant analysis in SPSS, minimum number of cases is: $N > 50 + 8m$ (where m = number of variables and N = number of cases). Hence, the minimal number of cases for the four independent variables (infrastructure, custom, services and reliability) in this study is therefore 82 (Tabachnick & Fidell, 2013, p.123).

Participation and Procedures for Recruitment

Participants in this study for criterion variable are people living in tropical countries that are exposed to NTDs. The success of preventive chemotherapy in controlling NTD depends on annual coverage of MDA in endemic communities. MDA coverage is measured as the ratio of the population treated with preventive chemotherapy drugs relative to the exposed population in need of PCT drugs in each country annually (WHO, 2014).

Likewise, participants for the predictor variables are supply chain professionals operating in their own countries with logistics responsibilities for the distribution of essential commodities across the country (World Bank, 2014). LPI is an online survey questionnaire that quantitatively evaluates the efficiency of custom processes, structural capacities, reliability and logistics services in each country (Arvis et al., 2007; 2014). The index combines an in-depth knowledge of logistics operators' understanding of country context, and global logistics environment and supplemented with quantitative data of trade performance in each country.

LMICs are categories of countries with annual Gross National Index (GNI) below US $13,000 measure per 2013-dollar value. LMIC are homes to more than 5 of the 7 billion-world populations accounting for 73% of the world's poor.

Data Collection

Instruments

The World Bank’s logistics indicators were used in this study. Started in 2007, the World Bank used the LPI to survey over 1000 professionals and agencies across 150 countries involved in the different sectors of supply chain core activities in each country (Marti, et al., 2011). Respondents to the survey were asked to assess their country’s performance in national and international trade facilitation consisting of custom processes, logistics services, infrastructure, tracking and tracing and timeliness. Each indicator was rated 1 through 5 with 5 being the highest and 1 the lowest (A sample of 2014 LPI questionnaire is provided in the Appendix).

MDA coverage, on the other hand, is the of number of people treated with at least one dose of PCT drugs, divided by the estimated number of people in exposed communities requiring PCT for one or more tropical diseases in the country (WHO, 2014). As part of the global effort to eliminate tropical diseases in endemic communities, the Tropical Disease Control Program in each endemic country initiates mapping of PCT as a strategy towards NTD elimination. Each PCT-initiated country voluntarily reports annual MDA coverage to the Global Health Observatory database for surveillance and monitoring progress towards global elimination. Successful annual coverage is benchmarked at >65% coverage of population requiring PCT, and six successful annual coverage may lead to elimination (Simonsen et al., 2010).

Data Collection Technique

This study used archival data collected by international public agencies for both the criterion and the predictor variables. The World Bank's data repository of LPIs for 150 countries was extracted for 2007, 2010, 2012 and 2014 survey periods as predictors. At the same time, data from the WHO Global Disease Registry (GDR) for annual MDA of PCT drugs for lymphatic filariasis was extracted for criterion variable.

Data Organization Techniques

Extracted data was systematically organized electronically and in hard copies. Electronic data organization techniques used are; *Dropbox*, *Google Drive*, *Zotero, Excel* files and folders. Folders were created for each type of data according to subject index, by country, and by predictor variable. At the same time hard copies of each dataset printed and kept in files for ease of reference and traceability. Other techniques of data organization were Historical Alignment Tool (HAT), journal logs, bibliography, and index cards. Collected data were secured in different formats electronically and hard copies and will remain so for at least 5years after the approved final dissertation. Data disposition shall follow Walden University's data disposition guidelines.

Data Analysis Technique

Statistical Tests

To test the research hypotheses, a multiple regression model was designed. The model was constructed to explore statistical relationship between the control of NTD, measured by annual MDA of PCT drugs, and each of the predictors; supply chain infrastructure (H_1), logistics services (H_2), customs and border procedures (H_3), and supply chain reliability (H_4). This model was used to test the four hypotheses for this study and labeled after the dependent variable, control of tropical diseases. The construct of the model was:

Control of NTD (Y) = β_0 + β_1Infrastructure(X_1) + β_2Services(X_2) + β_3Border and time (X_3) + β_4Supply chair reliability(X_4) + €.

The predictor variables are signified with X, and Y represents the dependent variable. The regression coefficients, β_n, for the models are the variance of scores attributed to each predictor variable relative to the outcome variable. The symbol € represents an error term generally distributed around a mean of zero.

Threats to Validity

Reliability

Reliability of survey instruments measure internal consistencies of scores, stability and administration over time (Creswell, 2013). The LPI have been used since its development in 2007 to collect data from more 1000 professionals across multiple countries and was found to consistently give repeatable result over the collection periods (Martí, Puertas, & García, 2014b). Outcome of the survey using LPI was used to compare logistics performance and trade facilitations in more than 140 countries in 2007, 2010, 2012 and 2014 which consistently ranked logistics performance in participating nations (Arvis et al., 2007; 2010; 2012; 2014).

Validity

Validity in quantitative research refers to whether meaningful conclusions can be drawn from scores of a particular instrument (Creswell, 2013). Researchers in business and administration have used the outcome of LPI surveys to guide policymakers in creating sustainable structures, improved transportation and facilitated trade comparisons among nations (Charkaoui, Ouahman, & Bouayyad, 2012). In developing the LPIs, professionals, academia and representatives of professional freight forwarding agencies rated the constructs in the index, which was statistically validated by the World Bank. According to the World Bank, the indicators of LPI were statistically validated using principal component analysis (PCA), a statistical technique used to reduce dimensionality of datasets, the Kaiser Criterion and the Eigenvalue scree plots (Arvis et al., 2014).

Ethical Procedures

Data employed in this study is historical archive, which is publicly available to researchers and other users. In addition, the data is aggregated at national level without revealing individual's personal information. Aggregated by country, the outcome variable is measured as a percentage of number of people treated with one or more chemotherapy drugs, irrespective of health status, over estimated number of people in need of preventive chemotherapy. There is no indication of specific individual's health status or personal information that may compromise individual's right. The predictor variable, is an anonymous survey of freight forwarding professionals, and does not collect individual's health or personal information. Nonetheless, permission was requested from the World Bank and the WHO to use the data for this research (permission letters in

Appendix). Also, Walden University’s Institutional Review Board (IRB)’s approval was requested prior to collection and analysis of data.

Summary

This chapter highlighted the methodology used in this study. Specifically, definitions of participants, sample type, size, research questions, research hypotheses and statistical analysis used in the study were discussed. Data management techniques, validity and reliabilities of the survey instruments were given in this chapter. Datasets for the different constructs of the predictor and outcome variables of this study were similarly defined. In Chapter 4, the results of the study are displayed in tabular and graphical forms with discussions of the relevant research hypothesis.

Chapter 4: Results

Introduction

The purpose of this study was to explore the association between supply chain logistics capacity and the control of infectious NTDs in low- and middle-income countries. Specifically, the research explored answers to the following questions:

- Is there a relationship between supply chain infrastructure and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?
- Is there a relationship between logistics services and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?
- Is there a relationship between customs and border procedures, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?
- Is there a relationship between supply chain reliability, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

Secondary archival data was collected, reviewed and statistically analyzed to explore relationships between each of the four predictor variable and the outcome variable. This chapter highlights the results of statistical analysis (univariate, bivariate, and multiple linear regression) and hypothesis testing (answers to research questions) in tabular and graphical formats.

Data Collection and Validation

Archived secondary data was extracted between April and July 2015 from the WHO and the World Bank open access data libraries respectively, after obtaining permission from both agencies. The predictor variables, logistics performance index, were extracted for the survey periods 2007, 2010, 2012 and 2014 for all the 150 participating countries (World Bank, 2014). The criterion variable, annual MDA metadata, were extracted for the period 2000 through 2013 for lymphatic filariasis endemic countries (WHO, 2014). Because of observed differences in reporting periods (2000 to 2013 for criterion and 2007 to 2014 for predictors), and the variations in participating countries (150 for predictors, and 73 for criterion), direct sample stratification of related pairs, which is required for statistical analysis was not feasible. Related pairs are matched subjects (or countries) such that scores on each dependent and independent variables are matched or related for the same sampling period (Pallant, 2013). Because of this difficulty, purposeful matching pairs, using the baseline of LPI survey years, was used to compare predictor and criterion variables (Table 5). Consequently, LPI scores of participating low-and middle-income countries, stratified by regions, were purposefully matched for analysis. The reason for matching three consecutive years of MDA coverage to one LPI survey year is because of empirical evidence that tropical disease prevalence remains unchanged over a short range of period, as such, data from close years are approximated (Ramaiah & Ottesen, 2014).

Table 5.

Matching pairs for variability of LPI scores and MDA coverage

Scores of LPI survey period	Average MDA coverage period
2007	2006 , 2007 , 2008
2010	2009, 2010, 2011
2012	2011, 2012, 2013
2014	2013, 2014, 2015

In contrast to the direct stratified sample technique proposed in Chapter 3, purposeful stratified mapping of related pairs was used to map the independent with the dependent variables (Green & Salkind, 2011; Pallant, 2013). Whereas the scores for the 150 countries participated in the LPI surveys were available, 73 countries are classified as low-and middle-income countries. Of the 73 LMIC, 53 have initiated at least two years of MDA coverage mapping for lymphatic filariasis preventive chemotherapy; an inclusion criteria for this study (see Chapter 3). Therefore, related pairs mapped LPI scores with MDA coverage of PCT drugs yielded 41 countries for each participating years of 2007, 2010, 2012 and 2014, resulting to 164 (41*4) related cases. For a statistically significant analysis in SPSS, minimum number of cases is: $N > 50 + 8m$ (where m = number of variables and N = number of cases). Hence, the minimal number of cases for the four independent variables (infrastructure, custom, services and reliability) is 82 (Tabachnick & Fidell, 2013, p.123).

Missing Data

Missing data may influence the output of statistical analysis. Therefore, investigating missing data and adjusting thereof, improves generalization of statistical output. IBM SPSS® missing value analysis was used to detect trend in missing data for the independent variables. No systematic pattern was observed, such that missing information in the data may be random, and will not significantly contribute to trend in the model (Salkind, 2011). To correct for missing values, multiple imputation technique and exclude cases pairwise options were used to control for the effect of missing values I the analysis.

Normality Assessment

Most statistical techniques assume normality of distribution of variables (Salkind, 2011). Several techniques are used to assess normality of distribution including histogram, boxplot, normal Q-Q plot and descriptive statistic – skewness, kurtosis, and Kolmogorov-Smirnov.

Table 6

Assessing Normality of dependent and independent variables

Tests of Normality

	Kolmogorov-Smirnov[a]			Normality Statistic		
	Statistic	df	Sig.	Skewness	Kurtosis	Std. Error
Supply Chain Infrastructure	.085	150	.010	.721	.458	.198
Customs and Border Process	.067	154	.088	.621	.615	.195
Logistics Services	.076	154	.032	.385	-.117	.195
Supply Chain Reliability	.103	154	.000	.381	.377	.195
National MDA Coverage	.141	164	.000	-0.036	-1.513	.190

a. Lilliefors Significance Correction

In addition to inspection of histogram, boxplot, normal and extrended normal Q-Q plots of the distributions, statistical test for normality revealed deviation of the dependent variables from normal distribution (Table 6). *Skewness* indicates symmetry of the distribution along dumbbell shape of a normal distribution curve. Positive skewness suggest scores are clustered to the left lower values; negative skewness suggest clusters around high scores. Kurtosis gives information on the peak of the distribution; positive kurtosis predicts peak scores at the center, and negative kurtosis predicts flatness of the distribution with too many extreme values (Pallant, 2013, p.59; Tabachnick & Fidell, 2013, p.80). On the other hand, Kolmogorov-Smirnov statistics gives normality of scores with a non-significant result ($p > 0.05$) indicates normality (Pallant, 2013). Form the result of this analysis (Table 6), the dependent variable's Kolmogorov-Smirnov statistic is significant ($p < 0.001$), negative kurtosis (- 1.053) and negative skewness (skewness = -0.037), suggesting significant deviation from normality (Table 6). Therefore, the dependent variable was re-assigned from continuous to nominal variable as low MDA coverage (≤65%) and high MDA converge (≥65%).

Outliers

Extreme value outliers may affect the statistical significance of normal curve distribution. To determine extreme value outliers, graphs (histogram and boxplot) and statistic (5% Trimmed Mean) were used (Green & Salkind, 2011; Pallant, 2013). Observing shapes of normality curve of histograms of each independent variable - infrastructure, customs process, logistics services and supply chain reliability - revealed no point deviation from the rest of the distribution; reflecting the absence of extreme value outliers. Accordingly, the independent variables approximate normality with no extreme outliers affecting statistical assumptions of the model. In addition, extreme value points are marked with an asterisk, *, on a boxplot, to indicate outliers with more than three-box-lengths away from the edge of the box (Figure 1). No case with asterisk was observed on the boxplot graph representing the absence of extreme value outliers in the distribution (Figure 1).

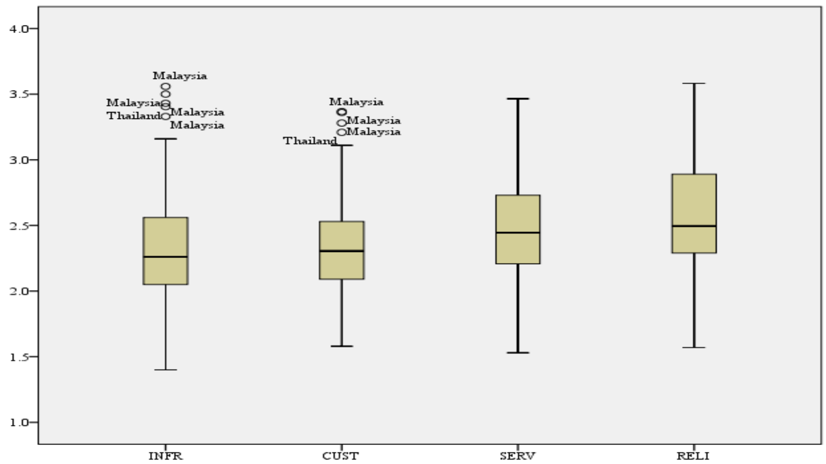


Figure 1. Boxplot of independent variables showing outliers.

The influence of outliers on statistical assumption can be confirmed with descriptive statistics. The statistic used is the 5% Trimmed Mean, which reflect changes in the central tendency of the distribution if outliers were removed. If 5% Trimmed Mean is very different from the sample mean, then the outliers will impact the normality assumption of the model; the alternative is true. Since there is minimal deviation between the sample and 5% trimmed means (Table 7), outliers are insignificant, and will not influence the statistical assumptions of the model.

Table 7

Sample and 5% Trimmed Means of independent variables

Indicator	*Sample Mean*	*5% Trimmed Mean*	*Mean difference*
Logistics Infrastructure	2.33	2.32	0.01

Customs and border processes	2.34	2.33	0.01
Logistics services	2.49	2.48	0.01
Supply chain reliability	2.58	2.57	0.01

Data Analysis

Multiple linear regression was used to test statistical association. Multiple linear regression enables the prediction of the association of multiple predictor variables with an outcome variable. Because the aim of the study was to explore the association between supply chain logistics indicators and the control of NTD, assumptions of linear regression was used as the basis of statistical analysis.

Using the IBM® Statistical Package for Social Sciences (SPSS) software, student version 21, the following variables were created for analysis:

Region: These are low-and-middle income economic regions: Africa Region (AFR), America Region (AMR), Eastern Mediterranean Region (EMR), South East Asia Region (SEAR), and Western Pacific Region (WPR). These are the five geographic regions with tropical climates that are home to one or more NTD.

Country and country code: This represent low-and middle-income tropical region associated with one or more NTD earmarked for mass treatment.

PopReqPCT: Population requiring preventive chemotherapy and transmission through mass treatment. This is total population, in each country, that are exposed to one or more NTD.

PopTreatPCT: This is population, in endemic communities, that were treated with one or combination of preventive drugs (Ivemectine and/or Albendazole) to prevent lymphatic filariasis.

Year: This is the logistics performance indicator survey period, which are 2007, 2010, 2012 and 2014.

MDACov: This is the mass drug administration coverage, also known as national coverage, which is the population treated with PCT drugs, divided by the population requiring PCT in each coverage year. This is a measure of success toward NTD control and eventual elimination.

INFR: The supply chain logistics infrastructure capacity in the county. Scored between 1(low) and 5 (high); the higher the score, the stronger the supply chain infrastructure in the country.

CUS: Custom and border procedures reflect the speed of processing of goods at the points of entries. Scored between 1 (low) and 5 (high); high scores represents expeditious processes at the points of entries.

SERV: Services is the availability of logistics services providers in the country. Scored as 1 (low) and 5 (high), it represents the quality of logistics services providers in the country, transportation and freight forwarding agencies.

RELI: Supply chain logistics reliability determines the ease of traceability of essential products from point of entry to the final consumer or patient. The higher the score (5), the more efficient logistics, and the lower the score (1), the less efficient.

With these variables, IBM ® SPSS's *Transform*, *Analyze* and *Graph* menus were used to transform variables, conduct statistical analysis, and create chart/graphs respectively to evaluate model assumption, univariate, bivariate and multivariate analysis.

Statistical Assumptions

Mullticollinearity and Singularity

Mullticollinearity occurs when two or more predictor variables are highly correlated (r= 0.7 or above), making the estimation of regression coefficient unstable, which may inflate standard errors of the coefficients (Pallant, 2013; Salkind & Green, 2011). Singularity, on the other hand, occurs when one predictor is a combination of multiple predictors, making the other predictor redundant in the model (Pallant, 2013). Mullticollinearity and singularity are shown as tolerance and variance inflation factor (VIF), in a regression model. Tolerance associates variability to each predictor and is calculated as $1-R^2$. VIF is the inverse of the Tolerance; the higher the Tolerance the lower the VIF and vice versa. Tolerance values of less than 0.1 or VIF values higher than 10 are indicative of mullticollinearity. Preliminary analysis shows the absence of mullticollinearity among the predictor variables (Table 8), because tolerance values were between 0.19 and 0.32 and VIF between 3.11 to 5.31; affirming the validity for the use of multiple regression analysis.

Table 8

Test for mullticollinearity of predictor variables

Model		Collinearity Statistics		
		Zero-order	Tolerance	VIF
1	(Constant)			
	INFR	.213	.221	4.527
	CUST	.234	.313	3.193
	SERV	.157	.188	5.306
	RELI	.176	.321	3.113

Normality, Linearity, outliers, homoscedasticity and independence of residual

Regression model assumes normality, independence, and homoscedasticity of residuals. These were determined simultaneously from the normal probability plot (P-P) of the regression standard residual, scatter plot, Cook's and Mahal distances of the multiple regression. Inspecting the residual plots, scatter plot and outcome statistics reveal no deviations from these assumptions, further validating the suitability of the use of regression model in this research.

Effect size statistics

Effect size is the strength of association between predictor and criterion variables, whether or not the association statistically significance (Salkind & Green, 2011). In regression analysis, effect size is determined by the Pearson product-moment correlation coefficient, R, and its squared, R^2, which are strength and variability relations respectively. R ranges from 0 to 1; 0 means no linear relations and 1 implies perfectly correlated variables. R^2 is the degree by which the variations in outcome is attributed to the predictor(s) in a linear relation (Salkind & Green, 2011).

Statistical Significance and Hypothesis Testing

Statistical significant of a model is tested using p-value, which is based on the assumption that null hypothesis (H_0) is true (Gerstman, 2008). A significant statistic is surety of reliability of test, it is not an indication of the practical importance or decision making utilities of that result (Gerstman, 2008). Rather, it explains the role of random chance in the observed differences in the relations. For that matter, p-values greater than 0.1 are not significant; but $0.01 \leq p \leq 0.05$ are significant. Consequently, failing to detect statistical significant is not the same as saying there is no relationship between variables (accepting null hypothesis), it merely says that evidence is not enough to unequivocally reject the null hypothesis (Gerstman, 2008).

MDA coverage for PCT

Since the inception of the Global Program for the Elimination of Lymphatic Filariasis in 2000, the population requiring preventive chemotherapy increased substantially from 135 million to more than 1 billion (Table 9).

Table 9

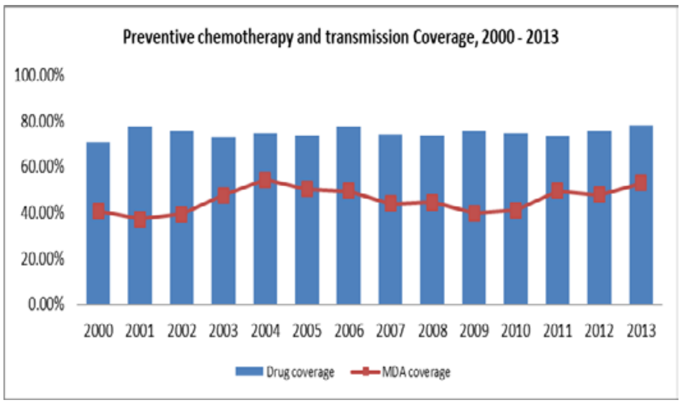
Baseline characteristics of PCT population in LMIC, 2000 – 2013

Years	*# of Countries*	*Pop. Requiring PCT*	*Pop. Treated*	*Target IU pop.*	*Drug coverage*	*MDA coverage*
2000	*12*	*135,377,200*	*2,932,265*	*3,810,780*	*70.93%*	*40.77%*
2001	*22*	*709,406,476*	*25,895,967*	*32,018,984*	*77.55%*	*37.14%*
2002	*32*	*1,361,063,705*	*91,717,535*	*107,976,969*	*75.46%*	*39.32%*
2003	*36*	*1,365,519,154*	*103,602,120*	*137,630,855*	*72.87%*	*47.58%*
2004	*36*	*1,373,818,069*	*356,630,049*	*570,539,058*	*74.66%*	*54.32%*
2005	*41*	*1,632,378,490*	*437,763,390*	*683,124,214*	*73.85%*	*50.36%*
2006	*36*	*1,636,856,054*	*702,212,284*	*1,271,325,926*	*77.58%*	*49.39%*
2007	*42*	*1,782,825,827*	*554,991,252*	*762,687,049*	*74.04%*	*43.96%*
2008	*37*	*1,740,001,822*	*502,737,840*	*697,144,592*	*73.68%*	*44.46%*
2009	*36*	*1,226,750,799*	*485,820,549*	*642,625,272*	*75.50%*	*39.85%*
2010	*33*	*1,240,636,180*	*484,367,054*	*655,941,539*	*74.45%*	*41.12%*
2011	*36*	*1,247,430,289*	*559,355,495*	*772,595,909*	*73.48%*	*49.48%*
2012	*32*	*1,211,551,251*	*612,140,284*	*830,549,776*	*75.49%*	*47.68%*
2013	*36*	*1,116,807,973*	*493,898,474*	*672,201,746*	*78.24%*	*52.84%*

At the same time, the number of people treated, through mass drug admiration, with preventive chemotherapy and transmission (PCT) drugs increased from less than 3 million in 2000 to nearly 500 million, 13 years later, representing less than 45% coverage. Within that same period, the number of LMIC participating in the program and initiating mapping for the control of NTD rises across the years, from 12 at baseline to 58 by 2013 (Table 9).

Figure 2

Thirteen years of MDA coverage in LMIC



Whereas the population requiring PCT had increased exponentially, access to preventive treatment still remain under 65% required for total elimination of the disease (Figure 3). Possible reasons attributed to this trend as well as factors infleuecing the attainment of bechmarked coverage in LMIC will be discussed in Chapter 5.

Table 10

Distribution of NTDs in LMIC

Region	*Frequency*	*Percent*
AFR	84	51.2
AMR	16	9.8
EMR	8	4.9
SEAR	28	17.1
WPR	28	17.1
Total	164	100.0

Descriptive Statistics

Sub-Sahara Africa has the highest burden of NTD in LMIC accouting more than 50% of endemic countries, with South-East Asia and Western Pacific regions contrubting additional 34% of endemicity, suggesting that efforts to eradicate NTD can be regionally targeted (Table 10). On the other hand, supply chain capacity indicators;- supply chain logistics infrastructure, custom and border process, logistic services and supply chain reliability have mean scores of less than 3, sggesting lower supply chain capacity in developing countries in comparison with their developed couterparts (Table 11).

Table 11

Univariate Distribution of Supply Chain Indicators in LMIC

	logistics infrastructure	*Customs and border processes*	*Logistics services*	*Supply chain reliability*
Mean	2.33	2.34	2.49	2.58
Std. Deviation	.41	.34	.39	.42
Minimum	1.40	1.58	1.53	1.57
Maximum	3.56	3.37	3.46	3.58

The average logisitics infrastructure in LMIC was 2.3, custom and border process 2.3, logisitics services 2.5 and supply chain reliabilty at 2.6 respectively. Indicating that across LMIC, logisitics infrastructure, custom and border processes are comparatively lower than logisitics services and supply chain reliability. However, some LMIC have reasonably high logisitics perfomance indicators (maximum score = 3.58), whiles others suffer from inadequate supply chain infrastructure (minimum score = 1.4), corresponding to endemic countries' level of development. For instance, Malaysia, Thailand, and Brazil have seen substantial improvemets in logisitics and supply chain indicators (above 3.0), whereas Niger, Guinea-Bissau and Sierra Leone lag behind (less than 1.5) in logistics indicators.

Supply Chain Infrastructure and MDA Coverage

Research Question 1: *Is there a relationship between supply chain infrastructure and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?*

A bivariate linear regression analysis was used to explore relationship between supply chain logistics infrastructure and the control of NTD by MDA coverage in low-and-middle-income countries. Preliminary analysis of the residual scatter plot and regression model summary predicted a linear association between supply chain infrastructure and control of NTD (Table 12).

Table 12

Bivariate linear regression model for logistics infrastructure and MDA coverage

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	11.76	14.09		.84	.405	-16.09	39.62
	logistics infrastructure	15.87	5.94	**.214**	2.67	**.008**	4.12	27.61

[a] Dependent Variable: National MDA Coverage

[b] Selecting only cases for which LPI survey year >= 2007

The value of the Spearman's Product Moment or Correlation Coefficient (r = 0.214), indicates a moderate linear relations between MDA coverage and logistics infrastructure, suggesting that infrastructure linearly predicts the success of MDA coverage for PCT in LMIC. The predicting equation is:

National MDA coverage = 0.21 *logistics infrastructure* + 11.76 ….. Eq. 1

and the 95% confidence interval (4.12 to 27.62), implies that the two variables are significantly related ($r = 0.21$, $n = 150$, $p = 0.008$). Additionally, 5% ($R^2 = 0.046$) of the variance in the national MDA coverage is accounted for by its linear relations with supply chain logistics infrastructure in tropical countries.

Customs and Border Processes and MDA Coverage

Research Question 2: *Is there a relationship between logistics services and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?*

To determine the association between customs and border procedures and the control of NTDs, a linear regression analysis was conducted. There is statistically significant correlation between the two variables (Table 13), implying that as customs and border processes improves, national MDA coverage for the control of infectious tropical diseases improves.

Table 13

Coefficient of Variation between Custom and Border Processes and MDA Coverage

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-2.381	16.810		-.142	.888	-35.592	30.830
	Customs and border processes	21.595	7.108	**.239**	3.038	**.003**	7.553	35.638

[a] Dependent Variable: National MDA Coverage

[b] Selecting only cases for which LPI survey year >= 2007

The covariate statistics *F* (1, 154) = 9.232, p < 0.01 and t (154) = 3.04, p < 0.01, are statistically significant at 95% confidence interval (7.55 to 35.64), implying there is a significant linear relationship between customs and border process and MDA coverage in the control of tropical diseases. The regression equation:

National MDA coverage = 0.24 *Custom and border processes* – 2.39 … Eq. 2

with the Pearson coefficient (r = 0. 24, n = 154, p < 0.01) further confirms the direct correlation between the two variables and that 6% of the variation in MDA coverage is accounted for by expedited custom and border processes in low-and middle-income countries.

Logistics Services and MDA Coverage

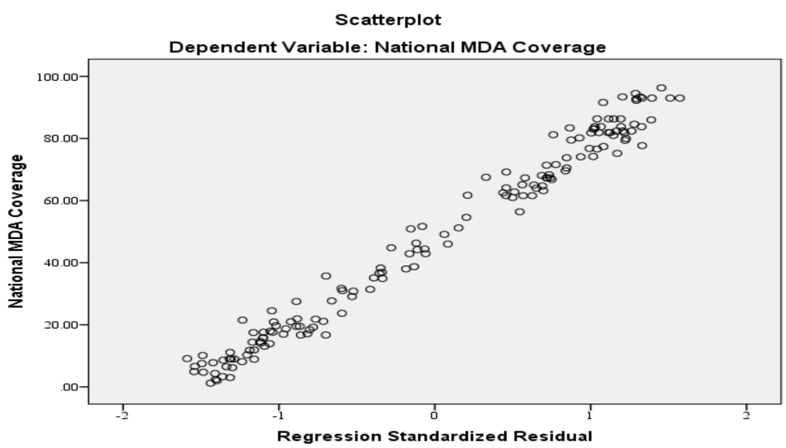
Research Question 3:

Is there a relationship between customs and border procedures, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?

Linear regression analysis was conducted to determine the relationship between logistics services and the control of tropical diseases in low and middle income countries, using MDA coverage. The regression model, and the residual scatter plot (shown in Figure 4), predicted that the two variables are linearly related, such that variations in logistics services correlates with MDA coverage.

Figure 3

Scatterplot showing the relationship between MDA coverage and logistics services



However, the relationship between the two is statically insignificant (p = 0.078) at 95% confidence interval (-1.26 to 23.44). Also, the Correlation Coefficient, r = 0.14, predicted lower linear strength in the correlation between logistics services and the control of NTDs. Further, the regression equation:

National MDA coverage = 0.14 *logistics services* + 11.1 …… …Eq. 3

and F (1, 152) = 3.15, p > 0.01; t (152) = 1.8, p > 0.01 confirms that there is non-significant linear relationship between logistics services and the control of neglected diseases in endemic countries, accounting for only 2% variation in MDA coverage.

Supply Chain Reliability and MDA Coverage

Research Question 4: *Is there a relationship between supply chain reliability, and NTD control in low- and middle-income countries, as measured by MDA coverage of PCT drugs?*

To answer this question, a linear bivariate regression analysis was conducted between supply chain reliability and MDA coverage in developing countries. The model analysis of variance (ANOVA), shown in Figure 14, revealed statistically significant linear relationship between supply chain reliability and the control of tropical diseases.

Table 14

Model analysis of variance for the relationship between supply chain reliability and MDA coverage

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3667.032	1	3667.032	4.037	**.046**[c]
	Residual	138057.920	152	908.276		
	Total	141724.951	153			

[a] Dependent Variable: National MDA Coverage

[b] Selecting only cases for which LPI survey year >= 2007

[c] Predictors: (Constant), Supply chain reliability

The predictor F (1, 152) = 4.04, p = 0.046 and the correlation coefficient (r = 0.16, n = 152) suggest positive and significant relations between the two variables. Hence, supply chain reliability positively predict control of tropical disease, but the strength of this relations is weak and account for only 2.6% of observed variations in MDA coverage. In this case, the regression equation:

National MDA coverage = 0.2 *supply chain reliability* + 11.6 …. Eq. 4

marginally predicts variations between predictor and the criterion variables.

Logistics Performance Index and MDA Coverage

A multiple linear regression analysis was conducted to determine whether supply chain capacity predict the control of neglected tropical disease by MDA of PCI drugs coverage. In this case, supply chain capacity is the index of supply chain infrastructure, custom and border processes, logistics services and supply chain reliability, known as the LPI, in low ad middle income tropical countries. The overall Pearson multiple correlation coefficient of the model is positively correlated (r = 0.27, n = 145, p = 0.02) indicating a direct linear relationship between logistics performance index and the control of NTDs. It also shows that LPI is statistically significant ($p < 0.05$) at 95% confidence interval, F (4, 142) = 2.9, p = 0.02, and accounts for 7% of variation in MDA coverage.

The relative strength and contribution of each predictor, independently and after controlling for all others is depicted in Table 15. None of the predictors in combination is statistically significant even though infrastructure and custom processes, and supply chain reliability were independently significant in their correlation with MDA coverage. Except for logistics services that is negatively correlated, the other three predictors positively correlate with MDA coverage. The multiple regression equation is therefore:

MDA Coverage = 0.2 *logistics infrastructure* + 0.3 *custom and border processes* – 0.3 *logistics services* + 0.1 *supply chain reliability* + 2.7……… Eq. 5

Table 15

Multiple Regression Model for MDA and LPI

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.70	17.76		.152	.88
logistics infrastructure	14.95	12.52	**.20**	1.19	**.23**
Customs and border processes	22.64	12.75	**.25**	1.78	**.08**
Logistics services	-21.51	14.14	**-.28**	-1.52	**.13**
Supply chain reliability	4.27	10.05	**.06**	.42	**.67**

On the basis of the multiple correlation, we may say that LPI or logistics capacity is a useful predictor of MDA coverage of PCT drugs in the control and eventual elimination of NTDs. In addition, the result of bivariate analysis revealed that supply chain infrastructure, customs and border procedures and supply chain reliabilities are significant predictors of MDA coverage in developing countries. On the other hand, quality of supply chain service providers is not significant predictor of MDA coverage. However, failing to determine statistical significant does not mean that the predictor is irrelevant, but rather the sample size might not have been large enough to determine significant at that level of confidence. Hence conclusions can be drawn on the impact of supply-chain capacity and tropical disease control with mass administration of preventive chemotherapy drugs in low-income endemic countries (Salkind & Green, 2011).

Summary

Using linear regression analysis, it was predicted that each logistics performance indicator is linearly correlated to MDA coverage in the control of NTD in low-and middle-income countries. Individually, logistic infrastructure, customs and border processes, and supply chain reliability are statistically significant in predicting the control of NTD. On the other hand, quality of logistics service providers is statistically insignificant in relations to MDA coverage of PCT drugs. The overall logistics capacity, measured by logistics performance index is significantly associated with MDA coverage at 95% confidence level ($p = 0.046$), accounting for 7% variation in MDA coverage in the control of tropical diseases. This finding is expected to contribute to existing literature on the control of NTD in low-and-middle income countries. As the field of supply chain epidemiology developed, more empirical evidence in public health literature will be available to further enhance studies on the impact of supply chain on disease prevention.

Chapter 5 discusses the contribution of this result to the scientific knowledge pool and to the overall strategic policy directions in the global efforts to eradicate NTD in developing countries.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this study was to investigate the relationship between supply chain logistics capacity and the control of NTDs in low-and middle-income countries. Specifically, the purpose was to explore whether supply chain infrastructure, logistics services, customs and border procedures and supply chain reliability were predictors of MDA coverage of PCT drugs in the control of lymphatic filariasis in endemic communities.

The results indicated linear correlations between each of supply chain logistics indicators and the coverage of MDA in the control and transmission of tropical diseases. This suggests that supply chain logistics indicators predict control of NTDs in low- and middle-income countries. Of the four logistics indicators, supply chain infrastructure, customs and border procedures, and supply chain reliability significantly predict the coverage of preventive chemotherapy drugs in low-and middle-income countries. Similarly, logistics services are statistically insignificant in predicting chemotherapeutic coverage for the control of tropical diseases.

This chapter discusses the relevance of these findings, their contribution to body of knowledge, their limitations and the recommendations based on them.

Interpretation and Discussion of the Findings

Preventive Chemotherapy and Transmission Drugs Coverage

There was an increased trend in the coverage of effective preventive drugs for the control of lymphatic filariasis in low-and middle-income countries. Since 2000, more than 700 million treatment doses of one or more preventive chemotherapy drugs in at-risk communities were delivered (see Table 9), which contributed to the substantial reduction in DALYs. This finding is consistent with earlier reports by the WHO on the success of PCT in the control of tropical diseases (WHO, 2014). Because of the devastating effect of lymphatic filariasis, which has social, economic and psychological consequences on individuals and communities, the increased trend in the coverage of preventive chemotherapy significantly contributes to achieving the Millennium Development Goals, which called for the elimination of neglected diseases by 2020 (Fenwick, 2012; Hanson et al., 2012; Linehan et al., 2011).

Even though the trend in the distribution of preventive chemotherapy drugs increased , there was a disproportionate increase in number of endemic communities requiring treatments annually (see Table 9). This can be attributed to the growing evidence of PCT as effective prevention strategy in the global elimination of disease. As a result, more endemic communities were participating in the program, further confirming the need for improved coverage of PCT in developing countries. Nevertheless, annual PCT coverage remains below the 65% benchmarked for elimination (see Figure 3). For instance, of the countries that participated in the MDA mapping in 2007, 2010, 2012 and 2014, approximately 22%, 34%, 44% and 51% attained the required 65% benchmarked MDA coverage (successful coverage) respectively, reflecting improvements in coverage towards global elimination by 2020. This finding compares with earlier studies, which revealed improved success of tropical disease control as preventive chemotherapy doses reach infected communities in Tanzania (Simonsen et al., 2013). Consequently, improved PCT coverage trends significantly contribute towards the global success in the elimination of tropical diseases (Cohen, Dibner, & Wilson, 2010; Hanson et al., 2012; Krentel, Fischer, & Weil, 2013). For this reason, structural and supply chain interventions that improve the coverage of preventive doses of PCT can lead to reduction in disabilities associated with lymphatic filariasis (WHO, 2013).

Supply Chain Logistics in Developing Countries

Supply chain logistics indicators remain relatively low in developing countries compared to their developed counterparts. For instance, the average scores (out of 5) for supply chain infrastructure, customs and border procedures, quality of logistics services, and supply chain reliability were 2.33, 2.34, 2.49 and 2.58 respectively (see Table 11). This places low income countries at the bottom rank of the LPI scale (Arvis, Mustra, Ojala, Shepherd, & Saslavsky, 2014). In contrast, Singapore, Germany and Netherlands – developed countries – have consistently scored above 4.0 on all logistics indicators over the same period. The findings in this study are similar to earlier works that related logistics performance indicators with country's development, economic competiveness and social development (Arvis et al., 2014; Guner & Coskun, 2012). As a result, improvements in logistics and supply chain are imperative in order to facilitate socio-economic development and global competitiveness of low income countries (Iwanow & Kirkpatrick, 2009; Puertas, Martí, & García, 2014) .

Supply Chain Infrastructure and Disease Prevention

There was a direct significant correlation between supply chain infrastructure and control of tropical disease in low and middle income endemic countries ($R = 0.21$, R^2 =

0.046, p = 0.008). Therefore, strengthening supply chain infrastructure will significantly improve preventive chemotherapy coverage for the control tropical diseases in developing countries. Hence, using the Ecological Theory of disease prevention, this research demonstrated that supply chain infrastructures are significant predictors of nation's health, particularly in resource-limited developing countries. The significant of this study is that, diseases prevention interventions can no longer neglect supply chain infrastructure as predictor of PCT coverage for the elimination of tropical diseases.

In a similar study using the Ecological Theory, Cohen et al., (2000), identified ecological structures contributing to nation's health as safe roads, transportation and vector control (Cohen et al., 2000). Also, using the LPI, Arvid et al., (2007, 2010, 2012 & 2014) identified the significant of supply chain infrastructure on social, economic and trade facilitation in developing countries.

Guner & Coskun (2012) performed regression analysis with LPI and concluded that logistics infrastructure predicts economic and social wellbeing in Organization for Economic Cooperation and Development (OECD) countries (Guner & Coskun, 2012). The authors argued that social predictors such as risky behaviors, democracy and human development, are ecological determinants of socioeconomic wellbeing of a country(Guner & Coskun, 2012).

In contrast, the current study confirms that logistics and supply chain infrastructure are predictors of MDA coverage for preventive chemotherapy in the control of tropical infectious diseases in developing countries. Consequently, strengthened supply chain infrastructure may significantly impact disease prevention and control interventions. Hence, this work revealed the role of supply chain infrastructure in predicting not just the socio-economic competitiveness of developed countries, but also in disease prevention strategies of developing countries. Others have shown how supply chain capacity improved on availability of life-saving blood-bank inventories (Nagurney, Masoumi, & Yu, 2012), vaccines (Haidari et al., 2013), essential medicines (Chandani et al., 2012), and outbreak response (Mbohwa, 2010). Hence, this study contributes to Supply Chain Epidemiology by affirming the role of strengthened supply chain infrastructures as mitigating interventions in the control of tropical diseases in endemic countries.

Customs and Border Procedures and Disease Control

There was a significant relationship between customs and border procedures and control of tropical diseases in developing countries ($r = 0.24$, $n = 154$, $p = 0.003$). This relationship implies that as customs and border procedures becomes expeditious or effective, so is the clearance and distribution of preventive chemotherapy in the control of NTDs. This finding is consistent with previously reported study by Wilson (2007) that expeditious customs and border processes facilitate trade and contribute to the availability of products that are sensitive to long and cumbersome customs procedures (Wilson, 2007). Hence, this finding affirms the earlier reported observation that improved customs and border procedures significantly contributes to countries' competitiveness (Wilson, 2007).

Ari-Pokka & Johan, (2009) also reported that, socioeconomic development correlates to modernized and regionally harmonized customs and border procedures which further highlight the impact of customs and border procedures on the overall wellbeing of nations. However, with limited modernization of customs and border procedures in developing countries, with reliance on obsolete infrastructure it is difficult for essential products (such as PCT drugs) to reach end-users at the right time (Ari-Pekka & Juha, 2009).

Inasmuch as this study affirmed earlier studies by Wilson (2007) and Ari-Pekka & Juha (2009), the current finding further predicted the significance of customs and border procedures to the coverage of preventive chemotherapy drugs in disease control. In preventive chemotherapy, anti-helminthic drugs – ivemectin, albendazole and others, are manufactured by international pharmaceutical companies (e.g. GlaxoSmithKline) outside developing countries, and donated to endemic countries, through WHO elimination program. However, it is the responsibility of recipient country to expeditiously distribute these pharmaceuticals from point-of-entry to hard-to-reach communities within the country. This requires speedy clearance processes, reliable transportation and supply chain infrastructure, which are inadequate thereby affecting the success of PCT coverage. As a result, control of tropical disease with preventive drugs, remain under threat with inefficient customs and border procedures in developing countries.

Logistics Services and Disease Prevention

Logistics services defined the quality and number of logistics service providers in the country. It evaluates the quality of transportation services delivered by road, rail, air, maritime, warehousing and distribution (Arvis et al., 2014). It is a logistics indicator that measures the performance of freight forwarders, logistics carriers, transportation agencies (air, rail, road and maritime) and other service providers along the supply chain.

There was a statistically non-significant ($r = 0.14$, $p = 0.078$) correlation between logistics services and the control of tropical diseases; implying quality of logistics services providers does not significantly influence the coverage of preventive chemotherapy in disease control. However, the absence of statistical significance correlation does not limit the practical utilization of this indicator for policy decisions. Its practical implication is that the quality of logistics services providers is somewhat related to disease prevention ($r = 0.14$), and hence improvements in the quality of providers may contribute to, albeit insignificant, to reducing the burden of tropical disease. In fact, Arvis et al., (2014) reported that clientele satisfaction was stronger in regions with quality service providers than those with lower quality of services (Arvis et al., 2014). Subsequently, improvements in the quality of rail, road, air and maritime logistics services providers will enhance the expeditious transport of PCT drugs to end-user which will contribute to achieving global goals.

Supply Chain Reliability and Disease Prevention

Supply chain reliability tracks the possible causes of shipments delays that is endogenous to countries' systems and procedures. Possible causes of shipments delays were identified as informal monetary payments (bribes), compulsory warehousing and maritime transshipments, which are affecting the overall performance of domestic supply chain capacity in developing countries. In contrast to developed countries with defined supply chain traceability through electronic transactions (e-commerce), developing countries still rely on multiagency transactions and direct solicitation of services and fees (Haidari et al., 2013). Thus, developing countries continue to have lower scores on supply chain reliability compared to developed nations, resulting in lower supply chain capacity for trade facilitation and disease prevention.

There was weak statistically significant correlation between supply chain reliability and disease control ($r = 0.16$, $p = 0.046$), in endemic countries. As a result, improvements in supply chain reliability marginally influence the control of tropical diseases in endemic countries. Nonetheless, leveraging on the experiences of developed countries, low-income countries can enhance the reliability of their supply chain if they eliminate informal monetary payments, introduce electronic transactions and streamline interagency bottlenecks.

LPI and Disease Prevention

The LPI is the combination of supply chain and logistics indicators used to assess the supply chain capacity of nations. Individually, these indicators measure specific strengths or weaknesses in countries' competitiveness in trade facilitation at national and international levels. Several studies have been conducted by the World Bank and the academia to relate LPI with trade facilitation, socioeconomic development, and human development indices (Arvis et al., 2014; Guner & Coskun, 2012; Puertas et al., 2014). Nevertheless, the application of LPI to control of tropical diseases was minimally explored; hence this study aimed at contributing to this body of knowledge.

Results from the multiple regression analysis revealed statistically significant ($r = 0.27$, $n = 145$, $p = 0.02$) correlations between LPI and the control of NTD. Further, the strength of the correlation index (r = 0.3) is higher than any of the individual indicator alone, implying synergic effect of the indicators as an index. Consequently, for developing countries to significantly control tropical diseases, strengthened supply chain capacity – infrastructure, customs and border procedures, logistics services and supply chain reliability – must attracts policymakers and researchers attention.

When LPI was ranked among nations, developing countries had lower average scores across all indicators compared to their developed counterparts, which is a confirmation of the role of logistics capacity to national development (Arvis et al., 2012). Researchers have correlated LPI with human development index, international competitiveness, and social and economic factors, and have concluded that low LPI scores are related to lower socio-economic status in developing countries (Arvis et al., 2014; Guner & Coskun, 2012; Puertas et al., 2014).

Expanding on the application of LPI to disease prevention strategies, this study demonstrated that LPI scores significantly impact the control of NTDs in low- and middle-income countries. Additional finding of this study is that endemic countries with improved supply chain capacity have experienced substantial reduction in the burden of NTDs. For instance, Malaysia and Thailand, which have consistently scored high on all logistics indicators, have reached their eradication benchmark, whereas Ethiopia, Guinea and Sierra Leone, with consistently lower LPI scores are yet to achieve eradication benchmarks. Further confirming the impact of supply chain capacity in attaining global benchmark targets of control and eventual eradication of tropical diseases by 2020.

Limitation of the Study

Data collection for MDA coverage was voluntary, and endemic countries were at different stages of PCT implementation creating gaps in the information reported to the central repository, making it difficult to attain statistically significant sample size for the criterion variable. However, the use of stratified purposeful sample as alternative to statistical sample technique still validates the reliability and subsequent generalization of this result (Pallant, 2013).

The value of Spearman's Correlation Coefficients (R) for this study, which ranges from 0.1 to 0.3 is interpreted as moderate correlation (Pallant, 2013), suggesting that other variables, which were not the focus of this research, may be contributory. Hence, this study is limited in claiming cause-and-effect relationship between supply chain capacity and disease prevention.

Recommendations

Policymakers should give consideration to supply chain infrastructure in developing strategies for controlling the burden of tropical diseases. In the application of preventive chemotherapy for the control of tropical diseases, it is imperative that mitigating factors affecting the distribution and availability of preventive drugs are considered. The WHO's five-point strategy for elimination highlighted PCT, vector control, human-veterinary interface, provision of safe water and sanitation, and strengthened national capacity on NTD control was proposed (WHO, 2013) as important determinant of success. However, policies on structure capacity, social determinants of health, and supply chain infrastructure for PCT drugs coverage have not received the desired attention. For this reason, some researchers have called for the halting of overmedication of the population as the principal strategy to NTD control (Spiegel et al., 2010). As shown in the current study, there exist relationships among supply chain infrastructure, logistics services, customs and border procedures, and supply chain reliability and MDA coverage of PCT drugs, which further confirms the need to develop supply chain strategic policy towards global eradication by 2020.

Research in developing Supply Chain Epidemiology as an area of study is highly recommended. From the current exploratory study, it became obvious that supply chain infrastructure can have significant impact disease control interventions in low and middle income countries. In 2006, the United States Government lunched a global supply chain project, the Supply Chain Management System, that has procured, and distributed over $10 billion worth of public health commodities to developing countries for over 5 million people requiring HIV treatment (PEPFAR 3.0 document, 2015). This project has collected substantial data and information on supply chain structures and challenges in developing countries. It is recommended that further research should be conducted using the collected data to relate supply chain capacity to prevalence, disability or mortality of HIV/AIDS to validate the significant investment in supply chain system strengthening.

Further research is recommended in Supply Chain Epidemiology to determine the relation between supply chain capacity and the prevalence of other communicable and/or non-communicable diseases including bed net distribution in malaria control, ARV distribution and HIV prevalence, directly observed therapy (DOT) for tuberculosis control, and vaccination with child mortality. This will further expand the reach of supply chain infrastructure capacity in the prevention, control and elimination of communicable and non-communicable diseases; the objective of Supply Chain Epidemiology.

Practical recommendation for the control of tropical diseases is providing technical and financial support to underdeveloped economies on sustainable infrastructure development and poverty alleviation. NTD has been termed “disease of poverty” because of its association with underdevelopment, poor sanitation ad hygiene Hence, developing sustainable socio-economic structures in endemic communities will alleviate the unintended hardship of these communities and provides alternatives to economic, social, and environmental wellbeing that influence population health.

Social Change Implications of this Research

This research has individual, community, and global social implications. At the individual level, I continually share the outcome of this study on social media (LinkedIn), community of practitioners (Association of Public Health Logisticians), and peer-review journal, in order to advocate for policies, and interventions using concepts and theories of supply chain epidemiology. With this effort, a new body of knowledge is developed and, when enhanced, will contribute to the global scientific community on the application of supply chain theories and principles to epidemiological investigations.

At the community level, availability of preventive chemotherapy drugs contributes to disease control, which eventually will lead to reduction in morbidity and mortality. Hence, there is value in identifying community-level mitigating factors that impact the distribution and availability of essential preventive drugs for the control of lymphatic filariasis in endemic communities.

The global effort to eradicate NTD by 2020 is under threat if supply chain infrastructure is not adequately strengthened in developing countries. This research therefore provided practical quantitative evidence on the impact of supply chain on the control of tropical diseases. From this study, there is the need to develop global supply chain strategies as a way of enhancing the existing interventions in order to achieve global benchmarked coverage for the control of tropical diseases in developing countries.

Conclusion

The objective of this study was to explore the role of supply chain indicators on the control of NTDs. The results of this study showed a linear correlation between supply chain infrastructure capacity and developing countries' ability to reach global eradication targets for the control and eventual elimination of tropical diseases. As a result, strengthening supply chain capacity in developing countries, through technical and financial prepositions, will significantly enhance the availability of preventive chemotherapy drugs, which will eventually reduce transmission, improve social wellbeing, reduce disability and eliminate disease-specific mortality.

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Appendix A: Permission Letter from the World Bank

Dear Farouk Umaru,

In response to your request under AI3647, the World Bank would like to refer you to World Bank Open Data site for free and easy access to World Bank data and statistics. Through this website, users have access to databases, pre-formatted tables and reports. Additional tools, including search, provide simple methods to find indicators and data quickly, with download and visualization options. Data is organized by Country, Topic, and Indicators, available in English, Spanish, French, and Arabic. The full set of the World Bank's indicators on development are also available in the Data Catalog with over 2,000 time series indicators, for over 200 economies, and in many cases for over 50 years. The range of topics covered includes:

Agriculture and Rural Development

Aid Effectiveness

Economic Policy and External Debt

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Energy and Mining

Environment

Financial Sector

Health

Infrastructure

Labor and Social Protection

Poverty

Private Sector

Public Sector

Science & Technology

Social Development

Urban Development

If you are unable to find data responsive to your request through the data.worldbank.org website, please send your query to data@worldbank.org or call the help desk at +202 473 7824. If you require additional information other than data, you can consult the following websites:

Country pages – provides information on countries

Topic Pages – provides information by topic

Documents and Reports Database – provides full-text project documents, research and working papers

Projects Database – provides information on projects and analytical and advisory services provided by the Bank

Archives Oral History Program – provides firsthand accounts of important events by present and former World Bank staff

ISAD(G) Finding Aids – provides more specific and historical information on a variety of topics

If you still cannot find the information you are looking for, you are welcome to submit a new request on line through the World Bank's website specifying the information you would like to have access.

Thank you.

Ann May

The World Bank

www.worldbank.org/wbaccess

Access to Information 2/2/2015

Appendix B: WHO Permission to use copyright information

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12. Headings. Paragraph headings in this Agreement are for reference only.

13. Dispute resolution. Any dispute relating to the interpretation or application of this Agreement shall, unless amicably settled, be subject to conciliation. In the event of failure of the latter, the dispute shall be settled by arbitration. The arbitration shall be conducted in accordance with the modalities to be agreed upon by the parties or, in the absence of agreement, with the rules of arbitration of the International Chamber of Commerce. The parties shall accept the arbitral award as final.

14. Privileges and immunities. Nothing in or relating to this Agreement shall be deemed a waiver of any of the privileges and immunities enjoyed by WHO under national or international law and/or as submitting WHO to any national court jurisdiction.

Appendix C: About Logistics Performance Index (LPI)

Verbatim narrative about LPI from the World Bank website:

Welcome to the LPI! The Logistics Performance Index is an interactive benchmarking tool created to help countries identify the challenges and opportunities they face in their performance on trade logistics and what they can do to improve their performance. The LPI 2014 allows for comparisons across 160 countries. The LPI is based on a worldwide survey of operators on the ground (global freight forwarders and express carriers), providing feedback on the logistics “friendliness” of the countries in which they operate and those with which they trade. They combine in-depth knowledge of the countries in which they operate with informed qualitative assessments of other countries where they trade and experience of global logistics environment. Feedback from operators is supplemented with quantitative data on the performance of key components of the logistics chain in the country of work.

The LPI consists therefore of both qualitative and quantitative measures and helps build profiles of logistics friendliness for these countries. It measures performance along the logistics supply chain within a country and offers two different perspectives: international and domestic.

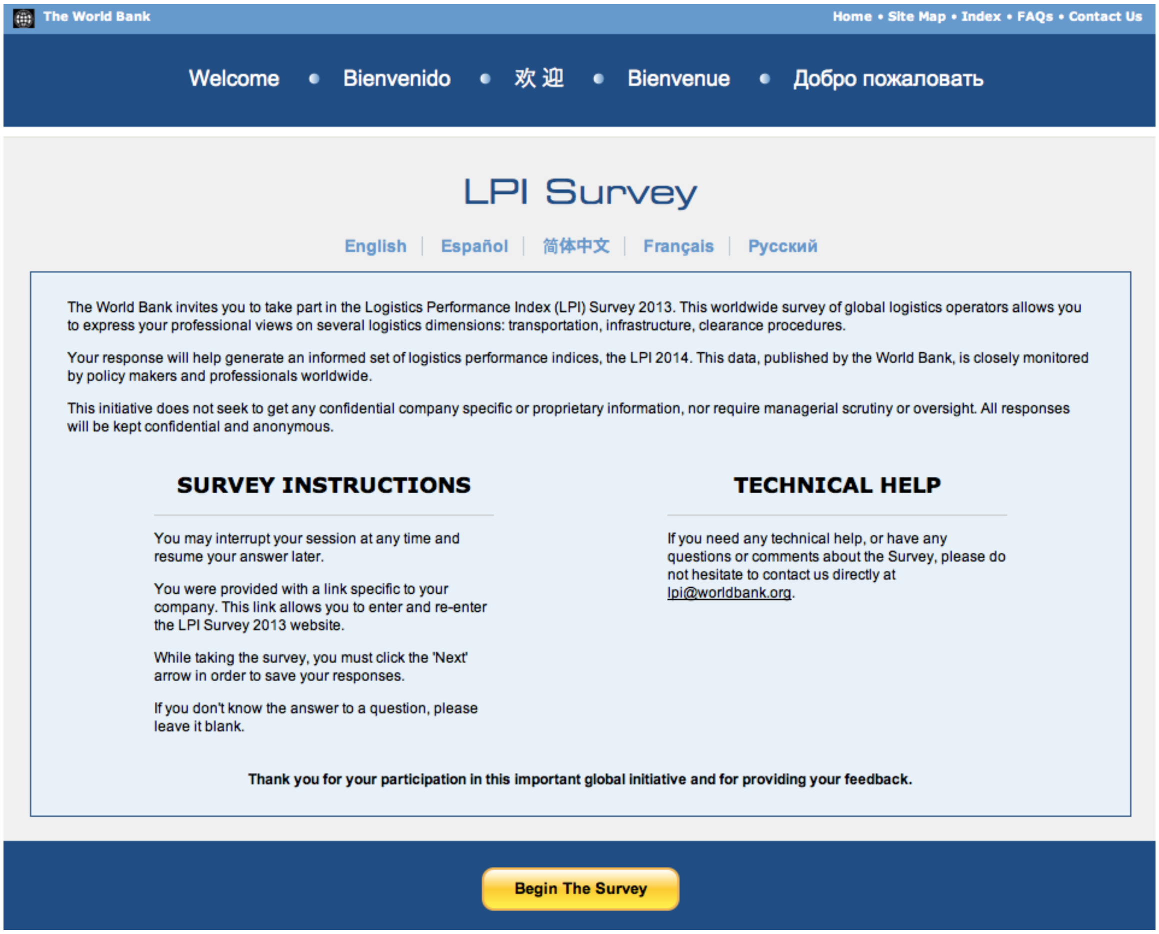
International LPI

Provides qualitative evaluations of a country in six areas by its trading partners—logistics professionals working outside the country.

Domestic LPI

Provides both qualitative and quantitative assessments of a country by logistics professionals working inside it. It includes detailed information on the logistics environment, core logistics processes, institutions, and performance time and cost data.

Appendix D: Example of 2014 LPI survey tool



You Are Here ▶ **Begin Survey** > International LPI > Domestic LPI > End Survey

Please select from each group the option that **best describes** your current work:

You must complete questions marked * to begin the survey.

1/34 Your position in your company (choose one)

- ○ Senior Executive
- ○ Area and/or Country Manager
- ○ Department Manager
- ○ Supervisor
- ○ Operations
- ○ Other

2/34 Organizational level

- ○ Corporate and/or Regional Headquarters
- ○ Country Branch Office
- ○ Local Branch Office
- ○ Independent Firm/Entrepreneur

3/34 What is the number of employees for your company (choose one) *

- ○ 1-9
- ○ 10-49
- ○ 50-249
- ○ 250-499
- ○ 500 or more

4/34 The freight mode you typically deal with in your work (choose one)

- ○ Maritime
- ○ Road
- ○ Rail
- ○ Air Transport
- ○ Express delivery
- ○ Multimodal

5/34 Direction of trade and transport you are primarily dealing with (choose one)

- ○ Export
- ○ Import
- ○ Export and Import
- ○ Domestic
- ○ International transit
- ○ Most of the above

6/34 Main line of your work (choose one)

- ○ Full Container/Trailer Loads
- ○ Less than Full Container/Trailer Loads
- ○ Bulk/Break Bulk Cargo
- ○ Customer Tailored Logistics Solutions
- ○ Warehousing and Distribution
- ○ Courier Services
- ○ Most of the above

7/34 Which of the following geographical regions do you deal with most in your work (choose one)

--- Select ---

8/34 The country you are currently working in *

--- Select ---

☐ Check here to confirm country selection

You have selected

as the country you are currently working in. If this is not correct, please go back and select the correct country.

9/34 Enter the postal or ZIP code of your facility (alternatively enter the name of the city)

Email

Please enter your email address to use the 'resume later' button (optional)

You Are Here ▶ Begin Survey > **International LPI** > Domestic LPI > End Survey

+ Survey Status

In this part of the questionnaire, questions 10 to 16, you are invited to rate eight countries listed below along seven key dimensions in logistics performance. The countries have been generated based on the trading partners of your selected country of work. (United States)

Based on your experience in **international logistics**, please select the option that **best applies** to each individual country against the generally accepted industry standards or practices. If you are not familiar with the clearance process in a particular country, leave that country blank.

10/34 Rate the **efficiency of the clearance process** (i.e. speed, simplicity and predictability of formalities) by border control agencies, including Customs in ...

	Very low	Low	Average	High	Very high
Korea, Rep.	○	○	○	○	○
Taiwan	○	○	○	○	○
Chad	○	○	○	○	○
Georgia	○	○	○	○	○
El Salvador	○	○	○	○	○
Denmark	○	○	○	○	○
Sudan	○	○	○	○	○
Libya	○	○	○	○	○

You Are Here ▶ Begin Survey > **International LPI** > Domestic LPI > End Survey **+ Survey Status**

11/34 Evaluate the **quality of trade and transport related infrastructure** (e.g. ports, railroads, roads, information technology) in...

	Very low	Low	Average	High	Very high
Korea, Rep.	○	○	○	○	○
Taiwan	○	○	○	○	○
Chad	○	○	○	○	○
Georgia	○	○	○	○	○
El Salvador	○	○	○	○	○
Denmark	○	○	○	○	○
Sudan	○	○	○	○	○
Libya	○	○	○	○	○

12/34 Assess the **ease of arranging competitively priced shipments** to ...

	Very Difficult	Difficult	Average	Easy	Very Easy
Korea, Rep.	○	○	○	○	○
Taiwan	○	○	○	○	○
Chad	○	○	○	○	○
Georgia	○	○	○	○	○
El Salvador	○	○	○	○	○
Denmark	○	○	○	○	○
Sudan	○	○	○	○	○
Libya	○	○	○	○	○

You Are Here ▶ Begin Survey > **International LPI** > Domestic LPI > End Survey **+ Survey Status**

13/34 Evaluate the overall level of **competence and quality of logistics services** (e.g. transport operators, customs brokers) in ...

	Very low	Low	Average	High	Very high
Korea, Rep.	○	○	○	○	○
Taiwan	○	○	○	○	○
Chad	○	○	○	○	○
Georgia	○	○	○	○	○
El Salvador	○	○	○	○	○
Denmark	○	○	○	○	○
Sudan	○	○	○	○	○
Libya	○	○	○	○	○

14/34 Rate the **ability to track and trace your consignments** when shipping to...

	Very low	Low	Average	High	Very high
Korea, Rep.	○	○	○	○	○
Taiwan	○	○	○	○	○
Chad	○	○	○	○	○
Georgia	○	○	○	○	○
El Salvador	○	○	○	○	○
Denmark	○	○	○	○	○
Sudan	○	○	○	○	○
Libya	○	○	○	○	○

You Are Here ▶ Begin Survey > **International LPI** > Domestic LPI > End Survey

+ Survey Status

15/34 When arranging shipments to the countries listed below, how often do they **reach the consignee within the scheduled or expected delivery time**?

	Hardly Ever	Rarely	Sometimes	Often	Nearly Always
Korea, Rep.					
Taiwan					
Chad					
Georgia					
El Salvador					
Denmark					
Sudan					
Libya					

16/34 How often do shippers **ask for environmentally friendly options** (e.g. in view of emission levels, choice of routes, vehicles, schedules, etc.) when shipping to ...

	Hardly Ever	Rarely	Sometimes	Often	Nearly always
Korea, Rep.					
Taiwan					
Chad					
Georgia					
El Salvador					
Denmark					
Sudan					
Libya					

You Are Here ▶ Begin Survey > International LPI > **Domestic LPI** > End Survey

+ Survey Status

Your Country of Work

United States

In this part of the questionnaire, questions 17 to 22, you are invited to provide **your assessment** on the logistics environment and institutions **in your country of work** (United States).

The questions have been grouped according to the following themes: cost, quality of infrastructure, competence, clearance.

17/34 Based on your experience in **international logistics**, please select the options that **best describe** the operational logistics environment **in your country of work** (United States)

	Very high	High	Average	Low	Very low
Port charges	○	○	○	○	○
Airport charges	○	○	○	○	○
Road transport rates	○	○	○	○	○
Rail transport rates	○	○	○	○	○
Warehousing/transloading service charges	○	○	○	○	○
Agent fees	○	○	○	○	○

18/34 Evaluate the **quality of trade and transport related infrastructure** (e.g. ports, roads, airports, information technology) in your country of work (United States)

	Very low	Low	Average	High	Very high
Port infrastructure	○	○	○	○	○
Airport infrastructure	○	○	○	○	○
Road infrastructure	○	○	○	○	○
Rail infrastructure	○	○	○	○	○
Warehousing/transloading facilities	○	○	○	○	○
Telecommunications infrastructure and IT services	○	○	○	○	○

Your Country of Work

United States

19/34 Evaluate the **competence and quality of service** delivered by the following in your country of work (United States)

	Very low	Low	Average	High	Very high
Road transport service providers	○	○	○	○	○
Rail transport service providers	○	○	○	○	○
Air transport service providers	○	○	○	○	○
Maritime transport service providers	○	○	○	○	○
Warehousing/transloading and distribution operators	○	○	○	○	○
Freight forwarders	○	○	○	○	○
Customs agencies	○	○	○	○	○
Quality/standards inspection agencies	○	○	○	○	○
Health/SPS (Sanitary and Phyto-Sanitary) agencies	○	○	○	○	○
Customs brokers	○	○	○	○	○
Trade and transport related associations	○	○	○	○	○
Consignees or shippers	○	○	○	○	○

20/34 Evaluate the **efficiency** of the following processes in your country of work (United States)

	Hardly Ever	Rarely	Sometimes	Often	Nearly Always
Are import shipments cleared and delivered as scheduled?	○	○	○	○	○
Are export shipments cleared and shipped as scheduled?	○	○	○	○	○
Is the Customs clearance procedure transparent?	○	○	○	○	○
Is the clearance procedure of other border agencies transparent?	○	○	○	○	○
Do you receive adequate and timely information when regulations change?	○	○	○	○	○
Do traders demonstrating high levels of compliance receive expedited clearance?	○	○	○	○	○

You Are Here ▶ Begin Survey > International LPI > **Domestic LPI** > End Survey

Survey Status

Your Country of Work

United States

21/34 How often in your country of work (United States), you experience

	Nearly Always	Often	Sometimes	Rarely	Hardly Ever
Major delays due to compulsory warehousing/transloading	○	○	○	○	○
Major delays due to pre-shipment inspection	○	○	○	○	○
Major delays due to maritime transshipment	○	○	○	○	○
Criminal activities (e.g. stolen cargo)	○	○	○	○	○
Solicitation of informal payments in connection with logistics activities	○	○	○	○	○

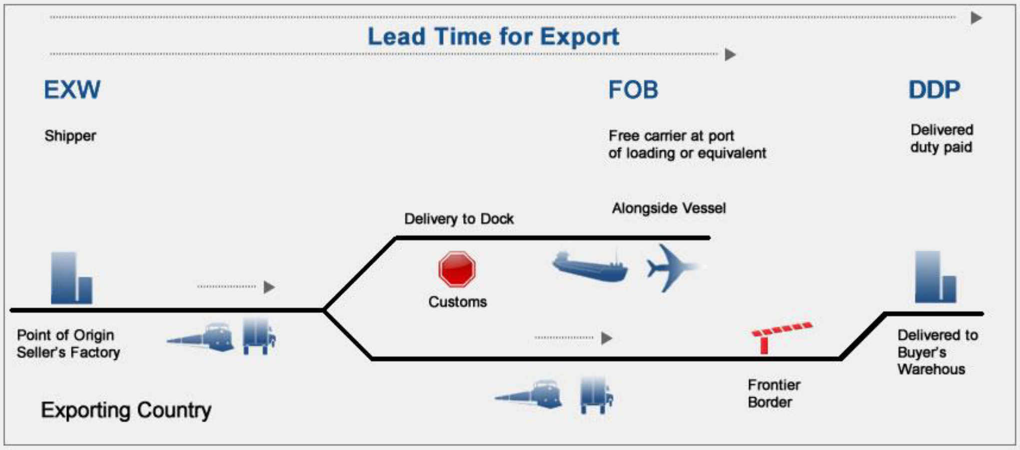
22/34 Since 2011, have the following factors improved or worsened in your country of work (United States)

	Much Worsened	Worsened	About the Same	Improved	Much Improved
Customs clearance procedures	○	○	○	○	○
Other border-related government agencies clearance procedures	○	○	○	○	○
Quality of trade and transport related infrastructure	○	○	○	○	○
Quality of telecommunications/IT infrastructure	○	○	○	○	○
Quality of private logistics services	○	○	○	○	○
Regulation related to logistics	○	○	○	○	○
Solicitation of informal payments in connection with logistics activities	○	○	○	○	○

Your Country of Work

United States

In this part of the questionnaire, questions 23 to 34, you are invited to provide **your assessment** on the logistics performance in **your country of work**: United States



23/34 When **exporting** a full load from your country of work (United States), please estimate the following **time** and **cost** parameters.

Please select from below the portion of the supply chain that best describes your work

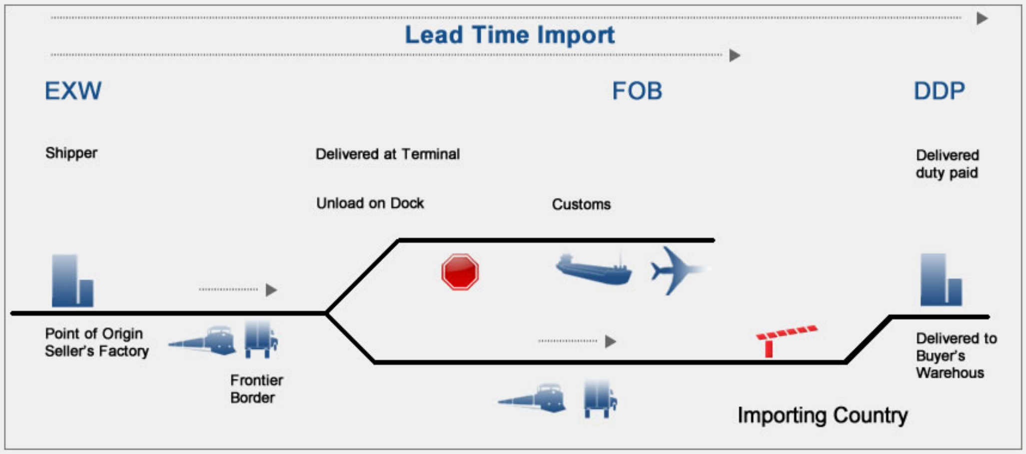
- ○ TO PORT / AIRPORT – Export pre-carriage: EXW to FOB
- ○ BY LAND – Export carriage: EXW to DDP
- ○ Both

24/34 Consolidation: How much more would it cost to send a one ton shipment as less than full (container, truck) load (LCL/LTL) as compared with a ton sent as part of a full load (FCL/FTL) when exporting from your country of work (United States) on the same routes?

--- Select ---

Your Country of Work

United States



25/34 When **importing** a full load to your country of work (United States), please estimate the following **time** and **cost** parameters.

Please select from below the portion of the supply chain that best describes your work

- ◯ FROM PORT/AIRPORT – Import on-carriage: DAT to DDP
- ◯ BY LAND – Import carriage: EXW to DDP
- ◯ Both

26/34 As a logistics provider, do you maintain indicators of service level to client? If yes, what is the percentage of imports to your country of work (United States) meeting your quality criteria for delivery to the consignee

--- Select ---

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27/34 How many government agencies involved in the clearance process do you **typically** deal with in your country of work (United States)

For imports	--- Select ---
For exports	--- Select ---

28/34 How many forms do you **typically** have to submit, for clearance, in your country of work (United States)

For imports	--- Select ---
For exports	--- Select ---

29/34 For imports, estimate the average **time** taken between the submission of an accepted Customs declaration and notification of clearance in your country of work (United States)

Without physical inspection	--- Select ---
With physical inspection	--- Select ---

30/34 What are the main methods for determining whether shipments are physically inspected by **Customs**

	Yes	No	N/A	Do not know
Automated risk assessment	○	○	○	○
Inspector discretion	○	○	○	○

31/34 On average, what percentage of your import shipments is **physically inspected** (excluding X-ray and scanning) in your country of work (United States)

--- Select ---

32/34 Of all the import shipments what percentage are **physically inspected more than once** in your country of work (United States)

--- Select ---

You Are Here ▶ Begin Survey > International LPI > **Domestic LPI** > End Survey

+ Survey Status

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33/34 Does Customs regularly apply reference prices or other forms of arbitrary uplifts?

- ○ Yes
- ○ No
- ○ N/A
- ○ Do not know

34/34 Please evaluate the following statements regarding Customs, in your country of work (United States)

	Yes	No	N/A	Do not know
Can Customs declarations be submitted and processed **electronically and on-line**?	○	○	○	○
Can supporting documentation be submitted and processed **electronically and on-line**?	○	○	○	○
Does Customs allow for **pre-arrival processing** of import shipments?	○	○	○	○
Does Customs code require importers to use a **licensed** Customs Broker to clear goods?	○	○	○	○
Are you or your customer able to choose the **location of the final clearance** of the goods for imports?	○	○	○	○
Can goods be **released pending final clearance against an accepted guarantee**?	○	○	○	○
Are you and your peers **invited for dialogue by Customs** through a formal process (periodic meeting, consultative forum or committee or the like)?	○	○	○	○
In cases of dispute with Customs or another border agency, is a non-judicial **review/appeal procedure** available?	○	○	○	○
Are up to date import/export requirements and procedures **published on an official website**?	○	○	○	○