AN INTERNATIONAL SPATIAL ANALYSIS OF THE WELFARE SPENDING'S INFLUENCE ON MEASLES IMMUNIZATION

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By
Mary Ellen Walker

ABSTRACT

Background: Welfare policy may reflect political-economic contexts that have important implications for peoples' lives, including their health. Previous research has explored how welfare policies influence health, but no research has explored how welfare spending influences health interventions. Furthermore, little research on welfare policy or published in nursing journals has used spatial analysis.

Purpose: The objective of this study is to develop an analytical approach to maximise exploration of welfare spending's influence on the relationship between measles vaccination rates and measles infection rates over time and geographic location.

Methods: The objective of this study is addressed with four manuscripts. A scoping review provides an analysis of literature that explores welfare spending in relation to immunizations. A theoretical model manuscript combines the Levels of Prevention model and the Ecological model for Health Promotion to outline relationships between the concepts of interest. The methodology manuscript outlines an analytical approach for statistical methods that lead to implementation of spatial regression. It includes the process of building generalized linear mixed models and implementing Bayesian analysis. Using this analytical approach, global and local Moran's I tests indicate that spatial relationships are present among the variables of interest. Therefore, a conditional autoregressive model is also tested to account for spatial random effects. In the fourth manuscript, these results outline the findings from the model testing.

Results: The final model finds that both the first dose of measles vaccine (B = -0.835, 95% Cr. I. = -0.975, -0.699), public social protection (B = -0.936, 95% Cr. I. = -1.132, -0.744), and their interaction (B = -0.239, 95% Cr. I. -0.319, -0.156) have a negative relationship with measles rates. Spatial random effects are not included in the final model because they do not improve the model fit.

Significance of findings: These results suggest that national welfare spending may influence the relationship between measles infection rates and measles immunizations. Furthermore, the analytical approach manuscript makes spatial regression more accessible to health researchers.

These findings, and the analytical approach used to reach them, have potential to build on the nursing and health literature while increasing the understanding of policy’s influence on health.

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Dean
College of Graduate and Postdoctoral Studies
University of Saskatchewan
116 Thorvaldson Building, 110 Science Place
Saskatoon, Saskatchewan S7N 5C9 Canada

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DEDICATION

To my mother, who always pushed me to be my best.

To Noor and Janet.

To Jack, Kolt, Parker, and Layton.

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LIST OF ABBREVIATIONS

AIDS – acquired immune deficiency syndrome

BCE – before common era

BCG – Bacillus Calmette-Guérin

BIC – Bayesian Information Criterion

CAR – conditional autoregressive

CME – coordinated market economy

CODA – convergence output and diagnostic assessments

DTP – diphtheria-tetanus-pertussis vaccine

FLF – female labor force

FTE – full time equivalent

GDP – gross domestic product

GLM – generalized linear models

GLMM – generalized linear mixed models

LISA – local indicator of spatial correlation

LME – liberal market economy

MCMC – Markov Chain Monte Carlo

MCV1 – first dose of measles containing vaccine

MCV2 – second dose of measles containing vaccine

PCA – principal component analysis

PSP – public social protection

SAS – statistical analysis system

SAS – statistical analysis system

SaTScan – software for the spatial, temporal and space-time scan statistics

SPSS – statistical package for the social sciences

VPC – variance partition coefficient

WHO – World Health Organization

WinBUGS – Windows operating system for the Bayesian analysis using Gibbs sampling

1.0 INTRODUCTION AND BACKGROUND

1.1 Introduction

The political environments in which people live may have implications for shaping their daily lives, including their health (Jorm & Ryan, 2014). Welfare policies have a significant role in shaping national political environments and impact people's lives from infancy to death (Ferrarini, 2006). A country's level of spending in providing welfare benefits and services may have implications for how people respond to health interventions. Therefore, it is reasonable that nurses consider welfare spending as an important influence on health and the outcomes of health interventions.

Because nurses provide care to people in diverse contexts, nurse researchers may benefit from research investigating the influence of welfare spending on health interventions. However, no research has focused on welfare spending's influence on the relationship between health interventions and outcomes. Most research focuses on countries clustered by similar welfare policies and the differences in health outcomes between these clusters of countries (Bergqvist, Aberg Yngwe, & Lundberg, 2013). Interestingly, countries with similar welfare policies often lie in close proximity of each other, yet limited research explores the impact of geography on these relationships.

Nurses could benefit from considering how place, or spatial location, influences their work and the populations they serve. Spatial analysis techniques published in the nursing literature include mapping, spatial statistics, and geographical information systems (GIS). However, in an exhaustive search of nursing journals, only one article reports using spatial regression methods, and this article does not report the results because the authors state that the findings are not significant (Blake, 2014). Therefore, the nursing literature would benefit from an analytical approach that presents spatial regression in an accessible way for nurse researchers. An analytical approach such as this will help nurses to expand their understanding of spatial analysis, including the process of analyzing spatial polygon data. This analytical approach will allow nurses to investigate how location influences their work and their patients' lives.

These literature gaps need to be addressed to expand nursing knowledge exploring the connection between welfare policy and health interventions. Therefore, this chapter introduces a dissertation that (1) presents the development of an analytical approach that will make spatial analysis more accessible to nurses and their inter-professional colleagues; and (2) addresses the influence that national levels of welfare spending have on the relationship between a preventative health intervention and its associated outcome on a global scale. The study aims to identify the influence of welfare spending levels on the relationship between a health intervention and its associated outcome while considering geographic location.

1.1.1 Significance

Nursing knowledge is broad because nurses interact with people in diverse contexts. The welfare policy of a country is one such context that is important for nurses to understand because welfare policy impacts many determinants of health. A country's welfare policies have implications for its peoples' health, education, work, and personal lives (Korpi, 1983). Welfare influences these aspects of life through socializing risk and providing equal opportunities (Esping-Andersen, 1990; Esping-Andersen, 2009; Kolberg & Esping-Andersen, 1992; Korpi, 2001). Supportive welfare policies for women have increased women's education, labor participation, and economic independence (Esping-Andersen, 2009). As more women enter the workforce, welfare policies are especially important in supporting families with child and elder care (Esping-Andersen, 2009; Ferrarini, 2006). Furthermore, male-breadwinner families are becoming less common, while dual-earner and single-parent homes are becoming more common (Esping-Andersen, 2009). This trend shows how welfare policies can influence family structure (Ferrarini, 2006) and have a significant impact for children.

Welfare policies play a role in children's lives because family conditions of childhood are rooted in social inheritance and impact opportunities and life chances (Esping-Andersen, 2002). For example, children are less likely to be exposed to poverty when their mothers work and have access to affordable childcare (Esping-Andersen, 2002; Esping-Andersen, 2009; Ferrarini, 2006). Quality childcare can even the playing field for children in terms of socialization and cognitive development (Esping-Andersen, 2009). Consequently, child health indicators are important to consider while exploring the influence of welfare spending on a preventative health intervention.

Nursing research has not often explored the political environment in relation to its impacts on nursing interventions and patient outcomes. Children may be especially vulnerable to the political environments in which they live. A study of the influence that a country's welfare spending has on the relationship between a preventative health intervention aimed at children and its associated outcome will address this gap in the literature. The study requires advanced statistical methods not found in nursing journals. Therefore, an analytical approach is developed to make spatial analysis more accessible to nurses and health researchers. This analytical approach is developed in analysis exploring the welfare spending in relation to prevention interventions.

1.2 Problem Statement

The current body of literature does not address a country's welfare spending in terms of its influence on the relationship between preventative health interventions and the associated outcomes that result from preventative health interventions. Researchers who explore countries' welfare policies often use groupings of countries that differ between studies and largely include countries in Europe and North America (Bergqvist et al., 2013). In addition, neither welfare policy research, nor research related to the political environment, have used spatial analysis to take into account relationships that exist between countries. There is also a lack of spatial research published in the nursing literature. Spatial analysis can capture the influence of geography on these international relationships, therefore is important to explore its influence.

1.3 Objectives and Research Questions

The purpose of this study is derived from the described gaps in the literature. The overall purpose is to develop an analytical approach to examine the influence of welfare spending on a preventative health intervention's relationship to its associated outcome considering geographic location over time. This analytical approach allows the research to make the most of the data while considering its characteristics. It is important to develop an analytical approach to explore this relationship because spatial modeling is underdeveloped in the nursing literature. The analytical approach can be used to aid other nurse researchers to explore spatial relationships to answer nursing research questions. This study will use country-level data in relation to welfare spending, immunization rates, and disease rates to address the objectives and questions of this study.

1.3.1 Objectives

The objectives of this study are to:

- develop an analytical approach for analysis of data considering geographic location over time; and
- use the analytical approach to enhance the evaluation of the influence that welfare spending has on the relationship between a childhood immunization series rate and its associated disease rate.

1.3.2 Research Question

To examine welfare spending, this study looks specifically at public social protection expenditure as a proportion of gross domestic product (GDP). Social protection expenditure as a proportion of GDP represents spending to reduce and prevent poverty, vulnerability, and social exclusion, including child and family benefits, maternity protection, unemployment support, employment injury benefits, sickness benefits, health protection, old-age benefits, disability benefits, and survivors' benefits (International Labour Organization, 2017). The preventative health intervention and outcome is represented with childhood the measles immunization series and its associated disease rates. Measles vaccination rates and numbers of measles cases were chosen to represent preventative health services because the World Health Organization (2017a) identifies measles as a highly infectious disease that can lead to serious complications, and it impacts millions of people every year. The inclusion of measles-related targets in the United Nations (2015) Millennium Development Goals underscores the importance of measles to global health. The emphasis that international organizations have put on measles has led to data collection regarding infection and immunization rates in most countries over several years, making data readily available for analysis. Furthermore, the World Health Organization (2017b) has a reporting process for collecting infectious disease and immunization data that aims for accuracy. This reporting process requires data collection from national ministries of health, annually, and the process allows for updates, clarifications, and revisions in order to aim for accuracy (World Health Organization, 2017b). For these reasons, measles represents preventative health services and its outcome in this study. Specific variables representing measles immunization series include measles containing vaccine first-dose (MCV1) and second-dose (MCV2), which represent the percentage of children who have received one or two doses of measles vaccine in a given year, respectively (World Health Organization, 2016). The disease outcome is total measles cases per country. These operationalized concepts allow for the following question to be explored:

- What analytical approach can be used to analyse how a variable (net proportion GDP spent on social protection) influences the relationship between a health intervention (MCV1 and MCV2) and its outcome (measles cases) while accounting for time and geographic location?

1.4 Definitions

For this study, there are concepts which need to be defined. These concepts include welfare spending, decommodification, defamilialization, and prevention. Additional definitions can be found in the glossary. Welfare spending is defined as the share of a country's income spent on social protection, as stated above. Previous research has used the term "welfare generosity." However, the word "generosity" may imply that a country that invests more in welfare policies is morally superior to a country that spends less on welfare policies. This terminology is problematic because it implies that high levels of welfare spending is the best policy option, while the research findings have not been conclusive. Therefore, the term welfare spending will be used in this proposal. Decommodification and defamilialization are linked with welfare spending (which will be explained in the theoretical literature review) because they represent means of social protection that are alternatives to making money in the market. Decommodification de-emphasizes income as the main determinant one's welfare, and it involves the state taking responsibility for welfare through the provision of benefits and services (Esping-Andersen, 1985; Esping-Andersen, 1990). Defamilialization involves the state taking over the costs and burdens associated with having a family (Esping-Andersen, 1999). This study will focus on primary prevention as a means to protect against a disease before it reaches a human (Clark & Leavell, 1965).

1.5 Background Literature

The literature gaps described above are informed from a comprehensive literature review. The focus of the literature review is to evaluate theory and research relating to national political environments and their relationship to health. Overall, the influence of political environments on health is underappreciated in the nursing literature. However, health researchers are increasingly addressing the political influences on health in various ways. These diverse research topics are based on a broad body of theoretical work, including democratic, economic, and welfare policy theories. The research literature examines political environments in terms of political systems, civil liberties, female political representation, political transition, socialism and capitalism, governance, war and instability, and welfare state policies. The following discussion outlines theories used to inform research concerning the link between political environments and health, a review of the research literature is outlined after a review of the theoretical literature.

1.5.1 Theoretical literature

Theorising about the ways in which political environments influence health started as far back as fifth century BCE when Hippocrates linked the political system and social milieu to human health (Beckfield & Krieger, 2009; Mallin & Hull, 2008). In addition, Plato considered how society could be organized to promote justice, well-being, and happiness (Benditt, 1998). In the 1800s, Friedrich Engels (1887) illuminated the influence of class and economy on health in *The Condition of the Working Class in England*. He found that workers and their families experienced poor living and working conditions in concurrence with poor physical and mental health and lack of access to adequate health care. Engels was one of the early theorists who began to make the connection between political environments and health, which has laid the groundwork for modern theorists. The dominant theories used in research exploring the relationship between political environments and health include theories of democracy, economics, and welfare policy.

1.5.1.1 Democracy

Researchers exploring the influence of political systems on health often use theories of democracy, such as Amartya Sen's *Development as Freedom*. In his theory, he asserts that development is an important process in expanding freedoms (Sen, 1999). Development removes "unfreedoms," like poverty, tyranny, poor economic opportunities, social deprivation, neglect of public facilities, intolerance, and repression (Sen, 1999). Freedom is dependent on social and economic arrangements, like education, healthcare, political rights, and civil rights (Sen, 1999). Sen (1999) believes that political rights and democracy create incentives for leaders to protect people's health.

Other health researchers use theory that explains how competition for popular support in democracies influences human development (Ruger, 2005). The theory of distribution explores how politicians distribute resources to influence voters (Meserve, 2009). In addition, ideology theory asserts that leftists promote expansionary policies and social insurance, and rightists attempt to decrease inflation (Potrafke, 2010). Political business cycle theory claims that politicians will implement expansionary policies before an election (Potrafke, 2010). Finally, political ecology theory explores human-environment relationships and interactions, considering contexts, history, and structure (Kalipeni & Oppong, 1998). These democracy-related theories help researchers investigate the broader influences on health.

1.5.1.2 Health and Economics

Economic-related theories also allow researchers to investigate the wider influences of social structure on health. In the economically influenced *Demand for Health* theory, individuals are thought to inherit health stock that depreciates over time (Grossman, 1999). Health is a commodity that can be improved with investment or used as an investment to increase participation in market and non-market activities (Grossman, 1999). However, environmental variables, like health services and education, are also considered important in producing health (Grossman, 1999). This theory considers health influential for peoples' economic opportunities rather than something that results from economic status.

The varieties of capitalism theory is another economic-related theory used in the health literature. In this theory, employees, firms, producer groups, and governments interact, but firms are the key agents for economic performance (Beckfield & Krieger, 2009; Hall & Soskice, 2001; McLeod, Hall, Siddiqi, & Hertzman, 2012). A firm's success depends on its ability to coordinate with the above-mentioned actors for industrial relations, vocational training and education, corporate governance, inter-firm relations, and employees (McLeod et al., 2012). The firms' relationships with these actors create economies that lie on a spectrum between liberal market economies (LME) and coordinated market economies (CME). LMEs coordinate themselves via hierarchy, competition, and formal contracting, while workers have less job security, more mobility, and general skills (Hall & Soskice, 2001; McLeod et al., 2012). CMEs use non-market relationships to coordinate interactions between firms; use relational contracting; create networks to allow for information exchange, competency building, and strategic interactions; collaborate with trade unions; and encourage employees to acquire specific skills for well-paid, long-tenure jobs (Hall & Soskice, 2001; McLeod et al., 2012). Researchers have used the varieties of capitalism theory as one way to investigate national differences in health based on policy differences.

1.5.1.3 Welfare State

The welfare state is another theoretical base that health researchers use to explain national differences in health based on political environments. The welfare state has its origins in the class relations of capitalist democracies, a field of inquiry in which Karl Marx and Max Weber were highly influential (Korpi, 1983). Marx and Weber's theoretical contributions to welfare state theory are reviewed below, along with the main characteristics of welfare states and the dominant welfare state theory in the health literature.

1.5.1.3.1 Marx.

Karl Marx's writings had a strong influence on the political economy perspective of society, especially related to the welfare state (McDonnell, Lohan, Hyde, & Porter, 2009). His primary criticism of capitalism was based on the means of production and private ownership because he thought they created unequal classes (Arnold, 1998; McDonnell et al., 2009). He believed that class relations influence all aspects of life, including health and well-being (McDonnell et al., 2009). Classes are formed in capitalist states when workers (the proletariat class) are forced to sell their labor as a commodity to capitalists who own the means of production (the bourgeoisie class), while capitalists live off the labor of the workers (Arnold, 1998; Millar, 2005). For Marx, capitalism was flawed and would eventually lead to class-consciousness and self-destruction (Arnold, 1998; McDonnell et al., 2009; Millar, 2005). Marx's view on class and inequality illuminates how capitalism influences society, which is important for understanding the link between political environments and health.

1.5.1.3.2 Weber

Max Weber is another contributor to early theory regarding political economy. Weber emphasized class, market resources, and status for understanding sociopolitical divides (Korpi, 1983). Weber (2007) believed that economic order dictates power distribution among the classes. Furthermore, class influences peoples' life chances through property distribution, economic interests, and opportunities to generate income (McDonnell et al., 2009; Weber, 2007). In Weber's view, a person's chances in the market influence his or her class differentiation, and owners are favored over non-owners because non-owners need to sell their labor, while owners can use their property to generate income (Weber, 2007). Weber's ideas about life chances are echoed in the welfare state literature. This echo is seen when welfare states try to alter the organizing effects of capitalist economies through policy to influence societies.

1.5.1.3.3 Welfare state characteristics

The welfare state involves a set of institutional structures that have developed from struggles between classes and interest groups (Korpi, 1983). Welfare states take responsibility for the basic welfare of citizens, protecting them from risks, and promoting equal opportunities (Esping-Andersen, 1990; Esping-Andersen, 2009; Kolberg & Esping-Andersen, 1992; Korpi, 2001). The welfare state is a central structuring agent in peoples' personal lives and the political economy, with the goal of balancing productivity, family, and leisure (Esping-Andersen, 1990; Ferrarini, 2006; Kolberg & Esping-Andersen, 1992). Welfare state institutions redistribute material resources between people in various socioeconomic positions and life stages (Ferrarini, 2006). This redistribution happens through social insurance and welfare programs and policies related to housing, education, health, labor markets, employment, taxation, the economy, production, consumption, etc. (Korpi, 1983). Welfare state theories have been used to categorize countries according to these welfare policies.

1.5.1.3.4 Three Worlds of Welfare

The most influential welfare state theory in the health literature is Gøsta Esping-Andersen's *Three Worlds of Welfare Capitalism*. In this theory, market, state, and family are the primary providers of welfare (Esping-Andersen, 1990; Esping-Andersen, 1999; Esping-Andersen, 2002; Esping-Andersen, 2009; Saint-Arnaud & Bernard, 2003). The market provides an income in return for work; the state collects civic and fiscal contributions and provides civic, political, and social rights; and the family involves a voluntary exchange of resources based on a mutual obligation (Saint-Arnaud & Bernard, 2003). Welfare policy influences the national context in which people live through these sources of welfare.

1.5.1.3.4.1 Concepts

Welfare policies shape society through social stratification, employment, and decommodification (Esping-Andersen, 1990). Welfare states have an active role in social stratification through provision of benefits which impacts the economic distance between classes (Esping-Andersen, 1990). Employment influences society through types and levels of benefits and how it relates to social status (Esping-Andersen, 1990). For Esping-Andersen (1985, 1990), decommodification is based on the right to access services and have a livelihood independent of the ability to work. Decommodification allows one to opt out of work, when necessary, without the loss of work, income, or welfare (Esping-Andersen, 1990). Decommodification represents the state taking over the responsibility of welfare from the market.

The state may also take over responsibility for welfare from the family. This is known as defamilialization. Defamilialization diminishes welfare dependence on kinship and is related to women's family responsibilities and economic independence (Esping-Andersen, 1999). In circumstances where women face family instability or obligations, defamilialization gives them social protection if they do not have access to adequate employment (Esping-Andersen, 1999; Esping-Andersen, 2002). Defamilialization plays a significant role in the way that welfare policies shape families and societies.

1.5.1.3.4.2 Types of welfare states

Defamilialization and decommodification are key concepts in understanding the differences between the types of welfare states. Esping-Andersen (1990) defined three welfare state types as liberal, conservative, and social democratic.

Liberal welfare states encourage the market for welfare provision and avoid high taxes and spending on social programs (examples include the United States, Canada, and the United Kingdom) (Esping-Andersen, 1990; Esping-Andersen, 1999; Esping-Andersen, 2002; Saint-Arnaud & Bernard, 2003). In fact, there are few publicly funded or delivered services outside of health and education (Esping-Andersen, 2002; Huber & Stephens, 2001). Assistance is means-tested with narrow eligibility, universal transfers are modest, and welfare assistance is often associated with social stigma (Esping-Andersen, 1990; Esping-Andersen, 1999; Esping-Andersen, 2002; Huber & Stephens, 2001; Saint-Arnaud & Bernard, 2003). Political leaders in liberal welfare states believe that state intervention in welfare disturbs competitive free-market exchange (Esping-Andersen, 1992). Therefore, neither decommodification not defamilialization have significant roles in liberal welfare states.

Corporatist welfare states emphasize the family for welfare provision (examples include Germany and France) (Esping-Andersen, 1990; Saint-Arnaud & Bernard, 2003). The Catholic Church has a strong influence in these countries, and traditional family values are dominant (Esping-Andersen, 1990; Korpi, 2001). Emphasis is on the male-breadwinner family pattern (Esping-Andersen, 2002; Huber & Stephens, 2001), family benefits and day cares are underdeveloped, and motherhood is encouraged (Esping-Andersen, 1990). Therefore, defamilialization is not emphasized. Corporatist welfare states are characterised by occupation-based entitlements, strong job protection, rights based on income and social position, and social insurance provision only when family capacity is exhausted (Esping-Andersen, 1990; Esping-Andersen, 1999; Huber & Stephens, 2001; Saint-Arnaud & Bernard, 2003). Welfare in these countries is focused on risks for workers who receive a high level of benefits in return for contributions; therefore, those who do not work are excluded from receiving welfare (Esping-Andersen, 2002; Huber & Stephens, 2001; Saint-Arnaud & Bernard, 2003). This type of welfare system leaves women and those with tenuous employment with inadequate social security (Esping-Andersen, 2002). These factors indicate that decommodification plays a small role in corporatist welfare states.

Social democratic (also known as Nordic) welfare states provide welfare through the state (Esping-Andersen, 1990) and are thought to provide the highest levels of welfare benefits (examples include Denmark and Sweden). These welfare states promote equality through universal rights and comprehensive social programs based on citizenship (Esping-Andersen, 1990; Esping-Andersen, 1999; Esping-Andersen, 2002; Huber & Stephens, 2001; Saint-Arnaud & Bernard, 2003). Social democratic welfare states provide services and benefits at a middle-class level; have high income replacement levels; crowd out the market and promote solidarity with a single, graduated insurance system; and promote maximum labor participation (Esping-Andersen, 1990; Esping-Andersen, 1999; Esping-Andersen, 2002; Huber & Stephens, 2001). These countries also promote gender egalitarian policies (Huber & Stephens, 2001; Saint-Arnaud & Bernard, 2003). Social democratic welfare states socialize the burdens of having a family with generous family benefits; transfers to children; state-provided care for children, elderly, and the disabled; and services for women (Esping-Andersen, 1990; Esping-Andersen, 2002; Saint-Arnaud & Bernard, 2003). Social democratic welfare states have the highest levels of decommodification and defamilialization of all welfare state types.

Other theorists have added Southern European, antipodean, and East Asian welfare states to Esping-Andersen’s theory. However, Esping-Andersen (1999) believes that these additional categories do not add enough to his theory to make up for the lack of parsimony. Yet, enough researchers use these additional welfare state categories to merit their brief review.

Southern European welfare states are similar to corporatist welfare states in their focus on family for welfare, the influence of the Catholic Church, and corporatist welfare benefits, but in

Southern European countries breadwinners have extensive fringe benefits, social policies are basic, and political clientelism is rampant (examples include Italy, Spain, and Portugal) (Esping-Andersen, 1999; Ferrera, 1996; Saint-Arnaud & Bernard, 2003). Antipodean wage-earner welfare states include New Zealand and Australia (Esping-Andersen, 1999; Huber & Stephens, 2001). In antipodean countries, social protection is provided through a wage-setting system; more emphasis is put on welfare state services and gender egalitarian policies than in liberal welfare states; there is moderate to low income replacement; and there are few publicly funded or delivered services outside of health and education (Huber & Stephens, 2001). East Asian welfare states are based on sustained full employment, highly regulated labor markets, compressed earning, egalitarian income distribution, authoritarian employment practices, low benefit levels, high family dependence, and corporatism (examples include Taiwan, South Korea, and Japan) (Esping-Andersen, 1999). These additional welfare states may have value, but they create confusion in comparing research that uses various combinations of welfare state types.

The choice of theory to test the relationship between political environments and health has an influential role in research designs and outcomes. Therefore, the above-discussed theories related to democracy, economics, and welfare states were reviewed as an overview of the most commonly used theories in the body of research examining the relationships between political environments and health.

1.5.2 Research literature

Research exploring the political environment in relation to health in these diverse ways has ultimately led to the decision to explore welfare spending in the proposed research. However, a review of research exploring the political environment in relation to health is valuable in comprehending the decision to pursue welfare policy research.

Ultimately, most researchers conclude that political environments influence health. Early research on the topic found that political economy is a strong predictor of health outcomes (Cereseto & Waitzkin, 1986a). Jorm and Ryan (2014) explored a variety of political influences on social well-being. They found that quality of government, length of time a country has been democratic, fulfillment of societal needs, and a bicameral parliament positively influence social well-being, and being a post-communist society negatively influences social well-being. They conclude that social well-being occurs in a package of higher income, relative equality, individualism, social welfare, political stability, democracy, and high life expectancy (Jorm & Ryan, 2014). These findings reflect most research related to the political environment's influence on health, but Jorm and Ryan's research examines many political influences on health.

Studies with a narrower focus may allow for more detailed analysis of the link between political environments and health, as discussed below. The research from a comprehensive literature review included studies exploring health through the lenses of political systems, civil liberties, female political representation, political transition, socialism versus capitalism, governance, war and instability, and welfare policies, as discussed below.

1.5.2.1 Political systems

Political systems have been found to impact population health and well-being independent of national and international economic factors (Krueger, Dovel, & Denney, 2015; Lena & London, 1993). For example, democracy is associated with better health policy outcomes (Mackenbach & McKee, 2015), better health, (Klomp & de Haan, 2009; Krueger et al., 2015), improved child health outcomes (Mackenbach & McKee, 2015; Welander, Lyttkens, & Nilsson, 2015), and improved life expectancy (Ng, Muntaner, & Chung, 2016; Patterson & Veenstra, 2016; Wigley & Akkoyunlu-Wigley, 2011). High levels of democracy are also associated with lower infant, child, and maternal mortality; greater life expectancy; and higher self-rated health (Alvarez-Dardet & Franco-Giraldo, 2006; Chuang, Sung, Chang, & Chuang, 2013; Chuang, Sung, Chao, Bai, & Chang, 2013; Krueger et al., 2015; Lena & London, 1993; Mackenbach & McKee, 2013; Ng et al., 2016; Patterson & Veenstra, 2016). Furthermore, countries with higher levels of democracy tend to implement more health policies and spend more on healthcare (Gregorio & Gregorio, 2013; Mackenbach & McKee, 2015). In fact, 81 percent of studies in a literature review found a positive relationship between democracy and health outcomes after adjusting for income, education, and income inequality (Muntaner et al., 2011). These results highlight what the mass of articles addressing democracy's influence on health find: democracy has an overall positive effect on national levels of health.

Despite the research that highlights democracy's positive impact on health outcomes, Houweling, Caspar, Looman, and Mackenbach (2005) found that democracy does not have a significant relationship with under-five mortality after adjusting for confounders, Batniji et al. (2014) found no consistent relationship between democracy and improvements in mortality in Arab countries, and Y. C. Chuang et al. (2013) found a positive association between democracy and under-five mortality in non-sub-Saharan countries while considering socioeconomic variables. Furthermore, democracy is negatively related to rates of measles vaccination in low and middle-income countries (Quamruzzaman & Lange, 2016). In European countries late to transition to democracy, inequalities in self-perceived health exist according to class, gender, and education (Espelt et al., 2008). These negative findings highlight the need for further comprehension of the relationship between political environments and health.

Some researchers have tried to understand the mechanisms through which democracy influences health. Democracy may influence health directly through individual income and provision of basic needs, and indirectly through economic growth and strong political institutions (Muntaner et al., 2011). However, the means through which democracy influences health is still unclear. For example, one study found that socioeconomic status, economic inequality, and public health and education investments are not significant mediators of this relationship (Krueger et al., 2015; Patterson & Veenstra, 2016). Other studies found that democracy's negative relationship with infant mortality and a positive relationship with life expectancy are not significant when adjusting for per capita income, executive constraint, competitive political participation, and democratic tenure (Franco, Gil, & Alvarez-Dardet, 2005; Patterson & Veenstra, 2016). Another study found that GDP per capita explained eight of the eleven years of added life expectancy that democracies have over other countries (Patterson & Veenstra, 2016). Income may be important in the relationship between political environments and health, as are the underlying beliefs that guide the use of a country's income.

Although research does not link health expenditure to ideology (Potrafke, 2010), several health outcomes are linked to the party ideology of national governments. For example, left-leaning governments have a positive effect on population health (Muntaner et al., 2011) and health outcomes (Holmberg, Rothstein, & Nasiritousi, 2009; Lena & London, 1993). Interestingly, strong right-wing regimes produce lower life expectancies and higher levels of overall, infant, and child mortality rates, and strong left-wing regimes produce higher life expectancies and lower child death rates (Lena & London, 1993). Furthermore, left-leaning governments are positively associated with infant death in low and middle-income countries (Quamruzzaman & Lange, 2016), but they have no association with health policy performance (Mackenbach & McKee, 2013).

The conflicting research may be explained with improved results only emerging after long periods of time through preventative health policy and income distribution (Mackenbach & McKee, 2013). Further explanation may be found in neoliberal practices adopted in the 1980s and 1990s that increased health inequalities (Beckfield & Krieger, 2009; Mackenbach & McKee, 2013; Potrafke, 2010) through less market regulation and decreased social spending (Tracy, Kruk, Harper, & Galea, 2010). Research exploring overall democracy gives important insights into the relationship between political environments and health. However, some may consider democracy too abstract to quantify, and policy meant to improve health through altering levels of democracy may be difficult.

1.5.2.2 Civil liberties

Other studies have been more specific by exploring civil liberties in relation to health, rather than overall democracy. One study found that civil liberties and political rights are moderately associated with health spending, but only civil liberties are associated with life expectancy (Ng et al., 2016). Freedom of the press has been linked to life expectancy in autocratic countries (Wigley & Akkoyunlu-Wigley, 2011) and political commitment to HIV in developing countries (Bor, 2007). Political rights foster infant mortality declines, and countries with more political rights enact more effective policies of infant care (Kick, Nasser, Davis, & Bean, 1990). Conversely, voter turnout has a positive association with infant mortality and under-five mortality in wealthy countries (Chung & Muntaner, 2006). The influence of civil liberties on health may help explain the overall relationship between health and political environments. However, civil liberties are also difficult to quantify and improving health through policy addressing civil liberties may be indirect and inefficient.

1.5.2.3 Female representation

Women’s rights and representation is another way in which researchers explore political influences on health. Women’s political representation is associated with lower rates of femicide and infant mortality; increased prevalence of child measles vaccination; stronger alcohol and road traffic control safety; less smoking; fewer motor vehicle accidents; increased maternal education; and reduced socioeconomic inequalities in child mortality (Beckfield & Krieger, 2009; Mackenbach & McKee, 2015; Quamruzzaman & Lange, 2016). These findings represent the influence that women have on the political environment of a country and how female political influence impacts health. However, while female political representation is an important issue and policies may support women's increasing involvement in politics, these policies may be far removed from having direct effects on health.

1.5.2.4 Political transition

The transition from one type of national political system to another has implications for men, women, and children. Social or economic reforms can be beneficial if they improve living environments, income, and healthcare (Liu, Rao, & Fei, 1998). However, changes that occur too quickly and dramatically cause social disruptions (Liu et al., 1998). Political and economic reforms are associated with declines in life expectancy (Eberstadt, 1990; Mackenbach & McKee, 2015), increasing mortality rates (Eberstadt, 1990; Simko & Ginter, 2014), a negative impact on public health, and weakened epidemic prevention services (Liu et al., 1998). In a literature review, eight of nine studies find that health inequality worsened in countries after the immediate period following transition to capitalism (Beckfield & Krieger, 2009). However, positive health trends were noted in some European countries after the transition from communism to capitalism, including improved life expectancy and increased healthy life years in the Czech Republic (Simko & Ginter, 2014) and Poland (Wroblewska, 2002). While political transitions clearly have health implications and provide a method for comparing political environments in the same population over time, a sample of countries that have recently transitioned is limited and the length of time that countries need to be studied before and after transition is unclear.

1.5.2.5 Socialism vs. capitalism

While transition from one political system to another has implications for health, so do stable economic systems that have been in place for a long period of time. For example, socialist countries have better health and physical quality of life outcomes than capitalist countries when controlling for country income levels, with differences being the greatest at low-income levels and narrowing at high-income levels (Cereseto & Waitzkin, 1986a; Cereseto & Waitzkin, 1986b). Countries with the longest history of socialism have the best improvements in infant mortality (Navarro, 1992). Furthermore, when compared to capitalist countries at the same income level, socialist countries have between two and three times lower infant mortality and child death rates, significantly more physicians and nurses per population, a higher percentage of required calorie intake, and higher physical quality of life scores (Cereseto & Waitzkin, 1986a;

Cereseto & Waitzkin, 1986b). Research comparing socialism and capitalism has some interesting outcomes. However, there may be more specific ways to study how political environments influence health.

1.5.2.6 Governance

Quality of governance within countries is a more specific aspect of the political environment that has been explored in relation to health outcomes. Research shows that a high quality of governance is good for population health outcomes in both poor and rich countries (Batniji et al., 2014; Holmberg & Rothstein, 2011). Furthermore, when institutions are strong enough to constrain political leaders' opportunistic behaviors, human development outcomes improve (Croke, 2012). For example, increasing health expenditure leads to improved health outcomes when the quality of institutions in a country is sufficiently high (Bousmah, Ventelou, & Abu-Zaineh, 2016; Makuta & O'Hare, 2015). Conversely, when the quality of institutions is poor, private health spending has negative impacts on health outcomes (Bousmah et al., 2016).

Quality of governance, including rule of law, government effectiveness, regulatory quality, institutional quality, and control of corruption, is positively associated with better health outcomes (life expectancy, subjective health) and negatively associated with adverse health outcomes (infant, under-five, child, maternal, cardiovascular, and diabetes mortality) (Bousmah et al., 2016; Holmberg & Rothstein, 2011; Holmberg et al., 2009; Idrovo, Ruiz-Rodriguez, & Manzano-Patino, 2010; Makuta & O'Hare, 2015; Pinzon-Rondon, Attaran, Botero, & Ruiz-Sternberg, 2015). Furthermore, political commitment to HIV is significantly and positively associated with government effectiveness (Bor, 2007). However, better governance is not significantly associated with maternal and reproductive health services (Alkenbrack, Chaitkin, Zeng, Couture, & Suneeta, 2015).

Other than one study's conflicting results, the associations between governance and health stand after adjusting for per capita income, expenditure on health, political and civil freedom, inequality, and women's status (Pinzon-Rondon et al., 2015). Similarly, neonatal mortality and within-country inequalities in child mortality are associated with poor governance (Wise & Darmstadt, 2015). Furthermore, political capacity has a quick and direct effect on mortality, but impacts on fertility are delayed and only if the political system is advanced enough to provide universal employment and education opportunities for women (Kugler, Organski, Johnson, & Cohen, 1983). Government effectiveness, rule of law, and voice and accountability have significant interactions with public spending on health in their associations with under-five mortality (Makuta & O'Hare, 2015). The problems in studying quality of governance in relation to health are the difficulty in quantifying its various components and the challenges in implementing policies that can change quality of governance. Nevertheless, quality of governance may be important for stabilizing a country to improve health outcomes.

1.5.2.7 War and instability

Research shows that political instability has a negative influence on health. Regime instability and war have a negative association with health and the health sector, including increased incidences of infectious disease, transportation accidents, homicides, and maternal conditions (Bousmah et al., 2016; Ghobarah, Huth, & Russett, 2004; Klomp & de Haan, 2009; Shandera, 2014). Civil war in a neighboring country contributes to a major loss of healthy life expectancy, increased cases of AIDS, malaria, tuberculosis, liver cancer, respiratory infections, and other infections, as well as increases in maternal conditions and female homicide, with women and children being the most common long-term victims of civil war (Ghobarah et al., 2004). The connections between war, instability and health may seem obvious. However, some of the limitations of this type of research include small number of countries that can be included in this kind of analysis and the difficulty of accurate data collection in these conditions.

The above discussion of the literature shows the various ways that researchers have studied political environments in relation to health. This research conveys the link between health and democracy, as well as health and socialism when examining countries at similar economic levels. However, when Muntaner et al. (2011) reviewed the literature, their most common findings were that international capitalism is detrimental for health in developing countries, and political power is unequally distributed in capitalist democracies (Muntaner et al., 2011). Clearly, political nor economic factors alone can explain health outcomes (Chung & Muntaner, 2006). However, study of welfare policy brings together economic and political variables. Furthermore, welfare policy variables are stronger predictors of health outcomes than political variables alone (Chung & Muntaner, 2006). These qualities of welfare policy in addition to the ability to study specific aspects of welfare policy in relation to health make them an important and interesting way of examining the political environment in relation to health.

1.5.2.8 Welfare states

Welfare states impact health through labor market policies that characterize each welfare state type (described above) and support for these policies also impact health (Navarro et al., 2006). Welfare state types represent labor market clusters that are predictive of population health (as they become increasingly egalitarian, population health improves), but this is mediated by health and education expenditures (Ng et al., 2016). Welfare policies, including health and education expenditures, are important for redistribution. Redistributive policies are positively correlated with health outcomes (Navarro et al., 2006). For example, welfare spending is a significant predictor of population health in East and Southeast Asian countries, independent of GDP per capita (Ng et al., 2016). Furthermore, 61 percent of studies in a review found a positive relationship between high levels of welfare benefits and population health (Muntaner et al., 2011).

The redistribution and benefits provided in welfare states also have implications for health. In wealthy countries, medical coverage had a significant relationship with under-five mortality, while medical coverage and social spending were both strong predictors of low birth weight (Chung & Muntaner, 2006). Infant mortality has a negative correlation with pro-redistributive parties' years in government and public health expenditure (Navarro et al., 2006). Overall, welfare states with long tenures have strong effects on population health and moderate effects on health inequalities (Muntaner et al., 2011).

However, in literature reviews examining welfare state research has mixed results. Five of nine studies examining the effect of the health system on health inequalities showed that welfare state provisions reduce health inequality (Beckfield & Krieger, 2009). Conversely, five of 11 studies showed that non-health related welfare policies counteract the market and other social policies in dampening health inequalities (Beckfield & Krieger, 2009). Furthermore, no significant differences were found between types of welfare states in infant mortality and health expenditure when controlling for GDP (Abdul Karim, Eikemo, & Bambra, 2010). However, adding welfare state categories to Esping-Andersen's original theory and altering the countries included in welfare state categories may have influenced some results.

In spite of limitations from categorising welfare states in diverse ways, this research has produced some interesting results. For example, social democratic countries' high levels of spending on welfare policies and decommodification appear to positively impact health

(Muntaner et al., 2011). During recession and non-recession times, Sweden is more protective of health than England when adjusting for education group (Copeland et al., 2015). In addition, social democratic welfare states are commonly found to have the lowest infant mortality rates (Abdul Karim et al., 2010; Chuang, Chuang, Chen, Shi, & Yang, 2012; Raphael, 2013b), and the highest infant mortality rates have been found in Eastern European countries (Abdul Karim et al., 2010) or liberal welfare states (Raphael, 2013b). Infant mortality rates in Asian welfare states are lower than in liberal welfare states and higher than in social democratic welfare states (Chuang et al., 2012). However, East Asian welfare states have the highest life expectancy, while Eastern European welfare states have lowest (Abdul Karim et al., 2010; Chuang et al., 2012). Furthermore, high levels of welfare benefits in Asian countries have a positive influence on life expectancy, even when controlling for GDP (Ng et al., 2016). Chuang et al. (2012) found that welfare state alone explained 45.8 to 49.2 percent of the variance in infant mortality and life expectancy.

Differences in welfare policy have some important implications for women and families. Welfare policy research has found that social democratic welfare states promote women's health (Borrell et al., 2014). For example, Finnish employees, representing social democratic welfare states, had the smallest differences in health between sexes when compared to British and Japanese employees, representing liberal and corporatist welfare states, respectively (Sekine et al., 2011). In fact, British workers showed the largest differences between sexes in physical and mental functioning, followed by Japanese and Finnish workers, respectively (Sekine et al., 2011). In fact, there was no statistically significant difference between men and women's mental functioning in Finland (Sekine et al., 2011). This finding led Sekine et al. (2011) to conclude that gender equality policies in Finland contribute to smaller differences in health between men and women. Conversely, female employees had poorer mental well-being than men in corporatist and Southern European welfare states (De Moortel, Palencia, Artazcoz, Borrell, & Vanroelen, 2015). Overall, employees' mental well-being differs by gender and welfare state (De Moortel et al., 2015). Clearly, differences in welfare state policy are reflected in gendered health inequalities.

Health inequality differences between welfare states go beyond gender. In Europe, the magnitude of health inequalities in self-rated health between the unemployed and employed varies significantly across countries according to social protections (Shahidi, Siddiqi, & Muntaner, 2016). There are significant interactions between unemployment and social protection and unemployment and public support for the welfare state in predicting self-reported health (Shahidi et al., 2016). This finding is reflected with poor self-reported health being less likely among the unemployed in countries with high levels of welfare benefits and where there is more public support for high levels of welfare benefits (Shahidi et al., 2016). This finding shows that public support for policies may also be important in predicting health outcomes.

Although public support for a policy is important for its implementation, government commitment for a policy is also crucial. Liberal and social democratic welfare states have the most explicit governmental commitments to the determinants of health, while conservative and Latin welfare states have less explicit commitments to health (Raphael, 2013a). However, implementation of these concepts in public policy is more prominent in social democratic nations than in liberal nations (Raphael, 2013a). Liberal welfare states' commitment to the determinants of health without implementation of related policies may be due to the focus on income production rather than developing social infrastructure, social services, and health services (Raphael & Bryant, 2006). While commitments are important, so are the implementation of these commitments. The differences in policy between welfare states regarding the determinants of health reflect the many differences between welfare states discussed above.

1.5.3 Summary of the Background Literature

Clearly, countries differ in their political environments based on the type of political system, civil liberties, gender representation, governance, stability, and welfare policies. The above theoretical and research literature review shows that political environments differ according to many variables. These differences have been the topic of debate going back to the time of Hippocrates and Plato (Beckfield & Krieger, 2009; Benditt, 1998; Mallin & Hull, 2008). However, more recent theories have focused specifically on the influence political and economic systems have on health. Most research exploring the relationship between the political environment and health finds that health has a positive relationship with democracy, socialism, female political representation, civil liberties, and good governance, although the mechanisms for these relationships are not well understood. Similarly, war, instability, capitalism, and political transition have overall negative relationships with health. While these findings are important in developing the understanding of country-level political influences on health, finding direct pathways to connect these variables to health may be difficult.

Theoretical and research literature related to the welfare state may make the linkages between country-level political and economic influences more explicit. Esping-Andersen's *Three Worlds of Welfare Capitalism* is the most common theory used to link welfare state characteristics to health, although many researchers have added welfare state categories or modified existing welfare state categories. The welfare state research has found that redistributive policies are good for health; social democratic welfare states often have the best health outcomes overall, between genders, and between classes; and social democratic states have policies to address their commitments to the determinants of health. This research has shown how policies directed at welfare benefits can have health consequences.

Despite the growing body of research examining welfare state types, focusing on categories of welfare states restricts research to few countries outside Europe and North America. Furthermore, grouping countries by type ignores instances where a country may not fit within a welfare state categorization for certain policies. What may be more important is the extent to which the country decommodifies and defamilializes welfare. Furthermore, no research found in the literature explores how welfare influences health interventions or takes spatial relationships into account. Therefore, this study is informed by the aforementioned gaps in the literature. This study will address welfare spending's influence on the relationship between a preventative health intervention (measles immunizations) and its associated outcome (measles disease rates). To complete this investigation, an analytical approach will be developed to address spatial relationships over time. This study will be reported in the subsequent chapters of this dissertation.

1.6 Dissertation Overview

This dissertation is formatted to provide a clear explanation of research that will explain its importance in expanding the nursing and health literature, provide nurses with an example of how to implement the research methods, and discuss how the results fit within the current health context. The following chapters address the objectives of this research by outlining the analytical approach used to examine the influence that welfare spending has on measles immunization and measles disease.

The study conducted as part this dissertation is presented via four manuscripts: a scoping review; a theoretical model paper; a methodology paper; and a results paper. The first manuscript outlines a scoping review completed to gather all existing evidence about the relationships between immunizations and welfare policies. The scoping review paper describes the methods used to search for articles, screen and filter articles, and analyze the results. It also describes the results in the context of the current literature. The scoping review results show the importance of addressing the relationship between welfare spending and measles immunizations and cases because it is an underdeveloped area of research.

The theoretical model used in this paper is outlined in a manuscript that describes the Levels of Prevention Theory (Clark & Leavell, 1965), the Ecological Model for Health Promotion (McLeroy, Bibeau, Steckler, & Glanz, 1988), and how they can be combined to study the influence of national policies on health interventions. This manuscript uses the Meleis (2007) theory description method to describe the theories and their relevance to nursing research and the study being described in this dissertation. The manuscript links the theoretical model with the study variables to outline how this study will test theory to move the nursing and health literature forward. Overall, the manuscript describing the theoretical model describes how theory has guided the design and interpretation of this research.

The manuscript outlining the methods used in this research includes a detailed overview of the analytical approach used to evaluate the data. This analytical approach is presented though the example of research that explores the relationship between welfare spending and immunizations. Therefore, it discusses important spatial and non-spatial considerations for examining spatial data, statistical methods used, computer software, and common challenges. The goal of this paper is to encourage greater use of spatial statistics in nursing research and outline the analytical approach used in this research to obtain valid results.

The results manuscript includes a general overview of the background, significance, theoretical approach, methods, and results of the research. The focus of the paper is the results of the research and how the results fit within the current literature. The results manuscript is an overall summary of the research completed for this dissertation.

This dissertation concludes with a final chapter that includes discussion and conclusions. This chapter also includes strengths and limitations, directions for future research and implications for nursing. The overall organization of this dissertation is meant to provide introductory background literature in this first chapter. The four manuscripts include a scoping review targeted to find research that specifically relate to this dissertation’s topic, a theory paper that describes the conceptual model used in this dissertation, an analytical approach to make spatial analysis more accessible for nurses, and a paper summarizing the overall research and its results. Finally, the discussion and conclusions chapter provides the overall impact and importance of the research in general and for nursing.

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2.0 MANUSCRIPT: SCOPING REVIEW

The influence of welfare spending on national immunization outcomes: A scoping review

Mary Ellen Walker, RN, MN, PhD(c)
Devan Tchir, MPH
Michael Szafron, PhD
Dr. June Anonson, RN, PhD

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Background: National policies influence the environments in which people live, but the ways in which these national policies influence people's health are not well understood. Welfare spending is one national policy that may influence population health. While some research indicates higher levels of welfare investment may positively influence health, mixed findings contradict this conclusion. These mixed results examining the link between welfare policies and health may be better understood by investigating the relationship between welfare spending and preventative health interventions, such as immunization. Objective: This article's purpose is to summarize the literature studying the relationship between national welfare spending and immunization outcomes. Design: This scoping review uses the Joanna Briggs scoping review method. Data sources: The scoping review utilized scholarly databases and a focused gray literature search to find research articles that explore relationships between welfare spending and immunization outcomes. Review methods: Data was extracted from articles, including themes, aims, populations, years of study, methods, and findings. The articles' themes were further analyzed with a word cloud and principal component analysis to determine which themes are more likely to coincide in the literature. Results: Seven articles are included in the review. Most of these articles do not address the relationship between welfare spending or policy and immunizations directly or with rigorous methods. Conclusions: Ultimately, the results of the scoping review suggest a lack of literature regarding the relationship between welfare spending and immunization outcomes. Further research is needed to understand the impacts of national welfare spending on immunization outcomes.

Keywords: Global health, health policy, immunization, principal component analysis, social welfare, vaccination

The influence of welfare spending on national immunization outcomes: A scoping review

This manuscript describes a scoping review conducted to gather evidence about the relationships between immunizations and welfare policies. The manuscript describes the methods used to search, screen and filter, and analyze articles and their results. It discusses the results within the context of the current literature. The scoping review results indicate that the research objective of addressing the relationship between welfare spending and measles immunizations is an underdeveloped area of research.

2.1 Introduction

The environments in which people live influence their health, and the distribution of national resources influence these environments (World Health Organization, 2018). The policies that are created to distribute national resources differ between countries. Consequently, national health policies within countries can vary greatly. Variations in national policies may result in differences in health outcomes between countries. National welfare spending is one such policy that is not well understood in terms of its health implications. Researchers began to investigate how welfare spending influences health outcomes in the mid-2000s. The associated research has shown that generous redistributive policies may have positive relationships with health outcomes (Navarro et al., 2006). Investigating the relationship between welfare spending and preventative health interventions may uncover how national welfare spending influences health.

One preventative health intervention often evaluated at a national level is immunizations (World Health Organization, 2017). Consequently, it is of interest to examine the influence of national welfare spending on the relationship between an immunization and its associated disease rate. This scoping review's purpose is to summarize literature exploring relationships between national levels of welfare spending and immunizations.

2.2 Background

The research exploring the relationships between welfare spending and immunizations may be better understood in the context of research that examines welfare spending in relation to overall health. Research exploring how national welfare spending and welfare policies influence health outcomes is being published with increasing frequency (Bergqvist, Aberg Yngwe, & Lundberg, 2013). Within this body of research, most studies compare health outcomes between countries categorised by welfare state types, but the countries studied are usually restricted to those in Europe, North America, and occasionally East Asia (Bergqvist et al., 2013). Therefore, the focus of the literature discussed here is on welfare spending and welfare policies research from all countries that have been included in published research literature.

In the literature that compares countries according to welfare spending or policies, no articles focus specifically on how welfare spending or policies influence health interventions. However, some research has found that redistributive policies are positively correlated with health outcomes (Navarro et al., 2006). For example, welfare spending is a significant predictor of population health in East and Southeast Asian countries, independent of gross domestic product per capita (Ng, Muntaner, & Chung, 2016); 61 percent of studies in a review found a positive relationship between high levels of welfare benefits and population health outcomes (Muntaner et al., 2011); and reduced social spending and a low proportion of citizens with medical coverage were both positive predictors of low birth weight (Chung & Muntaner, 2006). In addition, differences in self-rated health between unemployed and employed Europeans vary significantly across countries according to social protections available within the country (Shahidi, Siddiqi, & Muntaner, 2016). These results suggest a positive relationship between welfare spending and health outcomes.

Other research suggests that welfare spending's influence on health is not well understood. Only five of nine studies in a review showed that welfare provisions reduce health inequality (Beckfield & Krieger, 2009). Furthermore, only five of 11 studies in another review show that non-health related welfare policies reduce health inequalities (Beckfield & Krieger, 2009). Health practitioners could benefit from understanding how national policies, like welfare spending, influence the health of people and communities. This kind of research could help health professionals advocate for policies that will have beneficial effects for health. Research examining how welfare spending influences health interventions, like immunizations, may build on the understanding of how welfare spending influences health. Therefore, the question to be addressed in this scoping review is 'How has welfare spending influenced immunization outcomes at a national level?'

2.3 Objective

The overall objective of this scoping review is to summarize the literature examining how national level welfare spending influences immunization outcomes. This objective will allow for examination of how national policies create environments that influence health.

2.4 Methods

This review uses The Joanna Briggs Institute (2015) scoping review methodology. The Joanna Briggs scoping reviews follow a specific process that must include two reviewers (The Joanna Briggs Institute, 2015). Therefore, there were two reviewers used for this scoping review. The lead reviewer developed an a priori protocol that specified inclusion and exclusion criteria to filter the search results for articles relevant to the scoping review's purpose. Once the two reviewers screened articles via the inclusion/exclusion criteria and agreed upon the articles to be included in the review, the articles were further analyzed with principal component analysis (PCA) and a word cloud. The screening process is reported with the preferred reporting system items for systematic reviews and meta-analyses (PRISMA) (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009).

2.4.1 Inclusion & Exclusion Criteria

The phenomena of interest are immunizations and welfare spending. For this scoping review, welfare spending is defined as national public spending to reduce and prevent poverty, vulnerability, and social exclusion (International Labour Organization, 2017). Therefore, the scoping review search also included studies that examined welfare policies in relation to immunizations because these policies could be considered a proxy to public welfare spending. The context of interest is comparison between countries at the national level. Therefore, included studies analyze country-level data (rather than the state, province, etc.), and at least two countries have to be included in the analysis. Articles were excluded if they focused on precursors to immunization, like parental decision-making; adverse outcomes of immunization; or vaccine-specific funding. There was no exclusion based on year of publication. The complete scoping review inclusion and exclusion criteria are summarized in table 2.1.

2.4.2 Search Strategy

The literature search took place on March 14, 2018. Databases included Ovid Medline (1946-2018), Ovid Embase Classic+Embase (1947-2018), Ovid Global Health (1973-2018), and

EBSCOhost Political Science Complete (1887-2018). These databases were selected in consultation with a librarian to enhance the chances of finding all relevant articles. See table 2.2 for a list of keywords. Articles were limited to English language. No limits were set by publication year. Editorials, notes, commentaries, letters, and other publications that were not research-based were excluded. A focused grey literature search was used to look for articles on United Nations, World Health Organization, and World Bank websites. No relevant articles were found from the focused grey literature search. After completing the search, duplicates were removed.

Articles were entered into the Rayyan application for systematic reviews (Ouzzani, Hammady, Fedorowicz, & Elmagarmid, 2016), and the blind settings were turned on so that the reviewers were not aware of each others' decision to include or exclude an article. A set of 20 articles was selected to test agreement on article inclusion based on the inclusion and exclusion criteria. This pilot test showed that the reviewers agreed on article decisions. Title and abstract reviews were then completed on all articles. After title and abstract review, interrater reliability and Cohens kappa were calculated to determine the extent to which the two reviewers agreed on decisions to keep or discard articles (McHugh, 2012). When the reviewers disagreed on article decisions, they met to discuss the disagreed upon articles until they reached consensus. Full text review was completed on articles included from title and abstract review. The reference lists of these articles were also screened for more articles to include in the scoping review. However, the reference list screening did not provide any additional articles for inclusion.

2.4.3 Data Extraction, PCA, & Word Cloud

Once the group of articles from which to extract data was identified, a table was developed with columns that allowed for recording of relevant information (see table 2.3). Table columns include author, year of publication, year(s) of study, purpose, population, methods, variables, key findings, and limitations. Themes were also recorded and further analyzed with PCA using the Statistical Package for Social Sciences (Version 24). PCA is a dimension reduction technique that groups themes together into factors to explain the maximum amount of variance in the data (Polit & Beck, 2012). Themes were included in a factor if the themes showed moderate to strong correlation with the factor (above 0.4 or below -0.4). These factors help to explain how the article themes fit together. Once the themes were grouped into factors, the research team interpreted how the themes fit together and decided on an overarching topic that grouped the themes into a factor. In addition to the PCA, a word cloud was created to uncover common words in the titles and abstracts of each article. Words without meaning outside of their context in a sentence were removed. The extraction table, PCA, and word cloud allowed for analysis to determine the overall state of the literature regarding welfare spending and immunization.

2.5 Results

The above scoping review process yielded seven articles for analysis (Ahmed et al., 2016; Bryder, 1999; Daku, Raub, & Heymann, 2012; Fedson et al., 1995; Tapia Granados & Rodriguez, 2015; van den Heuvel et al., 2013; Williams & Miller, 1992). See figure 2.1 for a summary at each stage of the article review process. During article screening, there was 99.6% agreement between reviewers (Cohens kappa=0.86) (McHugh, 2012).

2.5.1 Summary of Papers by Topic

Data extraction from the seven articles allowed for analysis of the body of research related to welfare spending and immunization. Results are summarised in table 2.3 and highlights are discussed below.

2.5.1.1 Years of study

There is a large range in the articles' study periods. Some studies compare changes in variables from one time period to another, while other studies combine data from various years without accounting for the change in time periods. Since these studies analyse data over various time periods, the results between each study are difficult to compare and reflect the lack of focus on immunizations in the welfare spending literature.

2.5.1.2 Summary of paper aims

Although seven studies examine welfare spending and immunization outcomes, only Bryder (1999) and van den Heuvel et al. (2013) specifically aim to explore welfare policies influence on health, including vaccination outcomes. Daku et al. (2012) indirectly measures welfare spending with full-time equivalent (FTE) weeks of maternity leave and length of maternity leave while exploring their relationships to childhood vaccinations, while Fedson et al. (1995) considers influenza vaccination reimbursement for older adults. The remaining articles explore health trends in relation to several variables, some of which were relevant to welfare spending, such as government social spending, government health spending, and social benefits.

These findings indicate that the influence of welfare policy on immunization outcomes is not an area of study in which researchers have taken strong interest.

2.5.1.3 Countries studied

Research regarding welfare policy in relation to immunization is also limited in the population of studied countries. Most research focus on European and North American countries (Bryder, 1999; Fedson et al., 1995; Tapia Granados & Rodriguez, 2015; Williams & Miller, 1992). One study focuses specifically on low-income and middle-income countries (Ahmed et al., 2016). Only one study uses a large sample of 185 Countries (Daku et al., 2012). Most of these articles focus only on developed, high-income countries, leaving a large gap in the literature in terms of welfare spending's influence on immunization in less developed, medium- to low-income countries.

2.5.1.4 Summary of paper methods

The articles' data collection methods and analysis methods are diverse. All the studies included in the review use quantitative, country-level secondary data, but some researchers collect their own data in addition to the secondary data. However, the data analysis methods are varied. Three studies use comparative analysis to explore vaccinations in relation to welfare spending or policy. Only two studies use inferential statistics in their analysis. For instance, Daku et al. (2012) uses ordinary least squares regression to explore relationships between vaccination rates and maternity leave FTE and duration, and Tapia Granados and Rodriguez (2015) uses trend-break regression to determine changes in health and economic variables after an economic recession. Most studies do not use any rigorous research methods. The lack of statistical inference or rigorous qualitative analysis in these studies indicates an important weakness in the current body of research.

2.5.1.5 Summary of paper results

The varied aims, populations, years of study, and methods in these papers make their results challenging to interpret as a group. Although all the research articles have relevant results for the aims of this scoping review, many articles have additional results that are not relevant to this scoping review. Therefore, the discussion of results focuses only on the research findings that relate to the relationship between welfare spending and immunization outcomes.

Most studies find patterns or relationships in their data that suggested greater welfare spending might have a positive relationship with immunizations. To illustrate, Ahmed et al. (2016) find health spending as a percentage of GDP and diphtheria-tetanus-pertussis immunization (DTP) and measles immunizations in children 12-24 months simultaneously increased over the study period. Similarly, Williams and Miller (1992) observe that most European countries have higher pre-school immunization (DTP, polio, measles) rates than the United States, and Europeans also have greater access to family benefits, education, and preventative healthcare than Americans. Furthermore, Daku et al. (2012) found a positive relationship between child vaccination rates (DPT, measles, and polio) and maternity leave duration and FTE pay. Meanwhile, Fedson et al. (1995) suggest countries that reimburse older adults for influenza immunization might have higher rates of immunization. Bryder (1999) adds that political ideology influenced tuberculosis policy because social democratic Scandinavian countries were earlier in offering the Bacillus Calmette-Guérin (BCG) vaccination than conservative counties like the United States and the United Kingdom. Bryder also notes that post-World War II welfarism coincided with uptake if the BCG vaccine in the United Kingdom. These results might be helpful in generating the hypothesis that greater welfare spending could be linked to higher immunization rates, but it is important to consider that rigorous methods are not used in many of these articles.

Although most studies show patterns or relationships suggesting a positive association between welfare spending and immunization rates, there are two studies that do not show any patterns or relationships. For example, van den Heuvel et al. (2013) find no evidence of patterns in childhood immunization data when comparing five countries based on their welfare policy. In addition, Tapia Granados and Rodriguez (2015) do not find any obvious patterns when investigating changes in vaccination rates (diphtheria-pertussis, measles) and health spending in Finland, Greece, and Iceland before and after an economic recession. The findings that do not show any relationship between welfare spending and immunizations and the positive, but weak, findings discussed above make it difficult to make strong statements about the body of evidence when taken into consideration with the studies' limitations.

2.5.1.6 Summary of paper limitations

This limitation section refers to the limitations of the seven papers examined in the scoping review. (The limitations of the scoping review, overall, are included in the discussion section.) There are common limitations to the studies in this scoping review. These studies use international data that may be collected from various sources and with various methods. Furthermore, these international comparisons do not account for within-country variability. More specifically, many of the selected studies do not use any inferential statistics to analyze the quantitative data in their research (Ahmed et al., 2016; Fedson et al., 1995; van den Heuvel et al., 2013; Williams & Miller, 1992). In addition, some studies used a small population of countries in their analysis (Bryder, 1999; Tapia Granados & Rodriguez, 2015; van den Heuvel et al., 2013). Furthermore, a few studies appear to have averaged the data over selected years (Ahmed et al., 2016) or use data from various years based on what was most recently available (Daku et al., 2012; van den Heuvel et al., 2013; Williams & Miller, 1992). Overall, only one study tests the relationship between immunization outcomes and any kind of welfare spending or policy (Daku et al., 2012). Therefore, these limitations make the studies difficult to compare or combine in a way that allows for strong conclusions about the body of evidence regarding welfare spending in relation to immunizations.

2.5.2 Principal Component Analysis

When analyzing the extracted themes with PCA (see table 2.4), two factors are identified. These factors represent a strong emphasis on the subject matter in the articles, namely policies impacting maternal-child health and policies impacting general health. The themes are included in each factor when they show moderate to strong correlations (see table 2.5). The first factor includes maternal health, child health, welfare policies, health systems, and vaccines. Vaccines have a negative correlation, indicating that the vaccine theme was less likely to be seen in the literature when the other themes were present. This finding is congruent with the data because articles that discuss maternal or child health include only one or two vaccine types, while articles that do not discuss maternal or child health include three or four vaccine types. Overall, the first factor represents themes that impact maternal-child health. Health systems and vaccines have an important connection to maternal-child health. However, welfare policies may also be important because some countries have policies that promote defamilialization, where women have more financial independence and are less dependent on a male breadwinner for income (Esping-Andersen, 1999). The factor agreed with the word cloud findings emphasizing child health (discussed below), reinforcing the prominence of maternal-child health in the welfare spending literature related to immunizations.

Another factor came out of the PCA. This factor includes the themes maternal health, health systems, health indicators, and political economy. All the themes in this factor are positively correlated (see table 2.5). The themes in this factor reflect the policies that could influence health, including maternal health. This factor is congruent with the literature because it represents some articles that explore general political economy or health system policies in relation to large groups of general health variables. This factor mirrors one of the weaknesses of the literature because it represents a lack of specific focus found in some of the articles of this scoping review.

2.5.3 Word Cloud

A word cloud was created using each article's title and abstract (see figure 2.2) (WordClouds.com, n.d.). As expected, the word cloud shows that common words in the titles and abstracts are "countries," "health," "policies," and "vaccination". Interestingly, the word cloud reveals that "child," "children," "childhood," "development," and "early" are also common words. The world cloud allows for identification of the above-mentioned important concepts. The word cloud also agrees with the first factor identified in the PCA, indicating that maternal-child health is prominent in the body of literature related to welfare spending and immunizations. It is difficult to determine if the word cloud agrees with the general health factor identified with the PCA, as the factor lacks specificity.

Overall, there is little research that explores the relationship between welfare spending or welfare policy and immunization outcomes. Of the seven articles found in this scoping review, there are some that suggested the relationship between welfare spending and immunization outcomes may be positive, but some studies find no relationship. Most of the research in this scoping review does not use rigorous methods to explore this relationship. The lack of research and imprecise methods for exploring relationships render it difficult to make convincing statements about the relationship between the variables of interest.

2.6 Discussion

This scoping review reflects a lack of evidence about the relationship between welfare spending and immunization outcomes. The overall results of this scoping review indicate that there may be a link between increased welfare spending and higher immunization rates, but the evidence is not strong and there is a need for further study. Daku's (2012) study uses regression analysis to find a positive relationship between immunization rates and maternity leave length and reimbursement is the best evidence to back this conclusion. All other results are weak or show no relationship between the variables of interest.

2.6.1 Scoping Review Limitations

The weak findings from this scoping review's body of evidence are a result of the extracted articles' limitations. The most important limitation of the extracted articles is the lack of inferential testing on the data. Some studies merely display many health and political economy indicators in a table or chart and visually examine patterns in the data. This method of analysis is vulnerable to bias or missing obscure patterns. The PCA for this scoping review also reflects these over-generalized findings. Furthermore, the studies are limited in the population of countries included. Most research focuses on European and North American countries, which biases results toward Western, affluent countries. In addition, some studies analyze data over one year, but are inconsistent in the year of data collection for each variable. Analyzing one year of data without consistency in the year used or averaging data over years could result in type I or type II errors. As discussed earlier, the limitations of the studies in this scoping review make strong conclusion from this scoping review difficult.

This scoping review's methods also have limitations that may have impacted its results. Although consultation was sought from a librarian to use databases that would optimise the literature search, it is possible that more articles could have been found using alternative databases. Furthermore, the limits set on the search, such as exclusion of non-English language and non-research-based publication types may have lost some relevant articles. In addition, limiting articles to those that include immunizations as a variable of interest has made for a small number of articles included in this scoping review. The small number of articles may also impact the validity of the PCA results. Perhaps broadening the search to include any preventative health interventions could have given a larger sample of articles and more insight into the body of literature. Analysis of different immunizations or different preventative interventions may produce alternative findings than what are presented in this scoping review. A further limitation to this scoping review is that there is no formal assessment for the quality of each article, rather the strengths and weaknesses of the articles str reviewed (as discussed throughout this paper). However, this scoping review met its aim of discovering the ways in which researchers have explored the relationship between immunizations and welfare spending at a national level.

2.6.2 Context of the Current Literature

This scoping review is generated from a gap in the research literature related to the relationship between welfare spending and vaccinations at national levels. Furthermore, the research found in this scoping review mirrors what has been found in the research exploring welfare spending in relation to health outcomes. In the welfare spending research related to health outcomes, there is weak evidence that welfare spending may improve health outcomes. Similarly, this scoping review found that there is weak evidence that increased welfare spending may improve immunization rates. In addition, the study populations in the welfare spending literature related to both health outcomes and immunizations are biased toward European and North American countries. In particular, the welfare spending literature in relation to immunization lacks rigorous methodologies that account for covariates and spatial-temporal autocorrelation. Therefore, research exploring the welfare spending's influence on immunization rates that accounts for covariates and spatial-temporal autocorrelation will fill a gap in the current literature. Filling the gap in the literature found from this scoping review will aid in understanding how national-level policies influence the health and well-being of a nation's people.

2.7 Conclusions

This scoping review highlights a literature gap regarding the influence of welfare spending on immunization outcomes. Although a small group of articles address immunizations in relation to welfare spending, the evidence gathered from this literature is weak. Some articles find no relationship or patterns between welfare spending and immunizations, and other articles find patterns in the data to indicate that increased welfare spending may have a positive impact on immunization rates. Daku et al. (2012) find a positive relationship between immunization rates and maternity leave length and reimbursement. However, the Daku et al. article is the only study that aims to explore the influence of welfare policy on immunization. These findings support the conclusion that the relationship between welfare spending and immunizations are not well researched, and further study on this topic is warranted.

The findings from this scoping review are generated with The Joanna Briggs Institute (2015) scoping review method, with the addition of a word cloud and PCA. The scoping review guided the search for the seven articles that were analyzed for themes and patterns. The PCA found a factor of themes that are related to maternal-child health, and another factor of themes that reflect the tendency in the literature for researchers to use many variables that reflect general health or political economy, rather than specific welfare policies. The word cloud allowed for the identification of common words in the scoping review titles and abstracts. While this scoping review has limitations, the overall results indicate that welfare spending research in relation to immunizations is an area of research that will benefit from further investigation. This kind of research may aid in understanding how national policies influence overall health and shape the environments in which people live.

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2.9 Scoping Review Tables

Table 2.1. Inclusion and exclusion criteria.

Inclusion Criteria
• Considers immunization/vaccine rates or disease rates/cases in relation to immunization/vaccine, survival rates, morbidity, or mortality. • Considers welfare spending, social spending, social security spending, public spending on social benefits, social benefits, or welfare state/regime type at a national level. (Alternative terminology for a country's overall spending on public benefits is acceptable). • Analysis of national level data. • Considers at least two countries. • Based on data for humans. • Qualitative or quantitative research methods used.
Exclusion Criteria
• Only one country studied. • Focuses on animals. • Focuses on precursors to immunization (ex/parental decision making for immunizing their children). • Focuses on adverse events of immunization. (Unexpected, negative outcomes of immunization). • Focuses on immunization/vaccine specific funding. • Commentary, conference proceedings, conference abstracts, lectures, addresses, notes.

Table 2.2. Literature search keywords.

decommodif*	vaccine
financing, government	vaccination
government financing	vaccin*
government financ*	welfare
immunization	welfare nation*
immuniz*	welfare generosity
policy	welfare polic*
polic*	welfare regime
public policy	welfare state
social policy	welfare theor*
social polic*	welfare typ*

Table 2.3. Scoping review extraction table.

Authors	Aims/purpose	Countries studied	Years of study	Methods	Relevant findings	Limitations
Ahmed, et al. (2016)	Identify factors that facilitated progressed toward MDGs 4 and 5A (reduce child and maternal mortality)	Bangladesh, Cambodia, China, Egypt, Ethiopia, Lao People's DR, Nepal, Peru, Rwanda, Vietnam	1990-2015	Data collection • literature review, meetings/interviews with multi-sector stakeholders, secondary data from international agencies. Analysis • developed country reports, case study	• GDP and children 12-24 months immunized for DTP and measles increased in all counties. • Health spending as % GDP increased in 8/10 countries.	• Countries selected based on years different than study period. • No inferential statistics.
Bryder (1999)	Examine the differences in BCG vaccine implementation between Scandinavia, the UK, and USA.	Denmark, Norway, Sweden, UK, USA	1921-1960	Data collection • Medical literature related to BCG Analysis • Comparative approach, discourse analysis	• Political ideology influenced TB prevention and health policy. • UK and USA (conservative) focused on treatment with sanitoriums. • In UK, the post war welfarism coincided with uptake of BCG. • Scandinavian (social democratic) countries focused on prevention with BCG vaccine. • BCG vaccine policies mirrored social welfare traditions.	• Scandinavian countries grouped together for analysis. • Welfare policies not discussed in depth in relation to BCG and tuberculosis data.
Daku, et al. (2012)	Explore length of maternity leave in relation to child vaccination.	185 United Nations member countries	2006, 2007	Data collection • Secondary data from international agencies Analysis • Ordinary least squares regression	• Greater FTE weeks and duration of paid maternity leave are positively associated with childhood vaccination rates. • No significant relationship between governmental health care expenditure and vaccination rates.	• Limited data availability. • Vaccine costs to families or other forms of paid leave were not accounted for. • Did not account for spatial relationships.
Fedson, et al. (1995)	Investigate differences in influenza vaccination distribution for	Australia, Austria, Belgium, Canada, Denmark,	1980-1992	Data collection • Secondary data from international agencies, vaccine manufacturers,	• Countries showed increased influenza vaccine rates over time. • Differences between countries in influenza vaccination rates have persisted over time.	• Analyzed number of doses of influenza vaccine distributed in the general population

	people 65 years and older.	Finland, France, Iceland, Italy, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, The Netherlands, UK, USA		• Country influenza vaccine recommendations gathered by authors Analysis • histograms, charts, country comparisons	• Influenza vaccination rates may be associated with reimbursement policies.	and proportion of the population 65 years and older, not vaccinations in the 65 year and older age group. • No inferential statistics.
Tapia Granados & Rodriguez (2015)	Examine population health trends and health services trends after the 2008 economic recession.	Finland, Greece, Iceland	1990-2012	Data collection • Secondary data from international agencies Analysis • Graphs, trend break regression models	• Vaccination rates for DP, measles, and polio dropped below 90% in Iceland after the recession, while Greece and Finland did not show obvious changes. • Greece reduced total health spending per capita after the recession. • Government share of total health expenditure increased in Greece while stayed at similar levels in Finland and Iceland. • No overall patterns noted in immunization data.	• Only compared countries to themselves. • Unclear if statistical tests for changes in trend were completed. • Did not test the influence of economic variables on health. • Comparisons are only made graphically.
van den Heuvel, et al. (2013)	Highlight similarities and differences between countries related to social services, health services, and redistributive policies and their relationships to health outcomes for early childhood.	Canada, Cuba, Sweden, The Netherlands, USA	various years from 2005-2012 based on availability	Data collection • Secondary data from international agencies, supplemented with local or national data. Analysis • Navarro framework for comparing countries by political tradition/welfare policy	• No patterns or relationships emerged from immunization data.	• Data from various sources and various years. • Only one country represented each political tradition. No inferential statistics.

Williams, & Miller (1992)	To determine the health status of older infants and children, the standard preventative health services for children including type of provider system and routine of care, social supports linked to child health care and the mechanisms of linkage.	Belgium, Denmark, France, Germany, Ireland, Norway, Spain, Switzerland, The Netherlands, United Kingdom, USA	1980-1987	Data collection • Survey of child health experts • secondary data from international agencies, published reports. Analysis • country comparisons	• Most European countries have higher pre-school immunization rates for DTP, polio, and measles than the USA. • USA has the lowest social spending on children relative to older adults. • Most Europeans have access to family benefits, education, and preventative health care.	• Use a variety of data sources to fill in incomplete data. • Personal viewpoints when data not available. • No inferential statistics.

Table 2.4 Themes found in scoping review articles.

Article	Themes
Ahmed, et al. (2016)	Child health Countries by Income Health Systems Maternal Health Political Economy Vaccine Welfare Policies
Bryder (1999)	Countries by Income Inequality Political Economy Vaccine Welfare Policies
Daku, et al. (2012)	Vaccine Welfare Policies
Fedson, et al. (1995)	Countries by Income Vaccine Welfare Policies
Tapia Granados & Rodriguez (2015)	Health Indicators Political Economy Vaccine Welfare Policies
van den Heuvel, et al. (2013)	Child Health Determinants of Health Health Systems Inequality Maternal Health Political Economy Vaccine Welfare Policies
Williams & Miller (1992)	Child Health Welfare Policies Vaccine

Table 2.5. PCA rotated component matrix. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 3 iterations.

Themes	Component	
	1	2
Child Health	.941	-.223
Welfare Policy	.796	.139
Maternal Health	.588	.718
Health Systems	.541	.640
Vaccine	-.876	-.212
Political Economy	.117	.853
Health Indicators	-.176	.604

2.10 Scoping Review Figures

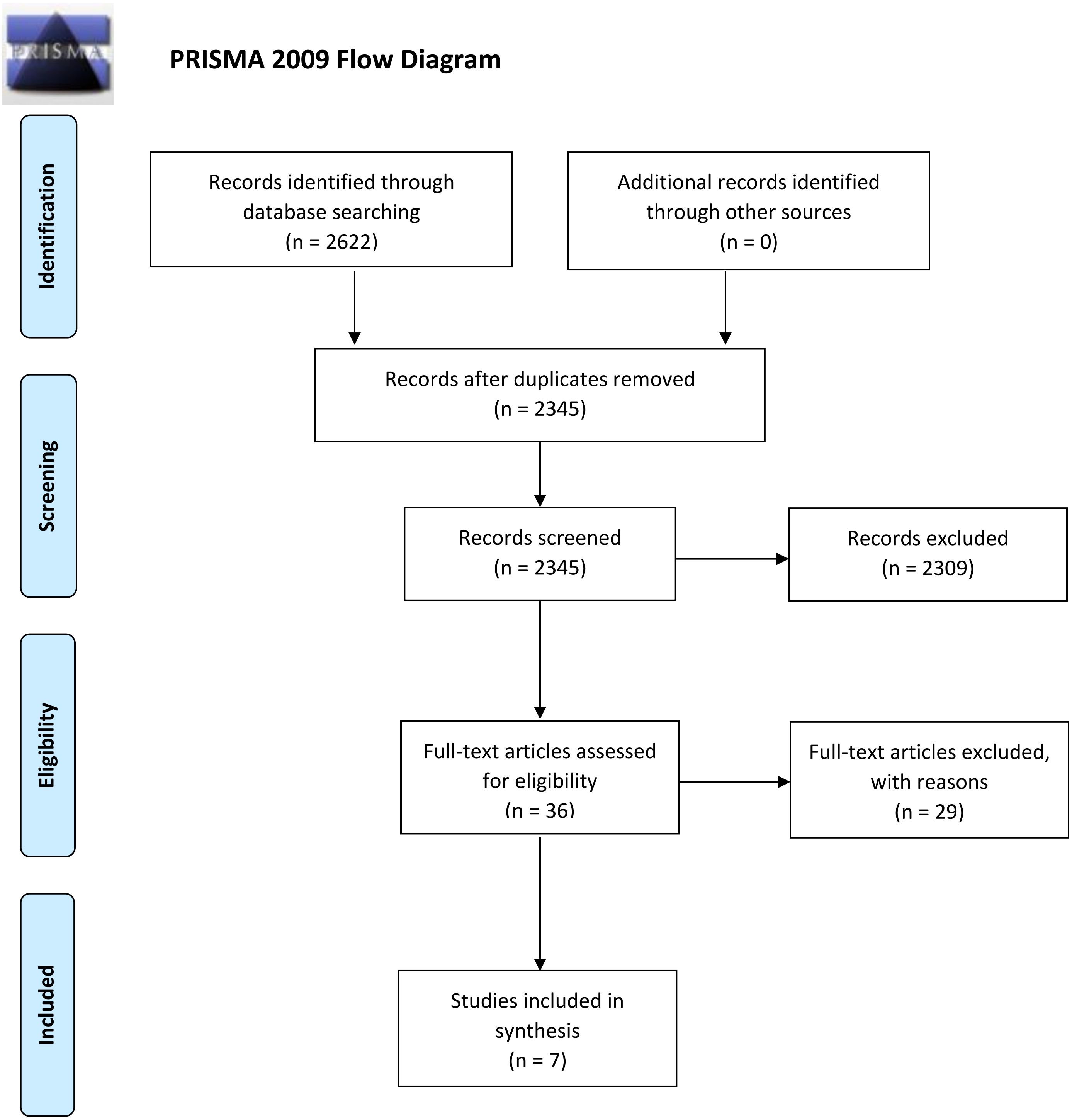

Figure 2.1. Preferred reporting system items for systematic reviews and meta-analyses (PRISMA) flow chart of literature search and screening. Adapted from Moher, Liberati, Tetzlaff, Altman, and The PRISMA Group (2009).

Figure 2.2. Word cloud created withWordClouds.com (n.d.).

3.0 MANUSCRIPT: THEORETICAL MODEL

The Levels of Prevention Model and the Ecological Model for Health Promotion: A Combined Model for the Study of Health Policy

Mary Ellen Walker, RN, MN, PhD(c)
June Anonson, RN, PhD
Michael Szafron, PhD

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Author contributions: MW conceptualised and designed the theory analysis; reviewed and analyzed the theoretical literature; and drafted, revised, and finalised the article. JA provided guidance on the theoretical analysis and made significant contributions to the article. MS provided guidance on the theoretical analysis and made significant contributions to the article.

Theoretical models are important for defining concepts and relationships that researchers aim to study. Defining a theoretical model under which research will be developed are important in testing theory and building evidence. Meleis' (2007) theory description method outlines the structure and function of theoretical works, as well as how they relate to the domains of nursing. Meleis' theory description is used to explain two theoretical models relevant to research that explores the influence of national policies on the effectiveness of prevention interventions for health. These theoretical models include the Levels of Prevention model by Clark and Leavell (1965) and the Ecological Model for Health Promotion by McLeroy, Bibeau, Steckler, and Glanz (1988). The combined conceptual model is discussed in the context of research designed to specifically examine the influence that welfare spending has on the relationship between measles immunizations and measles infections. This conceptual model has broader applicability to ecological factors influencing prevention at any level. This conceptual model can be tested with the research outlined in this paper, used in future research examining policy and prevention, and used to generate new research ideas relevant to nursing.

Key words: conceptual model, health policy, prevention, theory description.

The Levels of Prevention Model and the Ecological Model for Health Promotion: A Combined Model for the Study of Health Policy

This manuscript describes a theoretical model for the research outlined in the dissertation. The theoretical model combines the Levels of Prevention Model (Clark & Leavell, 1965) and the Ecological Model for Health Promotion (McLeroy, Bibeau, Steckler, & Glanz, 1988). The manuscript addresses how these theoretical works can be combined to study the influence of national policies on health interventions. More specifically, the manuscript links the theoretical model with the study variables and describes how the study tests theory to move the nursing and health literature forward. This manuscript describes how the theoretical model has guided the design and interpretation of the research in this dissertation.

3.1 Introduction

In order to define a study's conceptual rationale, a theoretical model is essential (Polit & Beck, 2012). For research, theoretical models help clarify concepts and the relationships between the concepts (Polit & Beck, 2012). Clarifying concepts and relationships allows researchers to test theories and build evidence to support or refute a theory. Meleis' (2007) theory description method is used to describe theoretical models relevant to research that explores the influence of national welfare spending on the effectiveness of prevention interventions for health. These theoretical models include the Levels of Prevention model by Clark and Leavell (1965) and the Ecological Model for Health Promotion by McLeroy, Bibeau, Steckler, and Glanz (1988). Frameworks, theories, and models are terms that are often used interchangeably in health research literature. However, these two theoretical works will be referred to as models, as they fit with the definition of a model outlined by Carpiano (2005). The models are described in relation to their structure, function, and relevance to nursing research. These models are also used to build a conceptual model for the above-mentioned study in which national policy factors impacting prevention interventions and national policies influencing health are explored. 3.2 Theory Description

In this paper, Meleis' (2007) theory description method is used to describe the two theoretical models. Meleis' method focuses on the structural and functional components of the theory, as well as the nursing domain concepts. The structural component includes assumptions, concepts, and propositions, while the functional component focuses on the relationships between the assumptions, concepts, and propositions (Meleis, 2007).

Analysis of a theoretical model's structure reveals its building blocks. Assumptions are the part of the structural component that determine the theorists' viewpoint (Meleis, 2007). Assumptions can reflect a philosophy, ideology, ethic, culture, social structure, or previously tested hypotheses (Meleis, 2007). Concepts are another important part a theory's structure. Meleis (2007) states that concepts need to be assessed for their clarity, conceptual definitions, observable properties, and boundaries. Concepts can be categorized as primitive (originating within the theory) or derived (borrowed from other theories), abstract or concrete, and variable or non-variable (Meleis, 2007). Concepts are linked together with propositional statements about the dimensions of concepts (Meleis, 2007). Propositions are meant to describe, explain, and predict relationships (Meleis, 2007). Propositions can be probabilistic or absolute, sequential or coexisting, necessary or substitutable, and reflect relationships that are contingent on a context (Meleis, 2007). Finally, function considers how the assumptions, concepts, and propositions fit together (Meleis, 2007). Theories' structures and functions are closely related. In fact, many theories define assumptions, concepts, and propositions by their function. Therefore, structure and function are discussed together in this paper.

Once the structure and function of a theory are described, they can be analysed in the context of the nursing (referred to as concepts of the domain). Concepts of the domain explore the purpose and consequences of the theory (Meleis, 2007). In Meleis' (2007) theory description, concepts of the domain ask who is acted upon; how the nursing paradigm concepts (nursing, person, environment, and health), nursing relationships, or nursing problems are defined; what are the sources of the problem; are there insights or guidelines for nursing interventions; does the theory provide guidelines for the role of nursing; and what are the consequences of action. This method of theory description allows for understanding theories and their relevance to nursing. Meleis' theory description method helps convey the important aspects of the Levels of Prevention model and the Ecological Model for Health Promotion so that these theories can be better understood and evaluated for their usefulness in research exploring welfare spending's influence on prevention interventions. Therefore, the following discussion for each model includes a summary of the model, how it has been used in nursing literature, its structural and functional components, and its concepts of the nursing domain.

3.3 Levels of Prevention Model

The Levels of Prevention model is described generally, in the nursing context, and in the context of Meleis' (2007) theory description. Clark and Leavell (1965) originally developed the Levels of Prevention as a guide for physicians and dentists to intervene at the earliest possible stage of disease. They conceptualized the disease process and how a practitioner can intervene as early as possible (Clark & Leavell, 1965). This model comes from a biomedical, epidemiological perspective (King, 1994; Kulbok, Baldwin, Cox, & Duffy, 1997) and is disease oriented, rather than health oriented (Pandve, 2014).

Although the Levels of Prevention model was originally intended for physicians, it has been heavily adopted in nursing education and research. Falk-Rafael (1998) criticizes the use of the Levels of Prevention in nursing because it is use of a medical model to determine nursing activities. In spite of such criticisms, it is clear that this model has had a significant impact on nursing. Because of its dominance in the health sciences literature, nursing researchers that examine preventative interventions, including the closely associated concept of health promotion, need to understand the Levels of Prevention model for conceptual clarity.

Foundational nursing textbooks, such as Potter, Perry, Ross-Kerr, and Wood (2001), and community health nursing textbook chapters, such as Baldwin and O'Neil Conger (2003); Edge (2008); Leeseberg Stamler (2012); Saucier Lundy, Janes, and Hartman (2003) include the Levels of Prevention. Furthermore, the Levels of Prevention have been used in nursing research (Baker, 1992; Elo & Calltorp, 2002; Figueira, e Ferreira, Schall, & Modena, 2009), nursing theory development (Levin, 2003; Munro et al., 2000), competencies for occupational health nurses (Parrish & Allred, 1995), and nursing undergraduate curriculum development (Adams et al., 2001; Burkhart & Sommer, 2007). There are instances where nurses have used the Levels of Prevention without crediting the original theorists (Adams et al., 2001; Baker, 1992; Edge, 2008; Flaskerud, 1992), leading to the suspicion that nursing educators and scholars have begun to unquestioningly adopt this model as valuable to nurses. However, the structure and function of a theoretical model need to be considered to determine a model's usefulness and appropriateness in nursing research and practice. Therefore, the following discussion includes the structure and function of the Levels of Prevention model.

3.3.1 Structural and Functional Components of the Levels of Prevention Model

As stated above, Meleis' (2007) structural component of theory description includes assumptions, concepts, and propositions. The functional component focuses on the relationships between the assumptions, concepts, and propositions. Each of these components are examined in relation to the Levels of Prevention model.

3.3.1.1 Assumptions

Clark and Leavell (1965) assumed that the objectives of preventative medicine are to promote optimal health, prevent departure from health, and prevent illness after disease is present. They believed that health and disease exist on a continuum and that a person's response to a disease stimulus is a process that begins before the person is affected (Clark & Leavell, 1965; Leeseberg Stamler, 2012). Clark and Leavell (1965) adopted the assumptions of the epidemiological triangle, stating that the disease process involves an agent, host, and environment (see figure 3.1). They believed that the disease process results from a continuous chain of events, not a single cause (Clark & Leavell, 1965). Some of these causes may include heredity, social and economic factors, and the physical environment (Clark & Leavell, 1965). There are also many internal and external barriers to disease that interact with the agent, host, or environment to prevent disease (Clark & Leavell, 1965). It is assumed that even for direct-care practitioners, prevention should reach beyond the individual level to have greater effects and that people should be supported to live and work within their fullest abilities (Clark & Leavell, 1965). The degree of success in preventing disease is thus related to knowledge of the natural history of disease and the ability to apply that knowledge (Clark & Leavell, 1965). These assumptions are fundamental to understanding the Levels of Prevention model.

3.3.1.2 Concepts and Propositions

The concepts and propositions of the Levels of Prevention model are difficult to separate because Clark and Leavell (1965) use many propositional statements to define concepts. They focus on defining the natural history of disease and discuss what type of prevention is most appropriate at a particular stage of disease. The Levels of Prevention are defined by their relationship to the stage of disease. Clark and Leavell do not discuss the predicted outcomes of interventions, but in the conceptual definition they discuss the goal for each level of application. Therefore, concepts and propositions will be discussed together.

The Levels of Prevention model is based on the epidemiological triangle: agent, host, and environment (Clark & Leavell, 1965). These borrowed concepts are the foundation for understanding the Levels of Prevention. An agent is defined as a substance or element whose presence or absence begins or perpetuates a disease process (Clark & Leavell, 1965). (This definition includes both infectious and non-infectious diseases.) When Clark and Leavell (1965) refer to a host, they do not specifically refer to the host itself (the human) but the factors that influence the distribution and occurrence of disease, such as age, gender, habits, customs, defence mechanisms, physical and mental characteristics, genetics, and psychobiologic characteristics. When they discuss environment, they are referring to a collection of all external influences and conditions impacting the life and development of an organism (Clark & Leavell, 1965). These environmental influences can be physical, social, economic, and biologic (Clark & Leavell, 1965).

Health and disease are the fundamental concerns of the Levels of Prevention model. Health is defined as a relative state of equilibrium maintained by the body's active response to adjust to disturbing forces (Clark & Leavell, 1965). Living and non-living disease agents, inherent and acquired characteristics, and environmental factors impact health (Clark & Leavell, 1965). Health is a slightly abstract and variable concept, as Clark and Leavell (1965) state that health exists on a scale. Disease is considered a process that depends on the characteristics of the disease, the human, and the human's response to the disease (Clark & Leavell, 1965). The more that is known about the disease, the earlier interventions can start (Saucier Lundy et al., 2003). The natural history of disease is a concept that reflects the progression of any disease for any person, and it includes the prepathogenesis period and the pathogenesis period (Clark & Leavell, 1965). The prepathogenesis period is the preliminary interaction of the agent, host, and/or environment before they reach humans (Clark & Leavell, 1965). The pathogenesis period begins when the disease stimulus reaches the person, and it involves any changes in a person's form, function, and health until the person reaches an equilibrium, recovers, or experiences defect, disability, or death (Clark & Leavell, 1965). The clinical horizon is the point at which a disease can be clinically diagnosed (Clark & Leavell, 1965).

The next set of concepts in the Levels of Prevention model concern prevention itself. Clark and Leavell (1965) state that they borrowed the definition of prevention from dictionary terms, meaning to anticipate or make impossible by advanced precautions. Prevention depends on choosing the appropriate measures to protect against the causes of diseases; knowledge of the agent, host, and environment; and the ability to counteract the disease (Clark & Leavell, 1965). They specify five levels of application to fit within the three levels of prevention. Primary prevention happens in the prepathogenesis period and includes promotion of optimal health and specific protection against diseases (Clark & Leavell, 1965). Health promotion is a means to support health and well-being, but it is not specific to a particular disease (Clark & Leavell, 1965). Clark and Leavell refer to health promotion activities like health education; healthy nutrition; attention to mental health, home and working conditions; and periodic selective health examinations. Specific protection is a means to prevent the causes of specific diseases before they reach humans, such as immunizations, sanitation and hygiene, hazard and accident prevention, or preventing allergens and carcinogens (Clark & Leavell, 1965).

There are several criticisms that the boundaries between health promotion and specific disease protection are blurred, causing difficulty in differentiating the two concepts (King, 1994). Some critics state that the two concepts are not mutually exclusive (King, 1994). This conceptual blurring may have led to confusion in the health sciences literature between health promotion and disease prevention (Baldwin & O'Neil Conger, 2003; Kulbok et al., 1997). Confusion about health promotion may be due to the changes in the definition of health promotion over time from a biomedical emphasis to an empowerment emphasis (Figueira et al., 2009; Potter et al., 2001). Health promotion is broader than prevention, but some say health promotion is still focused on preventing disease (Baldwin & O'Neil Conger, 2003; Potter et al., 2001). However, Clark and Leavell (1965) refer to health promotion as a concept that aims for well-being.

Secondary and tertiary prevention are included in the pathogenesis period. Secondary prevention begins in the early pathogenesis period when a disease is detectable (Clark & Leavell, 1965). It includes early detection and prompt treatment, as well as disability limitation (Clark & Leavell, 1965). Early detection and prompt treatment are meant to prevent the spread of disease, cure or halt disease to prevent complications, and prevent disabilities with interventions such as case-finding measures, screenings, and examinations (Clark & Leavell, 1965). Disability limitation is meant to prevent or delay consequences of the particular disease with adequate treatment and provision of facilities to prevent disability and death (Clark & Leavell, 1965).

Tertiary prevention happens later in the disease process after disease and disability are fixed, and the person has become stabilized (Clark & Leavell, 1965). If a disease gets to this stage, it is likely that more knowledge is needed to improve detection and interventions and interrupt the disease earlier in its history (Clark & Leavell, 1965). Tertiary prevention includes rehabilitation, which is meant to prevent further disability and return the person to their maximum use in society (Clark & Leavell, 1965). Rehabilitation can include physical, mental, and social interventions, such as education, retraining, and full employment of the patient through working with education and industry to utilize people with various abilities (Clark & Leavell, 1965).

3.3.2 Concepts of the Domain of the Levels of Prevention Model

The concepts of the domain discussion is based on how the Levels of Prevention have been used in the nursing literature. These concepts include person, health, environment, and nursing (Meleis, 2007) Clark and Leavell (1965) do not specifically address the relevance of their model to nursing, as Levels of Prevention is a model from medicine. However, many nursing scholars have adopted this model for nursing (see above). This adoption may be due to the ease of adjusting the Levels of Prevention to a nursing context.

In the nursing literature, the client or community is the target of preventative action. Clark and Leavell (1965) usually make reference to “man” or human beings as their target, especially in reference to secondary and tertiary prevention. However, they also make reference to extending prevention to the family, and some health promotion activities hint at policy interventions, like addressing housing and working conditions. However, in the nursing literature, primary prevention has been used in the home, community, primary health care, and advocacy context (Stanhope, Lancaster, Jessup-Falcioni, & Viverais-Dresler, 2011). Nurses also use secondary and tertiary prevention in the community and in institutional health care settings (Saucier Lundy et al., 2003; Stanhope et al., 2011).

The Levels of Prevention model does not define all the nursing metaparadigm concepts, but it does contain proxies to these concepts. Health is outlined as being on a continuum with disease (Clark & Leavell, 1965). Some nurses take issue with health and disease being on opposite ends of the spectrum, indicating that health is qualitatively different than disease and that people can achieve health while having a disease (Elo & Calltorp, 2002). Person is not given an explicit definition; however, when Clark and Leavell (1965) refer to "man," it seems they consider a person to be any human being prior to and after the onset of disease. Clark and Leavell refer to human beings in biological, physical, mental, occupational, social, sexual, economic, familial, and community contexts. This indicates that they had a holistic view of the person. This holism is fitting with nursing. In terms of environment, the Levels of Prevention model includes the epidemiological triangle concept of environment (see above), and it adds that the environment can include physical, social, economic, and biological dimensions. The epidemiological triangle concept of environment is quite different from nursing's usual conceptualization of environment as the patient context. However, the extended idea of environment beyond the individual context may be beneficial for expanding nursing theory.

Obviously, there is no definition for nursing or the role of nurses in this model. However, there are several examples within the nursing literature where nurses have put themselves in place of the physician in this model, and they have been able to provide interventions within their scope. In fact, nurses are involved in the three levels of prevention throughout peoples' lifespans, every day (Adams et al., 2001; Stanhope et al., 2011). Nurses have used this model to determine appropriate nursing interventions related to where the patient is on the continuum of health and illness to move toward the consequence of health promotion or disease prevention. This model is highly relevant to nursing science and is an appropriate theoretical model for nursing research examining how national policies influence prevention interventions.

The Levels of Prevention model is combined with the Ecological Model for Health Promotion to develop a theoretical model for research exploring how welfare spending influences prevention interventions. These two theories complement each other and build on each other's knowledge. Therefore, the Ecological Model for Health Promotion is also described generally, in the context of nursing, and in the context of Meleis' (2007) theory description.

3.4 Ecological Model for Health Promotion

The Ecological Model for Health Promotion is an important addition to the Levels of Prevention model for research examining welfare spending's influence on prevention interventions. To aid in understanding how national policies, like welfare spending, influence prevention interventions administered to individuals, an ecological model may be beneficial. Ecological models are important to the health sciences because health is influenced by many levels of the environment, as well as biology and human agency (MacDonald, Newburn-Cook, Allen, & Reutter, 2013). Ecological models recognize that health promotion interventions can happen at a variety of levels (MacDonald et al., 2013). Ecological models also break through the pervasive idea in society that health is an individual responsibility, which ignores the impact of class structure and the social environment (Rush, 1997). Ecological models are an important consideration for nursing because most nursing health promotion theories ignore social, political, and environmental contexts, which may impact the style of health promotion that nurses use in their practice (Rush, 1997). However, nurses are well positioned to use ecological theories to link health to its broader influences (MacDonald et al., 2013).

McLeroy et al. (1988) developed an ecological model for health promotion that includes both individual and socio-environmental factors as health promotion targets. McLeroy et al.'s Ecological Model for Health Promotion recognizes the reciprocal relationship between individuals and their environments and moves away from individual responsibility to consider the influence of environment (Rush, 1997). McLeroy et al. warn readers about the potential for environmental health promotion to be paternalistic, coercive, and limit rights and freedoms. Therefore, they emphasize the importance of consensus building, active engagement with the population, and empowerment. Therefore, McLeroy et al.'s conceptualization of health promotion fits well with the modern view of health promotion as empowerment (Raphael, 2008).

Scholars in nursing recognise the McLeroy et al. (1988) Ecological Model for Health Promotion as a seminal ecological model (Kaiser & Baumann, 2010). Although nurses do not always credit McLeroy et al.'s model (Head, Barr, & Baker, 2011; Raynor, 2013; Richards, Riner, & Sands, 2008), it is used in the nursing literature. Nurse researchers have used the model to explore the influences on overweight and obesity issues (Kim et al., 2012; Lindsay, Sussner, Greaney, & Peterson, 2011; Richards et al., 2008; Whittemore, Melkus, & Grey, 2004), nutrition and physical activity (Head et al., 2011; Kaiser & Baumann, 2010), and recovery from substance use disorders (Raynor, 2013). Nurses have also used McLeroy et al.'s model as a base from which to build their own models for access to prenatal care (Sword, 1999) and nature-based health promotion (Hansen-Ketchum, Marck, & Reutter, 2009). Clearly, nurses recognize the usefulness of the Ecological Model for Health Promotion. To enhance the understanding of the relevance that McLeroy et al.'s model has for nursing research, clarifying the model's structure, function, and connection to nursing concepts (concepts of the domain) is important.

3.4.1 Structure and Function of the Ecological Model for Health Promotion

The following discussion of the Ecological Model for Health Promotion is aided by Meleis' (2007) structural component of theory description, including assumptions, concepts, and propositions. The functional component focuses on the relationships between the assumptions, concepts, and propositions. Discussion of the structure and function of the Ecological Model for Health Promotion provides an understanding of its relevance to nursing and its fit with the Levels of Prevention model.

3.4.1.1 Assumptions

McLeroy et al. (1988) do not outline many assumptions in their model. However, they recognize the implicit assumption in their model that health promotion interventions are based on the beliefs, understandings, and theories of behaviour determinants (McLeroy et al., 1988). Their ecological model focuses on how environment impacts behaviours (McLeroy et al., 1988). They also assume that interventions should attempt to modify social relationships (McLeroy et al., 1988). They state that social relationships impact coping, addictive behaviours, health behaviours, where people live, political attitudes, and risk for morbidity and mortality (McLeroy et al., 1988). Social relationships also provide identity, resources, support, information, and assistance with life's responsibilities (McLeroy et al., 1988). These assumptions about social relationships are an important aspect of the Ecological Model for Health Promotion.

The Ecological Model for Health Promotion also has assumptions surrounding organizations. McLeroy et al. (1988) indicate that organizational structures and processes in peoples' lives have a large impact on their health and health behaviours, as well as the ability to maintain long-term individual change. They assume that organizations influence individuals through workload, work schedule, job complexity, management style of leaders, communication patterns, participation, and relationships, all of which impact individual stress levels (McLeroy et al., 1988). Clearly, McLeroy et al. consider the role of organizations important in shaping health.

McLeroy et al. (1988) are concerned with patterned behaviour as the outcome of interest. Patterned behaviour is assumed to be influenced by intrapersonal factors, interpersonal processes with primary groups (such as friends and family), institutional or organizational factors, community factors, and public policy (McLeroy et al., 1988). These five levels of analysis for the influences on behaviour are assumed to reflect strategies for health promotion interventions and are the basis for the Ecological Model for Health Promotion (McLeroy et al., 1988).

3.4.1.2 Concepts and propositions

The Ecological Model for Health Promotion has five levels, the first of which is the intrapersonal level (McLeroy et al., 1988). Intrapersonal factors include characteristics of the individual, such as knowledge, attitudes, skills, behaviours, self-concept, and developmental history (McLeroy et al., 1988). Health promotion at the intrapersonal level can use strategies at multiple levels of intervention, such as individual counselling, support groups, or mass media campaigns, but the focus of the change at the intrapersonal level is on individual characteristics (McLeroy et al., 1988).

The next level, interpersonal processes and primary groups, includes formal and informal social networks and support systems, such as family, friends, and work groups (McLeroy et al., 1988). At the intrapersonal level, individual behaviour change is usually targeted through social influences (McLeroy et al., 1988). Weaknesses of this level are that most health promotion aims to change individuals rather than changing the social norms or groups (McLeroy et al., 1988) and interventions are usually limited in terms of reaching populations (Whittemore et al., 2004).

Institutional or organizational factors is the next level of the model (McLeroy et al., 1988). Examples of organizations are day-cares, schools, universities, and work settings (McLeroy et al., 1988). Organizational factors include the social institutions, formal and informal rules, and regulations for operation (McLeroy et al., 1988). Organizations are considered social and economic resources for people that transmit norms and values, provide a social identity and social support, and mediate between individuals and the larger sociopolitical environment (McLeroy et al., 1988). At this level, organizational change to create healthier environments is the target of health promotion (McLeroy et al., 1988). However, many organizational health promotion interventions target individuals, rather than the organizational environment, with incentives, supervisor support, and benefits (McLeroy et al., 1988). The implementation of an organizational level health promotion intervention depends on upper management support, staff training, and provision or related materials (McLeroy et al., 1988). The degree to which an intervention becomes integrated into the organization depends on the perceptions of costs and benefits, support for the intervention, and alignment of the intervention with the organization's mission and goals (McLeroy et al., 1988).

The next level of the model includes community factors. Community level factors include the relationships between organizations and informal networks within defined boundaries

(McLeroy et al., 1988). There are three meanings for community factors. These diverse meanings are needed because they have different implications for health promotion (McLeroy et al., 1988). The first type of community factors refers to mediating structures, which include primary groups of individuals such as family, friends, religious organizations, and neighborhoods (McLeroy et al., 1988). Community, as a mediating structure, provides social resources and identity and influences community norms and values, as well as individual beliefs, attitudes, and health behaviours (McLeroy et al., 1988). These mediating structures connect individuals to larger society, and health professionals can work with these mediating community structures to influence policy (McLeroy et al., 1988).

The next type of community factors involves the relationships between organizations and groups in an area, such as schools, volunteer agencies, and health providing agencies (McLeroy et al., 1988). Many health promotion efforts are provided through community organizations (McLeroy et al., 1988). The community as organizational relations level recognizes that resources are limited, and community organizations need to collaborate to avoid the inefficiency that may come from competition for resources, like funding, volunteers, or media time (McLeroy et al., 1988). Collaboration and coordination of a community of organizations has the potential to build coalitions for health promotion, improve community awareness, align health policies, and make expenditures more efficient (McLeroy et al., 1988).

The last meaning for community involves geographical and political communities (McLeroy et al., 1988). These communities are influenced by one or more power structures (McLeroy et al., 1988), such as cities, municipalities, provinces, and countries. These power structures play a role in resource allocation and setting the public agenda (McLeroy et al., 1988). This definition of community is important because health promotion issues often have economic and political implications (McLeroy et al., 1988). Powerful people may attempt to block health promotion efforts, while those who would benefit most from the health promotion efforts have less power to influence the definition of the problem, its solutions, or what is put on the public agenda (McLeroy et al., 1988). Those with less political power are often less politically organized and cut off from political processes (McLeroy et al., 1988). Therefore, health promotion efforts need to increase access to larger political structures for the less powerful (McLeroy et al., 1988).

The final level of the Ecological Model for Health Promotion is the public policy level. This level concerns local, state or provincial, and national laws and policies (McLeroy et al., 1988). Policies can influence health by restricting and containing behaviours, allocating resources, restricting how resources can be used, and setting eligibility criteria (McLeroy et al., 1988). Policies may also indirectly influence behaviours, such as withdrawing price supports (McLeroy et al., 1988). McLeroy et al. (1988) assert that health professionals have a role to play in policy development through educating the public about the policy process; advocacy through encouraging political participation, lobbying, building coalitions, and monitoring policy implementation; and policy analysis through provision of policy options and promoting public input. These policy development initiatives are all possible avenues for nurses to promote health. The Ecological Model for Health Promotion is not a nursing theory, but it has many components that make it relevant to nursing science.

3.4.2 Concepts of the Domain of the Ecological Model for Health Promotion

The Ecological Model for Health Promotion aims to act on individuals; families or other groups; organizations; communities of individuals, organizations, or political areas; and public policy (McLeroy et al., 1988). In practice, these are areas in which nurses work to promote health. The multiple levels of health promotion intervention are a strength of the model and a reason for using it in nursing research and scholarship, as nursing theories often ignore the wider influences of the environment (Rush, 1997).

As this model is not a nursing theory, the nursing metaparadigm concepts (person, health, environment, and nursing) are not explicitly defined. The concept of person does not have a definition, although there are hints to its meaning. As stated above, the intrapersonal level of the model includes individual characteristics, like behaviour, skills, self-concept, knowledge, attitudes, and development (McLeroy et al., 1988). Furthermore, people are referred to within their interpersonal networks, educational and work organizations, communities, and power to influence policy (McLeroy et al., 1988). Therefore, it seems that McLeroy et al. (1988) defines a person in social, cognitive, psychological, occupational, developmental, and political terms, although most emphasis is on behaviour. Therefore, the concept of person in this model seems to be holistic.

The concept of environment is the focus of the Ecological Model for Health Promotion. Environment is considered a multi-dimensional concept that influences human behaviour.

McLeroy et al. (1988) consider the environment to exist at the intrapersonal, interpersonal, organizational, community, and public policy levels. The main concern with environment is how it influences human behaviour in relation to health promotion.

Nursing and health are not defined in the Ecological Model for Health Promotion. Health professionals are indirectly referred to as those who implement health promotion activities. Therefore, nurses can use this model to develop health promotion interventions that are congruent with nursing theory and scope of practice. Health is only referred to in terms of health promotion. There are many referents to the influences on health (individual factors, social relationships, organizational factors, communities, power) but no explicit definition of health, itself. McLeroy et al. (1988) state that health promotion should go beyond a behavioural and lifestyle view of health promotion to include social and organizational contexts. This implies that health is a consequence of the interplay between the ecosystem's levels (Cohen, 2012).

The Ecological Model for Health Promotion is valuable to nursing because it offers nurses perspectives of health and health promotion that lie both within individuals and outside individuals in their social groups, workplaces, communities, and power structures. This model gives nurses insights for interventions, although it does not provide interventions for any specific situation. Rather, this model asserts that multiple strategies at multiple levels of intervention will be the most helpful in promoting health (McLeroy et al., 1988). This model does not provide consequences for health promotion interventions at any given level, but it does imply that successful interventions will promote health. Overall, this model is general, but it gives nurses opportunities to examine the environment in several ways and apply it to many situations.

Both the Levels of Prevention model and the Ecological Model for Health Promotion are appropriate for nursing research examining the influence that welfare spending have on a prevention intervention (measles immunization) and its associated outcome (measles disease rates). These theories can be used together because the Levels of Prevention model explores prevention in health and the Ecological Model for Health Promotion connects these interventions to the political environment (see figure 3.2). Therefore, this research tests the influence of public policy (from the Ecological Model for Health Promotion model) on primary prevention interventions (from the Level of Prevention model).

3.5 Welfare Spending and Prevention Interventions: Study Variables

The above-mentioned conceptual model was used to design a study that explores how public policy influences preventative health services. This research investigates the influence that public policy has on primary prevention. More specifically, the variables used in this study relate to welfare spending, measles vaccination rates, and measles cases to represent public policy, specific protection in primary prevention, and the outcome of primary prevention, respectively.

3.5.1 Public Policy

Public policy is the overarching theoretical concept under which welfare spending is represented, and public social expenditure as a proportion of gross domestic product (GDP) is the specific variable representing public policy. Social expenditure as a proportion of GDP is commonly used to represent the share of resources distributed according to social criteria, rather than market criteria (Esping-Andersen, 1990; Korpi, 1983). Public social protection expenditure as a proportion of GDP is obtained from the International Labour Organization (2017). Huber and Stephens (2001) argue for the long-term analysis of welfare policy because short-term analysis over-emphasizes actors' choices rather than structural constraints and suppresses political effects. Therefore, this research uses social protection measures over time. Social protection expenditure represents the proportion of a country's domestic income redistributed for the purpose of social equity.

An aspect of public policy that is important to welfare spending is defamilialization. Defamilialization represents lack of dependency on the family for social protection. Female employment rates are used as a proxy for defamilialization, as employment gives women greater independence from a male breadwinner. Female employment rate is represented with the proportion of the female population aged 15 and above who participate in the labor force. This variable, retrieved from The World Bank Group (2017a), represents women who work or are looking for work, but does not represent unpaid or family workers. Therefore, this indicator may be a good representation of defamilialization.

3.5.2 Preventative Health Services

The relationship between a preventative health service and its associated outcome is represented with the measles vaccination series and measles cases, respectively. Measles vaccination series is represented with the proportion of one-year-old children who had the first dose of measles vaccine and the proportion of children who had the second dose of measles vaccine by the nationally recommended age, and it is available from the World Health Organization (2017). Reported measles cases represents the preventative health service outcome, also available from the World Health Organization (2016).

3.5.3 Control Variables

To account for variables that may impact the influence that welfare spending has on the relationship between preventative health services and outcomes, control variables that are included in the model were carefully selected. World region is accounted for by categorizing countries according to the United Nations (2017) geographical regions. World region is meant to account for any region-specific influences on health policies, social policies, or health outcomes. Democracy has an important role in the determination of how resources are distributed among a population. Therefore, the Polity IV democracy index from the Center for Systemic Peace (2017) represents democracy (or lack thereof) in a given country. The Polity IV is based on scoring countries according to democratic and authoritarian principles related to elections, transition of power after elections, constraints on the chief executive of the state, political participation, and competition between political parties (Marshall, Gurr, & Jaggers, 2017). This study also includes the Gini index, representing country income inequality. The Gini index represents a deviation from a perfectly equal income distribution (The World Bank Group, 2017b). Gini index values range from zero, representing perfect equality, to 100, representing perfect inequality (The World Bank Group, 2017b). The final control variable is GDP per capita. GDP per capita controls for the overall level of development in a country, and it is available from The World Bank Group (2017b).

Overall, the Ecological Model for Health Promotion and the Levels of Prevention model help to develop a conceptual model for a study that is relevant to nursing. The study explores how the relationship between measles rates and measles immunizations (a preventative health intervention often carried out by nurses) is influenced by national welfare spending (a policy that impacts nurses and their patients). This study control for variables including female employment rate, income inequality, GDP per capita, and level of democracy. This combined conceptual model could also be used in the future to generate more research questions related to health policy at various ecological levels and its influence on various levels of prevention. This conceptual model may be useful for nurses and health professionals who aim to examine topics in this area of enquiry in the future.

3.6 Conclusion

Meleis' (2007) theory description method has been used to explore two theoretical models that are chosen to guide the study described in this paper. A theory description method, such as Meleis' aids in deconstructing a theoretical model's structure and function and determining its usefulness to nursing research. Meleis' method was used to describe the Levels of Prevention model by Clark and Leavell (1965) and the Ecological Model for Health Promotion by McLeroy et al. (1988). These theoretical models were chosen for their relevance to research that explores the influence of a given country's national welfare policy on the effectiveness of prevention interventions concerning measles immunization. Understanding the theoretical models of one's research is important in producing valid research and framing research in a way that will increase its translation to policy for improved population health.

3.7 References

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3.8 Theoretical Model Figures

<table>
<tr><td colspan="5">→→→→The Natural History of any Disease→→→→</td></tr>
<tr><td colspan="2">Interaction of Agent, Host, & Environment
↓
Production of Stimulus →</td><td colspan="3">Reaction of Host to Stimulus
Early Pathogenesis →Discernable Early Signs →Advanced Disease →Convalescence →</td></tr>
<tr><td colspan="2">Prepathogenesis Period</td><td colspan="3">Period of Pathogenesis</td></tr>
<tr><td>Health Promotion</td><td>Specific Protection</td><td>Early Diagnosis & Treatment</td><td>Disability Limitation</td><td>Rehabilitation</td></tr>
<tr><td colspan="5">Levels of Application of Preventative Measures</td></tr>
<tr><td colspan="2">PRIMARY PREVENTION</td><td colspan="2">SECONDARY PREVENTION</td><td>TERTIARY PREVENTION</td></tr>
</table>

Figure 3.1. Levels of Prevention model by Clark and Leavell (1965).

→→→→The Natural History of any Disease→→→→				
Interaction of Agent, Host, & Environment ↓ Production of Stimulus →		Reaction of Host to Stimulus Early Pathogenesis →Discernable Early Signs →Advanced Disease →Convalescence →		
Prepathogenesis Period		Period of Pathogenesis		
Health Promotion	Specific Protection	Early Diagnosis & Treatment	Disability Limitation	Rehabilitation
Levels of Application of Preventative Measures				
PRIMARY PREVENTION		SECONDARY PREVENTION		TERTIARY PREVENTION

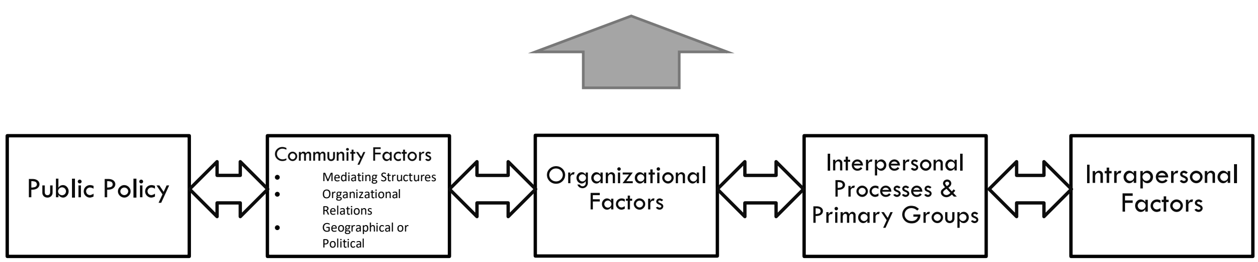

Figure 3.2. Levels of Prevention Model (Clark & Leavell, 1965) combined with the Ecological Model for Health Promotion (McLeroy et al., 1988).

4.0 MANUSCRIPT: METHODOLOGY

A Bayesian Approach for Spatial Regression and Generalized Linear Mixed Models

Mary Ellen Walker, RN, PhD(c)

Michael Szafron, PhD

June Anonson, RN, PhD

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Author contributions: MW conceptualised and designed the analytical approach; collected and analyzed the data used to develop the analytical approach; developed the software coding; and drafted, revised, and finalised the article. MS provided guidance on the methods and coding used in the analytical approach and made significant contributions to the article. JA made significant contributions to the article.

Nurses work to improve or promote health in a spatial plane. However, there is a lack of quantitative spatial methods published in nursing literature. The nursing research that uses spatial methods does not show results from spatial regression methods. However, there is immense potential for spatial analysis to expand the scope of nursing research. Therefore, an analytical approach was developed to make spatial analysis more accessible to nurse researchers and other health researchers. The analytical approach focuses on explaining how to implement spatial regression. It includes the initial stages of analysis, including exploratory descriptive statistics and choropleth mapping; investigation of spatial and non-spatial relationships among the variables; model building that progresses from bivariate, fixed-intercept models to generalized linear mixed models (GLMM); and practical tips on how to implement Bayesian spatial analysis. Research exploring the influence that welfare spending has on the relationship between measles vaccination and measles rates is used as an example to enhance the explanation of the analytical approach. Through a description of the analytical approach and an example, the process of spatial analysis (including spatial descriptive statistics, inferential tests, and regression) is made accessible for nurses and health researchers who are interested in using it.

Key words: Bayesian; generalized linear mixed models; quantitative methods; spatial analysis; spatial statistics

A Bayesian Approach for Spatial Regression and Generalized Linear Mixed Models

This paper's aim is to encourage use of spatial statistics in nursing research and outline the analytical approach used in this research to obtain valid results. This manuscript includes a comprehensive overview of the analytical approach used to study the data, using the example of research that explores the relationship between welfare spending and immunizations. It discusses key spatial and non-spatial considerations for examining spatial data, statistical methods used, computer software, and common challenges.

4.1 Introduction

The places where people live, work, and play have important implications for their lives, including their health. Nurses aim to improve or promote health in the spaces where people live, throughout their life spans. Therefore, nursing research could benefit from considering how place, or spatial location, influences nurses and the populations they serve. However, quantitative research that incorporates inferential spatial statistics is not often published in the nursing literature. The potential for spatial analysis to be used in nursing research is immense. This analytical approach could be applied to diverse nursing research problems based in communities or hospitals. For example, nurse researchers could use spatial analysis to explore the spread of infection between patient rooms in hospitals or long-term-care centers; examine the influence of geography on home care nursing assignments; or consider how proximity to various locations increase or decrease risk for a health outcome. Furthermore, spatial analysis may be used in outcomes research to determine the impact of geography on the policies and interventions that impact patients. Therefore, this paper makes spatial analysis more accessible to nurses and other health researchers by outlining an analytical approach that researchers can follow and apply to their studies. The analytical approach is complemented by a research example. Some of the research results are shown as an example, but these results are not the focus of this paper. However, this paper focuses on explaining how to implement the analytical approach, including data preparation, preliminary analysis, generalized linear mixed models (GLMM), and Bayesian spatial analysis.

4.2 Background & Literature Review

Spatial analysis in relation to health has been used for over a hundred years. One of the oldest and most cited examples of the early use of spatial analysis is John Snow's 1854 study of cholera in London, England (Waller & Gotway, 2004). Snow plotted the addresses of people who died from cholera and found clustering around a water pump, providing evidence that the water pump was contaminated (Waller & Gotway, 2004). However, John Snow's analysis went beyond mapping of cholera cases and included statistics to explore the data further (Waller & Gotway, 2004). Statistical analysis of spatial data is important for making inferences about questions that arise from the data. Since John Snow's time, spatial analysis in health research has expanded with the use of computers, geographical information systems (GIS), and advanced statistical software. These tools aid researchers in moving beyond visual analysis of maps to statistical inference that assesses differences in rates between geographical areas, separates random noise from patterns, identifies clusters, and assesses the significance of exposures (Anselin, 2018; Waller & Gotway, 2004). In addition, spatial statistical analysis accounts for Tobler's first law of geography, which defines spatial autocorrelation as the greater likelihood of observations that are closer together being more alike (when autocorrelation is positive) (Tobler. 1970; Waller & Gotway, 2004). Spatial autocorrelation is an important consideration in research that concerns people's health in diverse geographical areas.

Nursing researchers have started to use GIS and spatial statistics in their studies. However, the publication of the nursing profession's use of these methods has been very limited. Nurses may have published spatial analysis research in non-nursing journals. However, there is no current method of searching databases by the author's specialization. Therefore, nursing journals were searched to approximate the use of spatial methods in nursing research. In a literature review that aimed to find spatial analysis methods published in nursing journals, the following databases were searched: EBSCOhost CINAHLplus (1937 to present), Ovid Medline(R) (1946 to present), and Elsevier Scopus. Keywords included nurs*; geog*; Geographic Factors; Geographic Information Systems; maps; mapping, spatial*; models, spatial interaction; spatial analysis; spatial correlation; and spatial regression. Articles were searched by title and abstract, then full text. Each article was hand searched for reference lists and citing articles. This search uncovered 22 articles that use spatial methods and are published in nursing journals. Most of these articles only use maps to do visual analysis. Only four of the articles used spatial clustering analysis (Blake, 2014; Ghosh, Sterns, Drew, & Hamera, 2011; Lindley & Oyana, 2016; Santos et al., 2016). Blake (2014) is the only researcher who reported the use of spatial regression. However, Blake did not include the spatial regression results in her paper because the results were not statistically significant. Therefore, nursing research could benefit from being introduced to spatial statistical analysis in an accessible, step-by-step way. With the analytical approach presented here, this paper will help nurses to expand their understanding of spatial analysis, including the process of analyzing spatial polygon data. Hopefully, this paper will encourage more nurses to use spatial methods in their research.

4.3 Analytical Approach

This analytical approach was developed for research that explores the influence of country-level welfare spending's influence on the relationship between measles cases and measles immunization. Therefore, this example is used throughout the described analytical approach. However, the discussion focuses on how to implement the analytical approach, rather than the results of the research. (The workflow for the analytical approach is summarised in figure 4.1.) The purpose of this analytical approach is to provide nurse scholars with guidance on how to analyse spatial polygon data from the initial phases to completion. Polygons represent closed shapes with three or more sides and angles (examples include countries, provinces, municipalities, school districts, postal codes, etc.) (Waller & Gotway, 2004). Further reference may be needed for data that are not representative of a polygon.

4.3.1 Data Preparation

It is important to start any statistical analysis by exploring the data, including its missing values and its outliers; deleting, imputing, or simulating cases with missing values; and assessing the data with descriptive statistics (Duffy & Jacobson, 2005). The initial investigation of the data can include Little's Missing Completely at Random (Little's MCAR) available in SPSS (IBM Corporation, 2016). Little's MCAR determines if there are patterns in the missing data (IBM Corporation, 2016). If the data is missing in a non-random pattern, one must consider how the analysis should move forward (Duffy & Jacobson, 2005). For example, if the data is showing missing patterns by time or geographical area, the scope of the study may have to be reduced. Missing data is an issue that can have important impacts on the analysis and results. Therefore, it is important to carefully consider and document how missing data is handled.

For example, in the sample analysis, the welfare spending variable is only available in the years 1995, 2000, 2005, and 2010 to 2015. This variable is one of the main variables of interest. Therefore, the analysis was restricted to the years that the welfare spending variable was collected. Furthermore, many small, island countries had no data for measles cases or measles immunizations. Therefore, several of those countries had to be removed from the analysis.

Once outliers and non-random patterns are removed from the data, one may consider imputing missing values. Imputing data is a worthwhile practice because statistical programs remove cases, or subjects, from the analysis that have incomplete data. When there is a lot of missing data, few cases may remain in the final analysis. SPSS has a program that imputes missing values with Markov Chain Monte Carlo (MCMC) simulations (IBM Corporation, 2016). Discussion of this imputation method is beyond the scope of this paper but further documentation of can be found in IBM Corporation (2020). Several imputed datasets can be created at once. Researchers may consider using multiple imputations and repeating the analysis on the imputed datasets or averaging the imputed datasets for analysis (Duffy & Jacobson, 2005). Using multiple imputations can be used to check that imputed data is not having undue influence on results (Duffy & Jacobson, 2005). Our study used nine imputations to do the preliminary modeling (discussed below). Because all the preliminary model results had confidence intervals that overlapped for each variable, only one imputation was used in the final spatial analysis.

The imputed data's descriptive statistics further assesses the data to determine if any special considerations need to be made in the analysis, such as non-parametric tests or transforming the distributions of variables (discussed below). The mapping of variables is also useful in assessing the geographic spread of the variables. Choropleth maps are a common method of displaying polygon data (Waller & Gotway, 2004). These maps use combinations of colors and patterns to depict values associated with an area in a map (Waller & Gotway, 2004). Mapping can be done through programs, like ArcGIS (ESRI, 2016) or its free alternatives QGIS (QGIS Development Team, 2018) and MapWindow (MapWindow GIS Team, 2017). (It is helpful to watch videos or take classes to learn how to use these software packages.) Mapping is an important step in describing and understanding the data. Therefore, caution must be used in mapping because it can be deceptive if the mapping program settings are not carefully selected to create a representative map. In sample analysis, the descriptive statistics included means, standard deviations, scatter plots, box-and-whisker plots, histograms, and choropleth maps.

These descriptive statistics allow for an increased understanding of the data, anticipation of problems with data analysis, and decisions about how to proceed with the analysis.

Exploring dependent variable outliers is another important step in understanding the data. Outliers need to be identified and assessed to determine their influence on the data. Outliers are extreme values relative to most values in the distribution and appear to be inconsistent with the rest of the data (Duffy & Jacobson, 2005). Researchers should consider outliers by important dimensions of their data (Duffy & Jacobson, 2005), such as by spatial location and time. If there is a common element to the outliers, the outliers may need to be removed from the main dataset and analysed separately. Exploring outliers reveals the data's characteristics and helps with decision-making about which observations should be included in the regression analysis. For example, in our analysis, we considered countries that had zero measles cases in all the years studied to be outliers and removed them. All the same cases must be removed from each imputation, so we made sure that if a country's data was removed from one imputed dataset, it was removed from all the other imputed datasets. If there is a large group of outliers, they may warrant being analysed separately from the main dataset. However, once the cases for the dataset have been chosen, one can begin analysis.

4.3.2 Preliminary Analysis

Prior to starting modeling, it is important to test variables for their distributions, bivariate correlations, and spatial autocorrelations. In many cases, spatial polygon data has a dependent variable in the form of a count for each area (Dohoo, Martin, & Stryhn, 2012). For example, in a study exploring welfare spending and measles, the number of measles cases in each country in a given year was the dependent variable. Count data is often in the form of a Poisson or negative binomial distribution (Kery, 2010). Poisson distributions have a narrow requirement that the mean and variance should be equal (Langford & Day, 2001). Therefore, negative binomial models are often appropriate for spatial models using count data. Researchers can test that the dependent variable follows a certain distribution with an intercept-only generalized linear model (GLM) (discussed below). If the model is significant, then the dependent variables follow the distribution for which it was tested. We used this method to test our dependent variable (measles cases) overall and when divided into the world regions. We found that a negative binomial model was appropriate. Therefore, important modeling decisions, such as the correct distribution, may be made with preliminary inferential statistics.

Preliminary analysis can also include spatial inference tests. To complete these tests, researchers must decide how they want to define the neighborhood matrix (also referred to as a spatial weight matrix). Neighborhood matrices can easily be created in Geoda (Anselin, 2018), a free GIS program. There are many ways to define a neighborhood matrix, such as by distance, k nearest neighbors, or contiguous borders. One may also define neighbors in alternative ways, such as population-weighted centroids or relationships based on relevant interactions between polygons, like travel or commerce. Depending on the method of defining a neighborhood matrix, one must also consider how to address polygons without neighbors. Decision making about neighborhood matrices is beyond the scope of this paper, but the subject is thoroughly discussed in Waller and Gotway (2004).

For analysis of the welfare spending's influence on measles immunization and cases, the neighborhood matrix was based on shared borders (queen contiguity) but modified so that countries separated by 200km of water or less were coded as neighbors. This was modification was made to account for countries that were close, but not sharing a land border. We completed this modification by creating a 100km buffer around each country and setting the buffer layer to 50% transparency. If two countries, buffers touched over a body of water, the pair were considered neighbors. We chose this approach because it accounted for countries with a shared border or a close geographical distance. Changes to the neighborhood matrix can be made by opening the file in a program that edits .txt files. When editing the file, it is important to change the neighbor list and the total number of neighbors for each country involved in the changes. Be sure to save the altered file in the same file format as the original matrix (such as .gal), not as a .txt file. It may be beneficial to try multiple neighborhood matrices to see which one best captures the data's spatial autocorrelation.

Once the neighborhood matrix has been defined, global and local autocorrelation can be tested. Global spatial autocorrelation assesses for correlation between the same kind of measurements at different locations (Anselin, 2020a; Waller & Gotway, 2004). It is a summary of the spatial similarity between neighbors over the whole study area (Anselin, 2020a; Waller & Gotway, 2004). Positive spatial autocorrelation indicates that neighboring areas have similar values of the variable, while negative spatial autocorrelation indicates that neighboring areas have differing or irregular values of the variable (Anselin, 2020a; Waller & Gotway, 2004). There are many methods of computing global spatial autocorrelation. In our analysis, we used

Moran’s I. See Anselin 2020a or Waller and Gotway (2004) for a complete explanation of how Moran’s I is calculated.

Local indicators of spatial autocorrelation (LISA) look for areas of similar deviations from the overall mean, suggesting spatial similarity (Anselin, 2020b; Waller & Gotway, 2004). LISA statistics detect and identify clusters within the data, while global spatial autocorrelation statics can suggest spatial clustering, but cannot identify where the clustering is located (Anselin, 2020b; Waller & Gotway, 2004). Local Moran’s I is one such LISA statistic that we used in our analysis to detect local clustering (see figure 4.2 and figure 4.3 for examples). GeoDa is a user-friendly program for completing both Global and local spatial autocorrelation. The maps that Geoda creates are not easily altered to make suitable for publication. However, there is an option to save the results from Geoda in a table and merge the table with a shapefile in another program, like QGIS. Maps and statistics of global and local spatial autocorrelation are helpful tests in understanding the spatial distribution of the data.

The preliminary analysis should provide a plan for the statistical modeling stage. The data’s distribution will determine what kind of model will be used and the spatial correlation statistics and maps will help to determine if spatial effects should be investigated in the model. Once these steps are completed, model building can begin.

4.3.3 GLMMs

The spatial regression modeling can be analyzed with non-spatial regression methods to begin the modeling process. This analytical approach specifically examines how to analyze spatial polygon data with GLMMs. Further reference is needed for spatial point data. Many analyses of health data involve outcomes variables in the form of counts, proportions, or rates (Waller & Gotway, 2004). GLMs extend the basic concepts of linear regression, but they allow for a variety of distributions, including Poisson and negative binomial models for count data (Waller & Gotway, 2004). Like linear models, GLMs consist of a systematic component, defining the linear combination of explanatory variables (the model), and a random component, defining the distribution of errors (expected values) (Waller & Gotway, 2004). However, GLMs are distinct in their use of a link function to define the relationship between the systematic and random components of the model, which is usually in the exponential family (Waller & Gotway, 2004). In the case of count data, an offset is commonly needed in the model, as well. Offsets are used as a denominator for the dependent variable to account for differences in the size of spatial areas (Kery, 2010). If link functions (described above) are in the log form, the offset should also be logged (Kery, 2010). In the case of modeling the influence of welfare spending on country measles counts, the log of the countries' populations was used as an offset. GLMs are often useful when performing regression modeling on data that does not meet the assumptions of linear regression modeling.

In some GLMs that include spatial data, one needs to account for grouping of spatial units within larger spatial areas or multiple measures on the same subject (Healy, 2001). This is called nested, hierarchical, or multilevel data (Healy, 2001). The assumption in multilevel models is that there is less variability between observations within groups than observations drawn at random from any group (Healy, 2001). For example, a multilevel model where country measles count is the dependent variable considers countries being nested within world regions or continents. This method of analysis regards country observations within a region to be more alike than observations for countries drawn at random. This issue is important in spatial analysis because there may be political or environmental factors that influence small areas that are grouped together as part of a larger spatial region. To allow for grouped data to be analyzed this way, one or more extra error terms are added to account for the grouping variables (Healy, 2001). For example, an error term for the *j*th region accounts for the variability between each country within the *j*th region. The intercept for the *j*th region is the model intercept plus the error for the *j*th region. The model's intercept and any other coefficients are the fixed part of the model, and the extra error terms to account for grouping variables are the random part of the model (Healy, 2001). It is also possible to include error terms that give each nested value a coefficient (called a random slope) (Healy, 2001), but that topic is beyond the scope of this paper.

In our example, we ran a bivariate GLM for each dependent variable and control variable of interest in SAS using PROC NLMIXED (code provided in Appendix A) (SAS Institute Inc., 2020). If a variable was significant at 0.20, then it was included in a GLM with all significant variables. In this example, the computer program had difficulty running the models. Therefore, variables were transformed with the natural log and standardized to aid in the analysis. Finally, a GLMM with random intercepts for region and country was added to develop the final model to be analyzed with OpenBUGS (Spiegelhalter, Thomas, Best, & Lunn, 2014).

4.3.4 Bayesian Approach to Spatial Regression

Accounting for spatial relationships in regression models requires a move away from traditional statistical methods based on likelihood. Using likelihood-based models with spatial data becomes complicated because spatial autocorrelation violates assumptions of independence (Waller & Gotway, 2004). However, Bayesian inference can be used in models with correlated or autocorrelated data because it uses simulations to obtain parameter estimates and distributions (Waller & Gotway, 2004). Bayesian statistics differ from classical statistics because it considers the probability of unknown model parameters taking on certain values given the data and the probability model, rather than the probability of model parameters being close to the true parameter values (Cressie, 1993; Waller & Gotway, 2004). Bayesian statistics are based on a posterior distribution (the distribution of model parameters given the observed data) (Cressie, 1993), the likelihood function (the distribution of the data given the model parameters), and the prior distribution (the distribution of the parameters set by the researcher based on previous findings) (Waller & Gotway, 2004). For a more robust explanation of Bayesian statistics see Waller and Gotway (2004) or Cressie (1993).

In practice, Bayesian inference requires researchers to define prior distributions for each variable, in addition to defining the likelihood (model) (Spiegelhalter et al., 2014; Waller & Gotway, 2004). The prior distributions may be based on previously known information about the data, but often prior distributions are set as noninformative with a uniform or normal distribution that contains a wide variance (Waller & Gotway, 2004). Noninformative priors often result in estimates that are similar to traditional maximum likelihood methods (Waller & Gotway, 2004). Bayesian analysis provides estimates of the variables with MCMC algorithms (Spiegelhalter, 2014; Waller & Gotway, 2004). A Markov chain is a sequence of random variables where the distribution of one observation only depends on the observation before it, and after a Markov chain has run for long enough, it converges to a distribution where the probability of a chain taking on a particular value does not change (Waller & Gotway, 2004). The Markov chain is used to construct Monte Carlo simulations to generate stationary distributions for the parameter estimates (Waller & Gotway, 2004).

4.3.4.1 Practical tips for Bayesian analysis

To perform Bayesian analysis, a computer program is needed to run the analysis. For the example provided here, OpenBUGS (Spiegelhalter et al., 2014) was used. OpenBUGS is a free program that is available for download (https://www.mrc-bsu.cam.ac.uk/software/bugs/openbugs/). However, OpenBUGS and its earlier versions (WinBUGS) can be tedious to use. Therefore, practical tips for setting up data (see table 4.1) and sample code (see appendix B) are provided. However, reading the manual and working through examples is also worthwhile when learning to use OpenBUGS.

To run a model in OpenBUGS, three files are needed: data, a model, and initial values. Once the data is in the correct format, it can be loaded into OpenBUGS and the number of chains can be selected. In the OpenBUGS manual, Spiegelhalter et al. (2014) provide documentation and examples of how to specify which variables need to be sampled from the chains. The model should be run long enough so that all variables and random effects reach convergence, as evidenced by Brook-Gelman-Rubin (BGR) plot (Gelman & Rubin, 1992) (see figure 4.4 for an example). Convergence is reached when the chains reach equilibrium and values are generated from the target distribution (Ntzoufras, 2009).

The values generated before the chain converges on the stationary distribution are called the burn-in period (Ntzoufras, 2009). The burn-in period can be eliminated from the sample to avoid unrepresentative values influencing the results, or the sample can be run long enough so that the burn-in period has minimal influence on the results (Ntzoufras, 2009). The point at which the model converges on the BGR plot can be multiplied 100 to determine the burn-in period, but we chose a length of run that reduced the burn-in period to 5% of its total. The time between independent samples is the burn-in period divided by 10 (Sokal, 1989). For example, all of our variables and random effects converged by 1750 samples. Therefore, our burn-in was 175,000, our sample rate was 17,500, our length of run was 3,325,000, and we had 190 samples. However, after running convergence output and diagnostic assessments (CODA) (discussed below), we found that our model needed to be run for 20,020,000 time-steps with 1144 samples.

OpenBUGS generates several plots that help to determine if the chains have reached their stationary distribution, including trace plots, autocorrelation plots, and density plots (see figure 4.5). Trace plots give further evidence of convergence when the values fall into a consistent zone without any aberrations or irregular patterns (Ntzoufras, 2009). The plot should have a random pattern, yet the iterations should fall within a zone throughout the plot. The density plot shows the distribution of the chain (Ntzoufras, 2009) and is useful to determine that the chain has a unimodal distribution. Finally, the autocorrelation plot represents the correlation between samples from the chain (Ntzoufras, 2009). If the plot shows a high level of autocorrelation, the samples from the chain are not independent and the sampling rate may have to be increased (Ntzoufras, 2009). These plots help check that the model and its results are valid.

Once a non-spatial model is completed in OpenBUGS, its residuals can be examined for spatial correlation (Waller & Gotway, 2004). To do this, one may map the residuals and complete tests for global spatial autocorrelation or LISA (Waller & Gotway, 2004). If tests indicate that the residuals have a spatial correlation, including spatial regression may be indicated (Waller & Gotway, 2004). In our example, country residuals were tested for each year to determine if spatial correlation was present. Global spatial correlation was present in four of the nine years tested, which justified building and testing a model with spatial random effects.

To test for spatial correlation, maps must be appropriately formatted for GeoBUGS (Thomas, Best, Lunn, Arnold, & Spiegelhalter, 2014), which is available in the OpenBUGS map menu. For this research, we used the s-plus format. Most popular mapping programs do not use s-plus format. However, QGIS has a plug-in called maps2winbugs that converts a shapefile to s-plus format. Our map was too detailed for the conversion, but this issue was solved using the simplify tool in QGIS. The QGIS conversion numbers polygons based on their order within QGIS. Therefore, it is worth double-checking that s-plus map matches the OpenBUGS data if numbers, rather than names, are used to represent polygons. Once the map is appropriately formatted, the GeoBUGS manual gives clear uploading instructions.

In order to write a model for spatial random effects, the most appropriate model for polygon data is a Gaussian conditional autoregressive (CAR) model (Spiegelhalter et al., 2014). (Code for a random spatial effects model is shown in the appendix.) Once the spatial model is complete, it can be compared to the non-spatial model to determine which one best represents the data. The variance patrician coefficient (VPC) is used to determine the percentage of variance explained by the random effects (Browne, n. d.). It was difficult to determine the amount of error that spatial random effects accounted for in our model due to the shape of the error distribution. Therefore, we chose the non-spatial model to represent the relationships between the variables because there was a better model fit according to the Bayesian Information Criterion (BIC). However, if a spatial is chosen as the final model for presentation, providing maps to illustrate the spatial effects is an important part of the analysis.

4.3.4.2 CODA

Once the final model has been chosen and its convergence diagnostic plots indicate that convergence has been reached, CODA tests should be run to confirm that the chains have been run for long enough. The Gelman and Rubin (1992), Geweke (1992), Raftery and Lewis (1992), and Heidelberger and Welch (1981) tests determine that chains have been appropriately sampled. These tests determine that the sample size and length of the chain is appropriate, the burn-in period is long enough, and the distributions are stationary, for example. See each reference for specific details on each test. (R code for CODA tests provided in appendix C.) The data to run these tests is obtained by clicking on the “coda” button in the inference menu. The coda files can be copied and pasted into a .txt file and analyzed in Rstudio (RStudio Team, 2016). These tests are worthwhile because they provide confidence that the analysis has been done appropriately.

4.4 Discussion

This analytical approach includes many components and several computer programs. It requires perseverance to master each of the steps. Problem solving and guidance from an experienced researcher is also beneficial. Starting with basic skills and building toward the spatial modeling outlined in this analytical approach is rewarding. Nurses and other health professional researchers have the problem-solving skills to master this analytical approach. This analytical approach was created to make spatial analysis more accessible to nurses and other health professionals. As more nurses become comfortable with spatial analysis techniques, our knowledge and skills will open new possibilities for research that benefits nurses and the populations for whom they care.

In spite of the advantages of using this analytical approach, it has limitations that deserve consideration. Some of these limitations come from the nature of using spatial polygon data. For example, results may vary if data points grouped to represent types of geographical areas (polygons) had been grouped in a different way (countries vs. provinces vs. municipalities). Another limitation of this analytical approach is that geographical areas with diverse populations may be unfairly compared. For example, the number of people with an infectious disease in a small island country will impact the disease rate far more than the same number of people with the infectious disease in a highly populated country, like India or China. These limitations are inherent in any analysis of spatial polygon data. Further limitations of this analytical approach come from the analytical approach itself. Some of these limitations include its focus on only polygon data, its lack of accounting for the various sizes of the polygons (countries), its development with a specific dataset, and its ultimate rejection of the model with spatial random effects. However, in spite of these limitations, this analytical approach provides nurses researchers with information about how to implement spatial analysis techniques into their research. This kind of analytical approach has the potential to inspire more robust spatial analysis research in nursing.

4.5 Conclusion

The analytical approach described above provides an overview of how to complete analysis of spatial polygon data, including data preparation, preliminary analysis, GLMMs, and Bayesian spatial analysis. Providing this analytical approach and the associated example analysis is meant to make quantitative spatial analysis more accessible to nurse researchers and other health professionals because spatial methodologies are not frequently published in nursing literature. Increasing the nursing research that incorporates spatial analysis may broaden and deepen the body of nursing literature. Accounting for spatial relationships is important to nursing because nursing, in its many forms, takes place in a spatial plane.

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4.7 Analytical Approach Tables

Table 4.1. Tips for using OpenBUGS.

Setting up data	• Using list format is the simplest way to set up data.
	• Make sure all values of a variable have the same number of decimal places.
	• Errors may occur if there are redundant decimal places for a variable. (Unnecessarily having zeros at the end of all the values of a variable.)
	• Only the variables that are in the model can be present in the data. If data is present that is not represented in the model, it will cause an error.
	• To convert data to list format:
	    o Open data in Excel.
	    o Copy and paste the data into another sheet using the transpose option.
	    o Copy the transposed data and paste it in a Word document. Data points will be separated by a tab.
	    o Copy the tab between two data points, open “find and replace,” and paste the copied tab into the “find” box.
	    o In the replace box, type a comma followed by a space (i.e. “, ”) and click on replace all.
	    o At this point, there will only be minor changes needed to match the list format for data found in the OpenBUGS manual.
	    o Copy and paste the Word document into a OpenBUGS (.ods) file.
	• Keep a record of the order that the data is in after being converted, as this is the order that any residuals or random intercepts will be returned. This is especially important if using numbers to represent groups.

Model building	• Model building can be very tedious. Start to build a simple model that will load into the program and build in the more complicated elements as you go.
Initial values	• Each variable and each level of a random effect needs to have an initial value. See appendix B for sample. • The coefficient estimates from the preliminary models can be used as initial values. • The same initial value file may be used for each chain.

4.8 Analytical Approach Figures

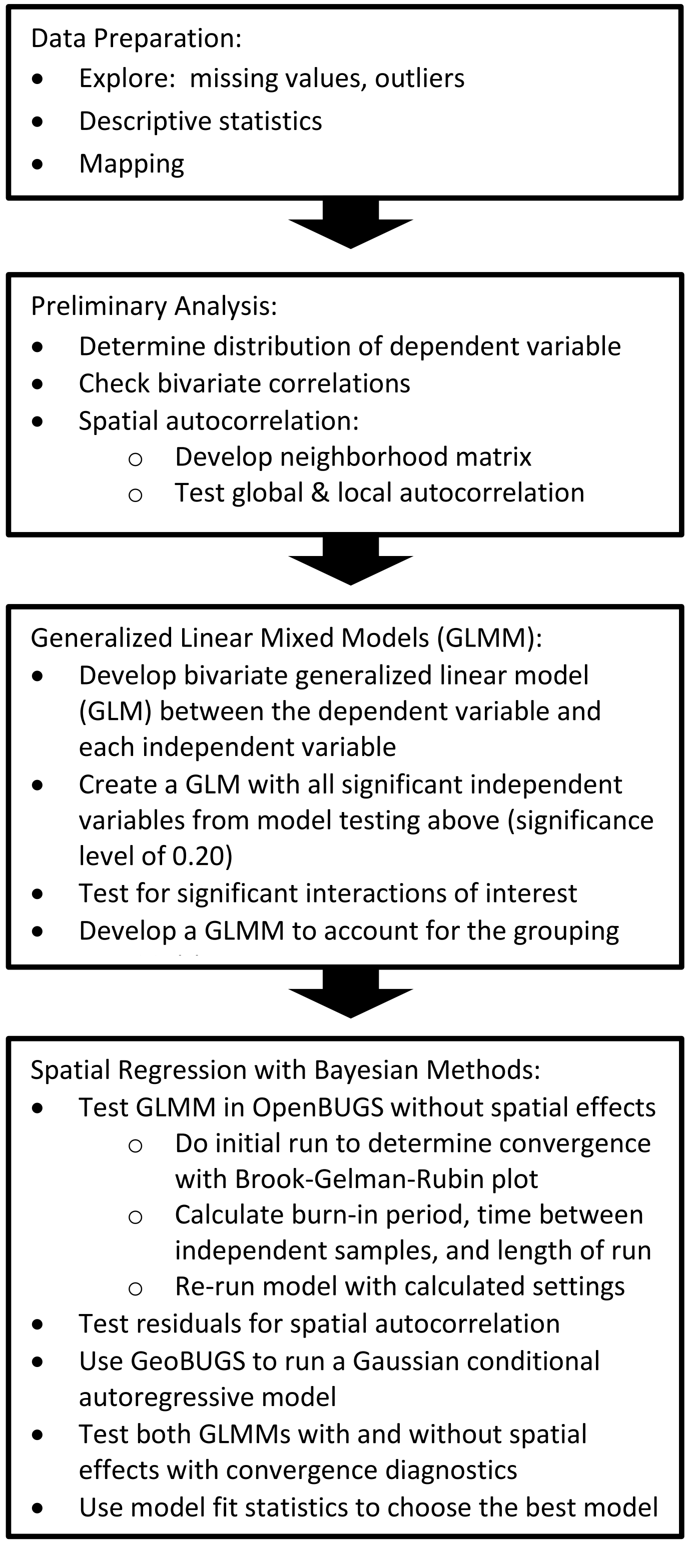


Figure 4.1 Workflow for performing spatial analysis with polygon data.

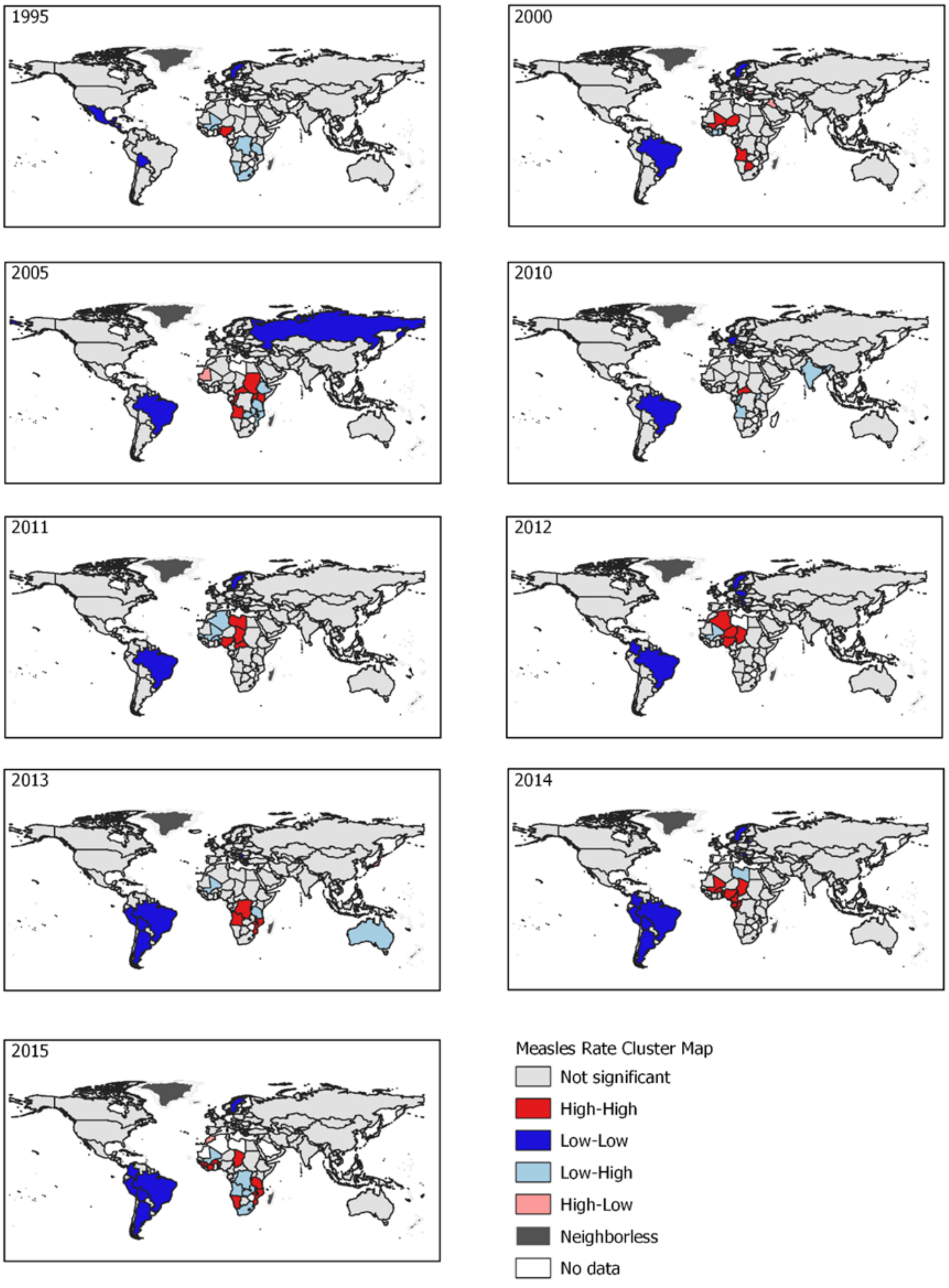


Figure 4.2. LISA cluster map for measles cases per 100,000 people.

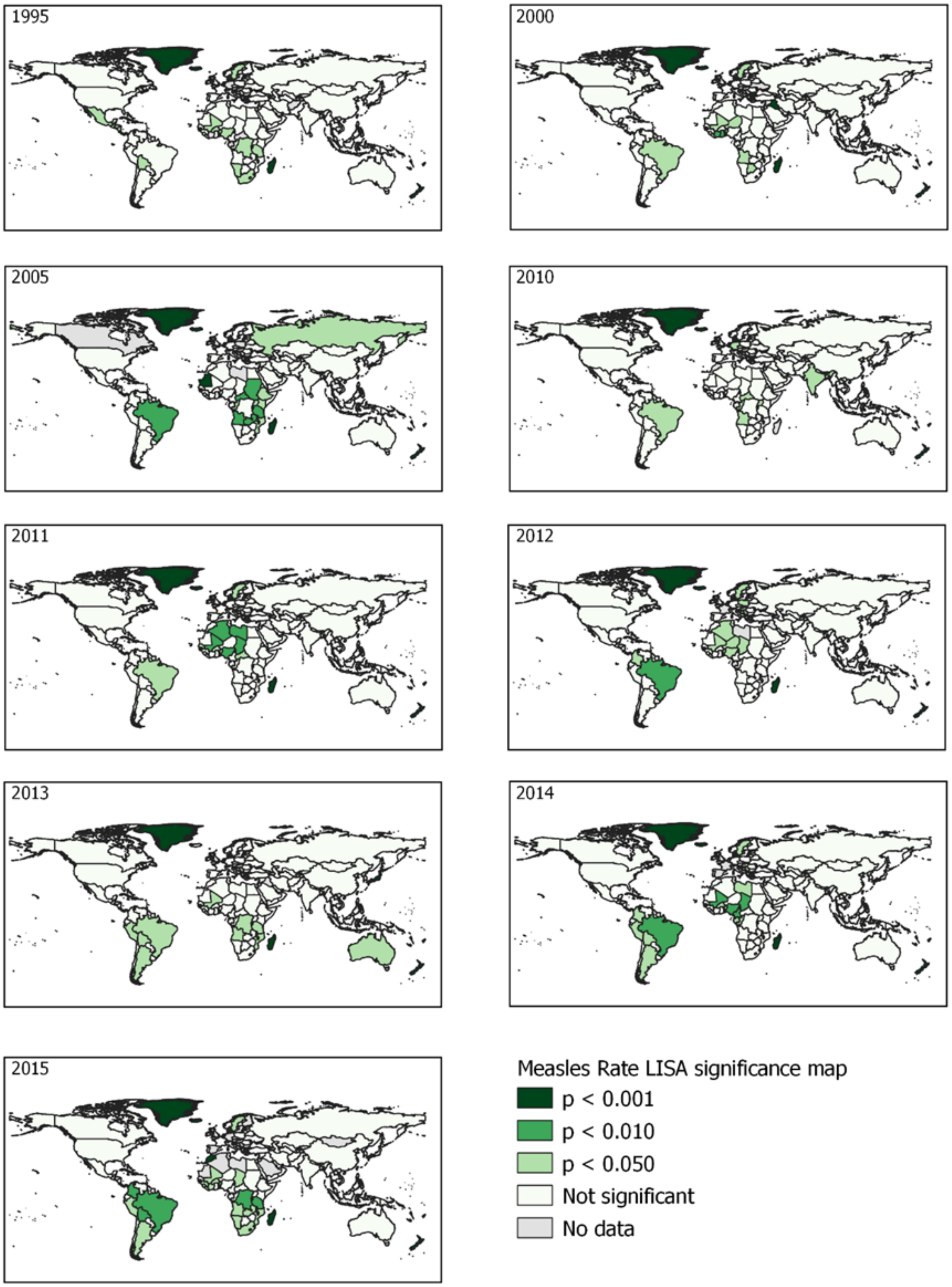


Figure 4.3. LISA significance map for measles rates per 100,000 people.

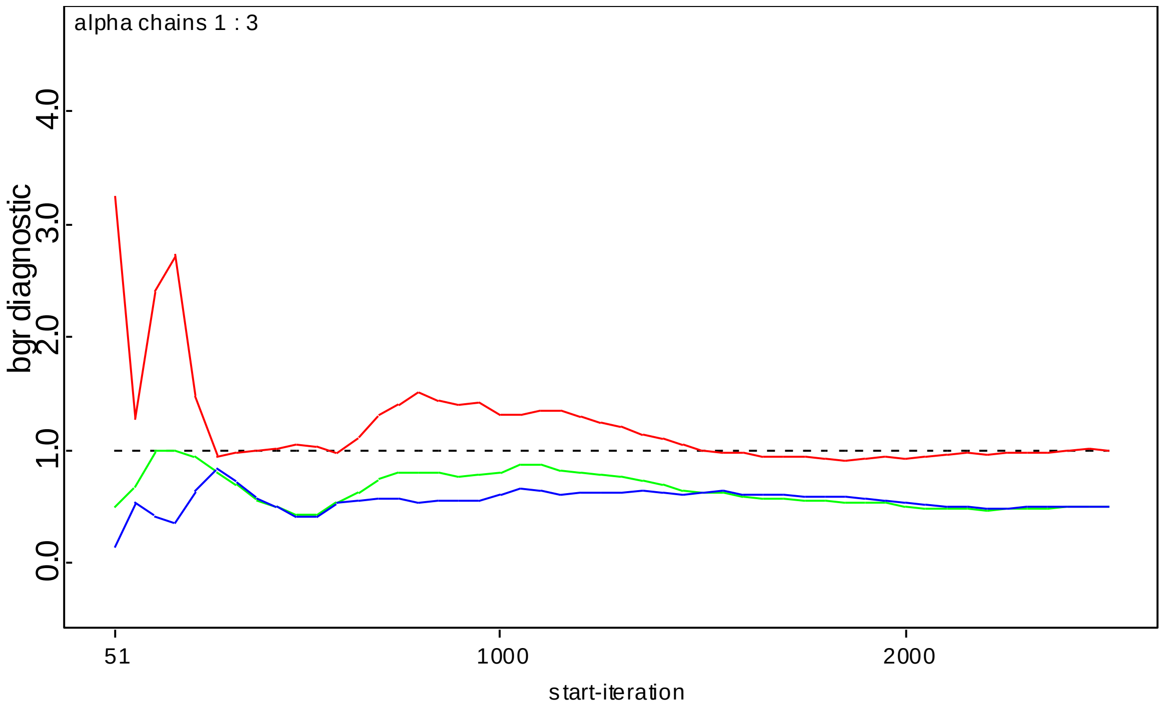
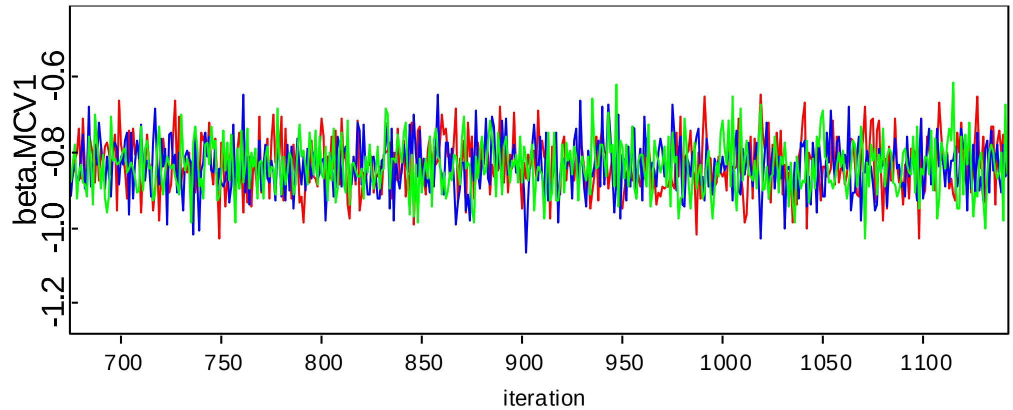
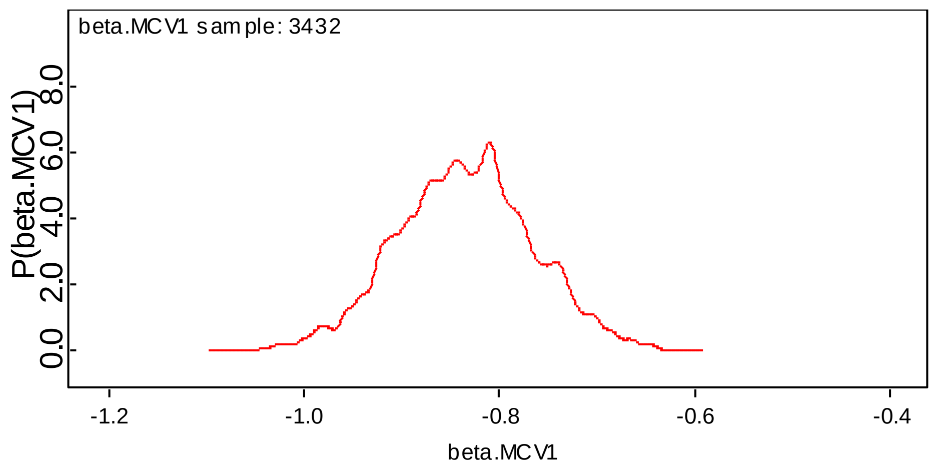


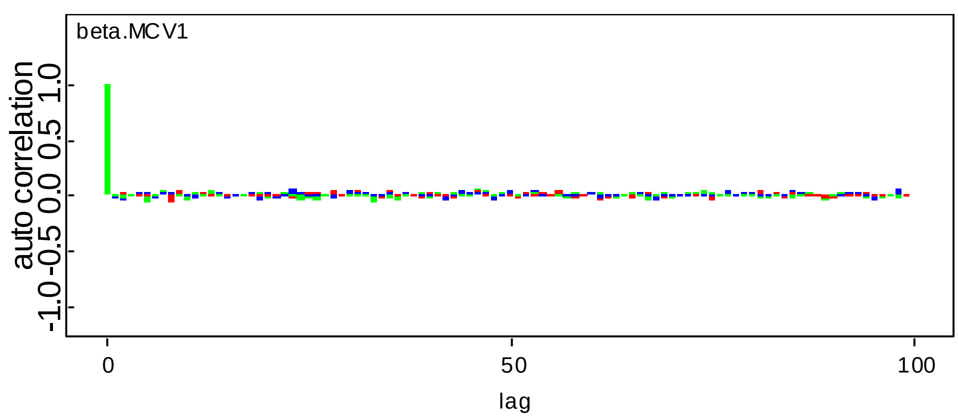
Figure 4.4. Example of a BGR plot used to determine convergence.



(a)



(b)



(c)

Figure 4.5. Output plots from OpenBUGS analysis of the sample analysis, including (a) a trace plot, (b) a density plot, and (c) an autocorrelation plot

.

4.9 Appendices

4.9.1 Appendix A – SAS Code

```
/*bivariate fixed models*/
/*MCV1*/
PROC NLMIXED data=phd.world1;
      PARMS b0 -10 bMCV1 1 alpha 6;
      xb=b0+bMCV1*ZlnMCV1;
      mu=exp(xb+lnPOP);
      m=1/alpha;
      p=1/(1+mu*alpha);
      MODEL measles~ negbin(m,p);
RUN;

/*MCV2*/
PROC NLMIXED data=phd.world1;
      PARMS b0 -10 bMCV2 1 alpha 6;
      xb=b0+bMCV2*ZlnMCV2;
      mu=exp(xb+lnPOP);
      m=1/alpha;
      p=1/(1+mu*alpha);
      MODEL measles~ negbin(m,p);
RUN;

/*FLF*/
PROC NLMIXED data=phd.world1;
      PARMS b0 -10 bFLF 1 alpha 6;
      xb=b0+bFLF*ZlnFLF;
      mu=exp(xb+lnPOP);
      m=1/alpha;
      p=1/(1+mu*alpha);
      MODEL measles~ negbin(m,p);
RUN;

/*GDP*/
PROC NLMIXED data=phd.world1;
      PARMS b0 -10 bGDP 1 alpha 6;
      xb=b0+bGDP*ZlnGDP;
      mu=exp(xb+lnPOP);
      m=1/alpha;
      p=1/(1+mu*alpha);
      MODEL measles~ negbin(m,p);
RUN;

/*GINI*/
PROC NLMIXED data=phd.world1;
      PARMS b0 -10 bGINI 1 alpha 6;
```

```
       xb=b0+bGINI*ZlnGINI;
       mu=exp(xb+lnPOP);
       m=1/alpha;
       p=1/(1+mu*alpha);
       MODEL measles~ negbin(m,p);
RUN;

/*PSP*/
PROC NLMIXED data=phd.world1;
       PARMS b0 -10 bPSP 1 alpha 6;
       xb=b0+bPSP*ZlnPSP;
       mu=exp(xb+lnPOP);
       m=1/alpha;
       p=1/(1+mu*alpha);
       MODEL measles~ negbin(m,p);
RUN;

/*POLITY*/
PROC NLMIXED data=phd.world1;
       PARMS b0 -10 bPOLITY 1 alpha 6;
       xb=b0+bPOLITY*POLITY;
       mu=exp(xb+lnPOP);
       m=1/alpha;
       p=1/(1+mu*alpha);
       MODEL measles~ negbin(m,p);
RUN;

/*Multivariate model with significant variables (FLF was not
significant)*/
PROC NLMIXED data=phd.world1;
       PARMS b0 -10 bMCV1 1 bMCV2 1 bGDP 1 bGINI 1 bPSP 1 bPOLITY
1 alpha 6;
       xb=b0+bMCV1*ZlnMCV1+bMCV2*ZlnMCV2+bGDP*ZlnGDP+bGINI*ZlnGIN
I+bPSP*ZlnPSP+bPOLITY*POLITY;
       mu=exp(xb+lnPOP);
       m=1/alpha;
       p=1/(1+mu*alpha);
       MODEL measles~ negbin(m,p);
RUN;

/*Multivariate model with interaction*/
PROC NLMIXED data=phd.world1;
       PARMS b0 -9 bMCV1 -0.5 bMCV2 0.2 bGDP -0.1 bGINI -0.1 bPSP
-0.5 bPOLITY 0 bMCV1PSP -0.2 alpha 6;
       xb=b0+bMCV1*ZlnMCV1+bMCV2*ZlnMCV2+bGDP*ZlnGDP+bGINI*ZlnGIN
I+bPSP*ZlnPSP+bPOLITY*POLITY+bMCV1PSP*(ZlnMCV1*ZlnPSP);
       mu=exp(xb+lnPOP);
```

```
      m=1/alpha;
      p=1/(1+mu*alpha);
      MODEL measles~ negbin(m,p);
RUN;

/*Multivariate model with random intercept for Region*/
PROC NLMIXED data=phd.world1;
      PARMS b0 -9 bMCV1 -0.5 bMCV2 0.2 bGDP -0.1 bGINI -0.1 bPSP
-0.5 bPOLITY 0 alpha 6;
      xb=b0+bMCV1*ZlnMCV1+bMCV2*ZlnMCV2+bGDP*ZlnGDP+bGINI*ZlnGIN
I+bPSP*ZlnPSP+bPOLITY*POLITY + u;
      mu=exp(xb+lnPOP);
      m=1/alpha;
      p=1/(1+mu*alpha);
      MODEL measles~ negbin(m,p);
      RANDOM u ~ normal(0,s2u) subject=Region;
RUN;

/*Multivariate model with random intercept for Region and
interaction for MCV1 and PSP*/
PROC NLMIXED data=phd.world1;
      PARMS b0 -9 bMCV1 -0.5 bMCV2 0.2 bGDP -0.1 bGINI -0.1 bPSP
-0.5 bPOLITY 0 bMCV1PSP 1 alpha 6;
      xb=b0+bMCV1*ZlnMCV1+bMCV2*ZlnMCV2+bGDP*ZlnGDP+bGINI*ZlnGIN
I+bPSP*ZlnPSP+bPOLITY*POLITY+bMCV1PSP*(ZlnMCV1*ZlnPSP) + u;
      mu=exp(xb+lnPOP);
      m=1/alpha;
      p=1/(1+mu*alpha);
      MODEL measles~ negbin(m,p);
      RANDOM u ~ normal(0,s2u) subject=Region;
RUN;

/*Multivariate model with random intercept for Country and
interaction for MCV1 and PSP*/
PROC NLMIXED data=phd.world1;
      PARMS b0 -9 bMCV1 -0.5 bMCV2 0.2 bGDP -0.1 bGINI -0.1 bPSP
-0.5 bPOLITY 0 bMCV1PSP 1 alpha 6;
      xb=b0+bMCV1*ZlnMCV1+bMCV2*ZlnMCV2+bGDP*ZlnGDP+bGINI*ZlnGIN
I+bPSP*ZlnPSP+bPOLITY*POLITY+bMCV1PSP*(ZlnMCV1*ZlnPSP) + u;
      mu=exp(xb+lnPOP);
      m=1/alpha;
      p=1/(1+mu*alpha);
      MODEL measles~ negbin(m,p);
      RANDOM u ~ normal(0,s2u) subject=Country;
RUN;

/*Model with Country nested within Region*/
```

```
PROC NLMIXED data=phd.world1;
       PARMS b0 -9 bMCV1 -0.5 bMCV2 0.2 bGDP -0.1 bGINI -0.1 bPSP
-0.5 bPOLITY 0 bMCV1PSP 1 alpha 6;
       xb=b0+bMCV1*ZlnMCV1+bMCV2*ZlnMCV2+bGDP*ZlnGDP+bGINI*ZlnGIN
I+bPSP*ZlnPSP+bPOLITY*POLITY+bMCV1PSP*(ZlnMCV1*ZlnPSP) + u + v;
       mu=exp(xb+lnPOP);
       rand=xb;
       m=1/alpha;
       p=1/(1+mu*alpha);
       MODEL measles~ negbin(m,p);
       RANDOM u ~ normal(0,s2u) subject=Country;
       RANDOM v ~ normal(0,s2v) subject=Region(Country);
       PREDICT rand OUT=phd.resid_random1;
```

4.9.2 Appendix B – OpenBUGS Code

```
# data for non-spatial model – data shortened with ellipses in the interest of space

list(n=1413, m=157, q=5, max=1000,

Country=c(3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 4, 4, 4, 4, 13, 13, 13, 13, 13, 13, 13, 13, 13, 16, 16, 16, 16,
16, 16, 16, 16, 16, 20, 20, 20, 20, 20, 20, 20, 20, 20, 21, 21, 21,..., 122, 122, 122, 122, 122, 122, 122,
122, 122),

Region=c(1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,..., 5, 5, 5,
5, 5, 5, 5, 5, 5, 5, 5, 5),

MEASLES=c(0, 63, 112, 103, 18, 2302, 25, 0, 8204, 1190, 4458, 8523, 2219, 1449, 118, 11699, 635,
258, 637, 10469, 4244, 288, 55, 392, 210, 786, 426, 5, 1, 853, 1, 7, 2672, 8, 0, 478, 253, 860, 7362, 99,
..., 38, 7135, 1222, 3730, 0, 0, 12, 77, 1923, 63, 0, 1, 0, 2, 0, 8),

lnPOP=c(17.48, 17.50, 17.42, 17.40, 17.44, 17.32, 17.46, 17.26, 17.18, 16.97, 17.04, 17.07, 16.62,
17.00, 17.14, 17.11, 16.47, 16.79, 16.12, 15.59, 15.74, 16.09, 16.17, 16.03, 15.89, 16.15, ..., 15.84,
12.07, 12.16, 12.17, 12.04, 12.15, 12.14, 12.17, 12.10, 12.13),

ZlnMCV1=c(0.48849, 0.48849, 0.48849, 0.48849, 0.48849, -0.17408, 0.48849, -0.35471, -0.54225,
0.38409, 0.59071, 0.27742, -0.11532, 0.11294, -0.35471, -0.05725, -1.37352, -3.17781, ...,, 0.27742,
0.53987, -0.05725, -1.22482, -0.47894, -2.01794, -1.68516),

ZlnMCV2=c( 0.55927, 0.55927, 0.50230, 0.48292, 0.48292, 0.46334, 0.44355, 0.36222, 0.23319, -
0.62808, -0.77484, -0.77484, -1.88945, -1.88945, -1.88945, -1.96003, -2.75465, -3.94407,..., 0.55927,
0.32019, 0.11842, 0.07046, -0.16200, -0.21783, -0.27538, -0.89300, -0.89300),

ZlnGINI=c(-1.88509, -1.96514, -1.59545, -1.55802, -1.42913, -1.33898, -1.33898, -1.07759, -0.32003,
0.03623, -0.55791, -0.76117, 0.52847, -0.12804, -0.19859, -0.33745, 0.05705, 0.00398, ..., 0.31204,
0.08927, -0.20074, 0.25266, -0.17489, 0.18601, -0.74380),

ZlnGDP=c(0.34362, 0.35784, 0.31377, 0.30634, 0.32429, 0.27146, 0.32985, 0.12081, 0.04551, -0.31951,
-0.30555, -0.28103, -0.73536, -0.31732, -0.27508, -0.27135, -0.86994, -0.64059, -1.21259, -1.40852, ..., -
0.35107, -0.36659, -0.39951, -0.38984),

ZlnPSP=c(0.22392, 0.39036, 0.28955, -0.18793, 0.10275, 0.15318, 0.10275, -0.01447, -0.35406,
0.39036, 0.25200, 0.40570, -0.72100, 0.55174, -0.06686, 0.32262, -0.07230, 0.02601, -0.14963, -
0.90768, -0.89764,..., -1.59080, -1.30071, -1.17711, -1.88837, -1.03049),

POLITY=c(2, 2, 2, 2, 2, 2, 2, 2, -3, -3, -2, -2, -2, -3, -2, -2, -2, -2, -2, 7, 6, 6, 7, 7, 7, 6, 7, 7, 8, 8, 8, 8, 8, 8, 8,
8, 7, 0, 0, 0, 6, 0, 0, -5, -3, 0, 6, 6, -1, 6, 6, 6, 6, 0, -1, 10, 10, 10, 10, 8, 10, 10, 8, 10, -4, -4, -4, -4, -4, -4, -
4, -4, -4, -1, ..., 3, 2, 2))


# code for non-spatial model

model {
for (i in 1:n) {
MEASLES[i] ~ dnegbin(p[i], r)
p[i] <- r/(mu[i] + r)
log(mu[i]) <- 1*lnPOP[i] + alpha + beta.PSP*ZlnPSP[i] + beta.MCV1*ZlnMCV1[i] + beta.MCV2*ZlnMCV2[i]
+ beta.GDP*ZlnGDP[i] + beta.GINI*ZlnGINI[i] + beta.POLITY*POLITY[i] +
beta.MCV1PSP*(ZlnMCV1[i]*ZlnPSP[i]) + u[Country[i]] + v[Region[i]]
```

```
}
r ~ dcat(pi[])
for (i in 1:max) {
pi[i] <- 1/max
}
for (j in 1:m) {
u[j] ~ dnorm(0, tau.u)
}
for (k in 1:q) {
v[k] ~ dnorm(0, tau.v)
}
for (i in 1:n) {
predict[i] <- log(mu[i]+1)-lnPOP[i]
residual[i] <- ((log(MEASLES[i]+1))-lnPOP[i]) - (log(mu[i]+1)-lnPOP[i])
}
alpha ~ dnorm(0, 0.001)
beta.PSP ~ dnorm(0, 0.001)
beta.MCV1 ~ dnorm(0, 0.001)
beta.MCV2 ~ dnorm(0, 0.001)
beta.GDP ~ dnorm(0, 0.001)
beta.GINI ~ dnorm(0, 0.001)
beta.POLITY ~ dnorm(0, 0.001)
beta.MCV1PSP ~ dnorm(0, 001)
tau.u <- 1/(sigma.u*sigma.u)
sigma.u ~ dunif(0, 100)
tau.v <- 1/(sigma.v*sigma.v)
sigma.v ~ dunif(0, 100)
tau.e <- 1/(sigma.e*sigma.e)
sigma.e ~ dunif(0, 100)

VPC.country <- (1/tau.u) / ((1/tau.u) + (1/tau.v) + (1/tau.e))
VPC.region <- (1/tau.v) / ((1/tau.u) + (1/tau.v) + (1/tau.e))
}

#initial values for non-spatial model

list(alpha = -10.09, beta.PSP = -0.66, beta.MCV1 = -0.98, beta.MCV2 = 0.15, beta.GDP = -0.57,
beta.GINI = -0.15, beta.POLITY = -0.04, beta.MCV1PSP = -0.29, u = c(1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1), v=c(1, 1, 1, 1, 1), r =2, sigma.e = 3.85, sigma.u = 1.92,
sigma.v = 1.88)

# data for spatial model – data shortened with ellipses in the interest of space

list(n=1413, m=157, q=5, max=1000,

Country=c(3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 4, 4, 4, 4, 13, 13, 13, 13, 13, 13, 13, 13, 13, 16, 16, 16, 16,
16, 16, 16, 16, 16, 20, 20, 20, 20, 20, 20, 20, 20, 20, 21, 21, 21,..., 122, 122, 122, 122, 122, 122, 122,
122, 122),

Region=c(1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,..., 5, 5, 5,
5, 5, 5, 5, 5, 5, 5, 5, 5),
```

```
MEASLES=c(0, 63, 112, 103, 18, 2302, 25, 0, 8204, 1190, 4458, 8523, 2219, 1449, 118, 11699, 635,
258, 637, 10469, 4244, 288, 55, 392, 210, 786, 426, 5, 1, 853, 1, 7, 2672, 8, 0, 478, 253, 860, 7362, 99,
..., 38, 7135, 1222, 3730, 0, 0, 12, 77, 1923, 63, 0, 1, 0, 2, 0, 8),

lnPOP=c(17.48, 17.50, 17.42, 17.40, 17.44, 17.32, 17.46, 17.26, 17.18, 16.97, 17.04, 17.07, 16.62,
17.00, 17.14, 17.11, 16.47, 16.79, 16.12, 15.59, 15.74, 16.09, 16.17, 16.03, 15.89, 16.15, ..., 15.84,
12.07, 12.16, 12.17, 12.04, 12.15, 12.14, 12.17, 12.10, 12.13),

ZlnMCV1=c(0.48849, 0.48849, 0.48849, 0.48849, 0.48849, -0.17408, 0.48849, -0.35471, -0.54225,
0.38409, 0.59071, 0.27742, -0.11532, 0.11294, -0.35471, -0.05725, -1.37352, -3.17781, ...,, 0.27742,
0.53987, -0.05725, -1.22482, -0.47894, -2.01794, -1.68516),

ZlnMCV2=c( 0.55927, 0.55927, 0.50230, 0.48292, 0.48292, 0.46334, 0.44355, 0.36222, 0.23319, -
0.62808, -0.77484, -0.77484, -1.88945, -1.88945, -1.88945, -1.96003, -2.75465, -3.94407,..., 0.55927,
0.32019, 0.11842, 0.07046, -0.16200, -0.21783, -0.27538, -0.89300, -0.89300),

ZlnGINI=c(-1.88509, -1.96514, -1.59545, -1.55802, -1.42913, -1.33898, -1.33898, -1.07759, -0.32003,
0.03623, -0.55791, -0.76117, 0.52847, -0.12804, -0.19859, -0.33745, 0.05705, 0.00398, ..., 0.31204,
0.08927, -0.20074, 0.25266, -0.17489, 0.18601, -0.74380),

ZlnGDP=c(0.34362, 0.35784, 0.31377, 0.30634, 0.32429, 0.27146, 0.32985, 0.12081, 0.04551, -0.31951,
-0.30555, -0.28103, -0.73536, -0.31732, -0.27508, -0.27135, -0.86994, -0.64059, -1.21259, -1.40852, ..., -
0.35107, -0.36659, -0.39951, -0.38984),

ZlnPSP=c(0.22392, 0.39036, 0.28955, -0.18793, 0.10275, 0.15318, 0.10275, -0.01447, -0.35406,
0.39036, 0.25200, 0.40570, -0.72100, 0.55174, -0.06686, 0.32262, -0.07230, 0.02601, -0.14963, -
0.90768, -0.89764,..., -1.59080, -1.30071, -1.17711, -1.88837, -1.03049),

POLITY=c(2, 2, 2, 2, 2, 2, 2, -3, -3, -2, -2, -2, -3, -2, -2, -2, -2, -2, 7, 6, 6, 7, 7, 7, 6, 7, 7, 8, 8, 8, 8, 8, 8, 8,
8, 7, 0, 0, 0, 6, 0, 0, -5, -3, 0, 6, 6, -1, 6, 6, 6, 6, 0, -1, 10, 10, 10, 10, 8, 10, 10, 8, 10, -4, -4, -4, -4, -4, -4, -
4, -4, -4, -1, ..., 3, 2, 2)

num = c(8, 10, 4, 5, 4, 2, 0, 5, 4, 5, 1, 2, 0, 11, 6, 1, 6, 3, 4, 5, 4, 7, 3, 0, 8, 8, 4, 3, 4, 7, 1, 3, 2, 5, 8, 3, 2,
0, 5, 4, 2, 3, 4, 10, 4, 2, 5, 0, 7, 11, 9, 3, 5, 0, 6, 2, 2, 5, 3, 3, 1, 3, 5, 5, 5, 1, 0, 4, 2, 3, 5, 2, 4, 5, 4, 7, 6, 1,
4, 1, 4, 7, 3, 0, 3, 2, 5, 4, 15, 2, 4, 2, 9, 4, 1, 2, 0, 2, 5, 2, 5, 2, 2, 3, 7, 4, 4, 4, 2, 4, 4, 5, 7, 1, 6, 9, 4, 3, 1,
3, 1, 6, 4, 2, 5, 4, 5, 4, 5, 2, 2, 1, 4, 3, 1, 5, 2, 0, 4, 2, 12, 6, 5, 4, 10, 6, 2, 4, 1, 3, 4, 4, 7, 0, 4, 4, 3),
adj = c(
133, 156, 145, 65, 64, 73, 151, 93,
115, 116, 136, 129, 155, 157, 43, 55, 14, 20,
145, 105, 44, 153,
134, 45, 40, 62, 26,
113, 153, 95, 85,
30, 74,

87, 49, 53, 123, 108,
…,
101, 145, 44, 60, 5, 3, 19,

157, 14, 2, 32,
151, 65, 89, 1,
155, 43, 2
),
sumNumNeigh = 618)


#code for spatial model
```

```
model {
for (i in 1:n) {
MEASLES[i] ~ dnegbin(p[i], r)
p[i] <- r/(mu[i] + r)
log(mu[i]) <- 1*lnPOP[i] + alpha + beta.PSP*ZlnPSP[i] + beta.MCV1*ZlnMCV1[i] + beta.MCV2*ZlnMCV2[i]
+ beta.GDP*ZlnGDP[i] + beta.GINI*ZlnGINI[i] + beta.POLITY*POLITY[i] +
beta.MCV1PSP*(ZlnMCV1[i]*ZlnPSP[i]) + u[Country[i]] + v[Region[i]] + sp[Country[i]]
}
r ~ dcat(pi[])
for (i in 1:max) {
pi[i] <- 1/max
}
for (j in 1:m) {
u[j] ~ dnorm(0, tau.u)
}
for (k in 1:q) {
v[k] ~ dnorm(0, tau.v)
}
sp[1:m] ~ car.l1(adj[], weights[], num[], tau.sp)
for(z in 1:sumNumNeigh) {
        weights[z] <- 1
}
for (i in 1:n) {
log_rate[i] <- ((log(MEASLES[i]+1))-lnPOP[i])
predict[i] <- log(mu[i]+1)-lnPOP[i]
residual[i] <- ((log(MEASLES[i]+1))-lnPOP[i]) - (log(mu[i]+1)-lnPOP[i])
}
alpha ~ dflat()
beta.PSP ~ dnorm(0, 0.001)
beta.MCV1 ~ dnorm(0, 0.001)
beta.MCV2 ~ dnorm(0, 0.001)
beta.GDP ~ dnorm(0, 0.001)
beta.GINI ~ dnorm(0, 0.001)
beta.POLITY ~ dnorm(0, 0.001)
beta.MCV1PSP ~ dnorm(0, 001)
tau.u <- 1/(sigma.u*sigma.u)
sigma.u ~ dunif(0, 100)
tau.v <- 1/(sigma.v*sigma.v)
sigma.v ~ dunif(0, 100)
tau.e <- 1/(sigma.e*sigma.e)
sigma.e ~ dunif(0, 100)
tau.sp ~ dgamma(0.5, 0.0005)

VPC.country <- (1/tau.u) / ((1/tau.u) + (1/tau.v) + (1/tau.e) + (1/tau.sp))
VPC.region <- (1/tau.v) / ((1/tau.u) + (1/tau.v) + (1/tau.e) + (1/tau.sp))
VPC.spatial <- (1/tau.sp) / ((1/tau.u) + (1/tau.v) + (1/tau.e) + (1/tau.sp))
}

#initial values for spatial model

list(alpha = -10.09, beta.PSP = -0.66, beta.MCV1 = -0.98, beta.MCV2 = 0.15, beta.GDP = -0.57,
beta.GINI = -0.15, beta.POLITY = -0.04, beta.MCV1PSP = -0.29, u = c(1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
```

1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1), v=c(1, 1, 1, 1, 1), sp=c(0, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, NA, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, NA, 0, 0, 0), r =2, sigma.e = 3.85, sigma.u = 1.92, sigma.v = 1.88, tau.sp=1)

4.9.3 Appendix C – Rstudio Code for CODA

```
#upload CODA copied and pasted to .txt files from the OpenBUGS
.ods file

library(coda)
chain_1=read.coda('chain1.txt', 'index.txt')
chain_2=read.coda('chain2.txt', 'index.txt')
chain_3=read.coda('chain3.txt', 'index.txt')

#combine into a mcmc.list object

combinedCHAINS=mcmc.list(chain_1, chain_2, chain_3)

#perform CODA diagnostics

gelman.diag(combinedCHAINS, confidence = 0.95, transform=FALSE)
geweke.diag(combinedCHAINS, frac1=0.1, frac2=0.5)
raftery.diag(combinedCHAINS, q=0.025, r=0.005, s=0.95,
converge.eps=0.001)
heidel.diag(combinedCHAINS, eps=0.1, pvalue = 0.05)
```

5.0 MANUSCRIPT: ANALYSIS AND RESULTS

An International Spatial Analysis of Welfare Spending's Influence on Measles Immunization

Mary Ellen Walker, RN, MN, PhD(c)

Michael Szafron, PhD

June Anonson, RN, PhD

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Author contributions: MW conceptualised and designed the study; collected and analyzed the data; and drafted, revised, and finalised the article. MS provided guidance on the methods used in the research and made significant contributions to the article. JA made significant contributions to the article and its relevance to nursing practice and global health.

National welfare policies have the potential to influence population health in many ways. Yet, no research has investigated the influence that welfare spending levels have on primary prevention interventions. This study uses generalized linear mixed model Bayesian analysis to explore how welfare spending (represented by public social protection spending) influences the relationship between measles disease rates and measles vaccination rates at a national level while using random effects to account for the nested structure of countries within regions. Global and local Moran's I tests indicate that spatial relationships are present among the variables of interest. Therefore, a conditional autoregressive model is also tested to account for spatial random effects. Spatial random effects are not included in the final model due to the Bayesian Information Criterion (BIC) being higher in the spatial model (BIC = 24225.730) than the non-spatial model (BIC=19743.090). The final model found that both the first dose of measles vaccine (B = -0.835, 95% Cr. I. = -0.975, -0.699), public social protection (B = -0.936, 95% Cr. I. = -1.132, -0.744), and their interaction (B = -0.239, 95% Cr. I. -0.319, -0.156) have a negative relationship with measles rates. Therefore, these results suggest that national welfare spending may influence the relationship between measles infection rates and measles immunizations. This finding provides evidence that welfare spending may enhance primary prevention interventions, like measles vaccination.

Key words: Bayesian; generalized linear mixed models; prevention; spatial analysis; vaccination; welfare spending.

An International Spatial Analysis of Welfare Spending's Influence on Measles Immunization

The results manuscript is an overall summary of the research completed for this dissertation. It includes an overview of the background, significance, theoretical approach, methods, and results of the research. The focus of the paper is the results of the research and how the results fit within the current literature.

5.1 Introduction

National policies are important in shaping people's day-to-day lives and have implications for health (Jorm & Ryan, 2014). Welfare policies have a significant role in shaping national political environments and impact people throughout their lifespan (Ferrarini, 2006). National welfare policies are important for nurses to understand because welfare policies impact many determinants of health. A country's welfare policies have implications for its peoples' health, education, work, and personal lives (Walter Korpi, 1983). Welfare influences these aspects of life through socializing risk and providing equal opportunities (Gøsta Esping-Andersen, 1990; G. Esping-Andersen, 2009; Kolberg & Esping-Andersen, 1992; W. Korpi, 2001). Welfare policies impact women's opportunities through increased education, labor participation, and economic independence (G. Esping-Andersen, 2009). As more women enter the workforce, welfare policies are especially important in supporting families with child and elder care (G. Esping-Andersen, 2009; Ferrarini, 2006). Furthermore, male-breadwinner families are becoming less common, while dual-earner and single-parent homes are becoming the predominant family models (G. Esping-Andersen, 2009). Consequently, welfare policies can influence family structure (Ferrarini, 2006). These influences on people and their families may also be important in shaping their health.

Welfare policies are important for nurses to understand as they navigate national policy environments and their impacts on patients and families. Gunn, Muntaner, Villeneuve, Chung, and Gea-Sanchez (2019) have investigated the link between welfare policies and nursing professionalization, but few nurses have researched health in the context of welfare policies. Research regarding the influence of welfare policies on preventative health interventions is lacking in the nursing literature. In the broader health literature, few researchers have investigated how welfare policies influence immunizations, and most of this research only uses descriptive statistics to explore many variables without statistical inference. In fact, in an extensive literature review, Daku, Raub, and Heymann (2012) were the only researchers to publish an article that uses statistical inference to explore countries' maternity leave lengths and income replacements in relation to childhood immunization rates. They found that maternity leave lengths and income replacements have a positive relationship with childhood immunization rates. The research in this article further builds on nursing and health literature that discusses health in the context of welfare spending.

A country's level of spending in providing welfare benefits and services is one kind of welfare policy that may have implications for how people respond to preventative health interventions. Immunizations are preventative health interventions that can have serious implications for individual and national health, and nurses are often involved in providing immunizations to populations. However, little research has focused on welfare policies' influence on immunizations and their outcomes. Measles immunization may be an important preventative health intervention to study because of its high level of infectiousness, recent outbreaks, and inclusion as an international health priority (United Nations, 2015; World Health Organization, 2017a). Therefore, the focus of this research is national welfare spending's influence on the relationship between measles immunizations and measles infection.

Interestingly, countries with similar welfare policies are often located near to each other (Gøsta Esping-Andersen, 1990; G. Esping-Andersen, 2009; Kolberg & Esping-Andersen, 1992; W. Korpi, 2001); yet, limited welfare policy research explores the impact of geography on these relationships. Spatial considerations are also important for the international analysis of infectious disease. Analysis of welfare spending and measles disease requires an approach that can detect and adjust for possible relationships between countries due to close geographic proximity. Therefore, spatial analytic methods are an important consideration in exploring relationships between measles and welfare spending.

In an extensive literature review of research using spatial analysis published in nursing journals, most articles only included mapping and spatial correlation with the exception of Blake (2014) who used spatial regression. This work will significantly add to the nursing literature through applying an underutilised methodology to a novel research topic. This study has the potential to add valuable insights to nursing research and the global health literature because it investigates a novel topic with an underutilised method.

5.2 Objectives

This study aims to identify the influence of welfare spending levels on the relationship between measles disease rates and immunization while considering geographic location. The objective of this study is to determine the influence that welfare spending has on the relationship between measles immunization rates and its associated disease counts. This study uses country-level data in relation to welfare spending, measles immunization rates, and measles disease counts. The hypothesis for this study is that welfare spending will have an interacting effect on the relationship between measles vaccination and measles cases. This hypothesis is derived from the positive relationship found between childhood immunizations and maternity leave length and income replacement rate in the study by Daku et al. (2012).

5.3 Assumptions

The assumptions for this study are as follows:

- welfare spending influences peoples’ health and access to healthcare;
- social influences on health take place over time and space;
- country-level data represents the average response for people living within a given country;
- values of a variable are correlated with multiple measures over time; and
- geographic locations that lie near each other are more influential than those that are distant.

5.4 Theoretical Model

To inform the analysis, two theoretical works were chosen as a basis for the study’s conceptual model. The conceptual model is informed by the Levels of Prevention model by Clark and Leavell (1965) and the Ecological Model for Health Promotion by McLeroy, Bibeau, Steckler, and Glanz (1988).

5.4.1 Conceptual Model

The Levels of Prevention model is concerned with health and disease. Health is a relative state of equilibrium maintained by the body’s active response to adjust to disturbing forces

(Clark & Leavell, 1965). The natural history of disease reflects the progression of any disease for any person, and it includes the prepathogenesis period and the pathogenesis period (Clark & Leavell, 1965). The prepathogenesis period is the preliminary interaction of the agent, host, and environment before reaching humans (Clark & Leavell, 1965). The pathogenesis period begins when the disease stimulus reaches the person, and it involves any changes in a person's form, function, and health until the person reaches an equilibrium, recovers, or experiences a defect, disability, or death (Clark & Leavell, 1965).

The Levels of Prevention model has five levels of application that fit within three levels of prevention. This research is concerned with the specific protection within primary prevention. Primary prevention happens in the prepathogenesis period and includes promotion of optimal health and specific protection against diseases (Clark & Leavell, 1965). Specific protection is a means to prevent the causes of specific diseases before they reach humans, such as immunizations (Clark & Leavell, 1965). Therefore, this research uses measles vaccination to represent specific protection as a form of primary prevention from measles disease.

The Ecological Model for Health Promotion has five levels: intrapersonal, interpersonal processes and primary groups, institutional and organizational factors, community factors, and public policy (McLeroy et al., 1988). This research is concerned with the public policy level. The public policy level concerns local, state or provincial, and national laws and policies (McLeroy et al., 1988). Policies influence health by restricting and containing behaviours, allocating resources, restricting how resources can be used, and setting eligibility criteria (McLeroy et al., 1988). Welfare spending represents public policies at the national level.

Research examining the influence that welfare policies have on a measles immunization and measles disease requires a theoretical model that explores prevention in health and connects these interventions to the political environment. This research tests the influence of public policy (welfare spending) on primary prevention (measles immunization and measles disease rates).

5.5 Variables and Selection of Measurement Methods

5.5.1 Welfare Spending

The variables used in this study relate to national levels of welfare spending, rates of measles vaccination, and numbers of measles cases. To examine national levels of welfare spending, this study looks specifically at public social protection (PSP) expenditure as a proportion of gross domestic product (GDP). Social expenditure as a proportion of GDP is commonly used to represent the share of resources distributed according to social criteria, rather than market criteria (Gøsta Esping-Andersen, 1990; Walter Korpi, 1983). Social protection expenditure as a proportion of GDP represents spending to reduce and prevent poverty, vulnerability, and social exclusion, including child and family benefits, maternity protection, unemployment support, employment injury benefits, sickness benefits, health protection, old-age benefits, disability benefits, and survivors' benefits (International Labour Organization, 2017). Using PSP to represent welfare spending may be a proxy for the welfare culture of a country. Representing welfare culture in this way may provide information on the value a country places on addressing inequality. PSP expenditure as a proportion of GDP was obtained from the International Labour Organization (2017), with data available for most countries in the years 1995, 2000, 2005, 2010, 2011, 2012, 2013, 2014, and 2015. Huber and Stephens (2001) argued for the long-term analysis of welfare policy because short-term analysis over-emphasizes actors' choices rather than structural constraints and suppresses political effects. Therefore, this research uses PSP measures over time to represent welfare spending.

5.5.2 Measles

The World Health Organization (2017a) identifies measles as a highly infectious disease that can lead to serious complications, and it impacts millions of people every year. The inclusion of measles-related targets in the United Nations (2015) Millennium Development Goals (MDGs) underscores the importance of measles to global health. The emphasis that international organizations put on measles has led to data collection regarding infection and immunization rates in most countries over several years, making data readily available for analysis. Furthermore, the World Health Organization (2017c) has a reporting process for collecting infectious disease and immunization data that aims for accuracy. This reporting process requires data collection from national ministries of health, annually, and the process allows for updates, clarifications, and revisions to aim for accuracy (World Health Organization, 2017c). For these reasons, the number of measles cases represents the preventative health services outcome.

The measles immunization series consists of a measles-containing vaccine first-dose (data is available for most countries 1980-2016) and second-dose (data is available for most countries 1999-2016). We define the variable MCV1 as the percentage of children, age one year, who have received one dose of measles vaccine in a given year (World Health Organization, 2017b); and MCV2 as the percentage of children who have received their second dose of measles vaccine according to nationally recommended standards (The World Bank Group, 2017b). The disease outcome is the total number of measles cases per country. The reported number of measles cases represents the preventative health service outcome, available from the World Health Organization (2016). The number of measles cases is standardized by population size with national population counts of the same year (The World Bank Group, 2017b).

5.5.3 Control Variables

To account for variables that may impact the influence that welfare spending has on the relationship between preventative health services and outcomes, control variables that are included in the model have been carefully selected. World region is accounted for by categorizing countries according to the United Nations (2017) geographical regions. World region is meant to account for any region-specific influences on health policies, social policies, or health outcomes. The regions North America and South America were combined into one Americas region due to the small number of countries within North America.

Defamilialization represents women's lack of dependency on the family for social protection (G. Esping-Andersen, 1999). Female employment rates are a proxy for defamilialization, as employment gives women greater independence from a male breadwinner. Female employment rate is represented with the proportion of the female population aged 15 and above who participate in the labor force. Data is available for most countries from 1990 to 2017. This variable, retrieved from The World Bank Group (2017a), represents women who work or are looking for work, but it does not represent unpaid or family workers. Therefore, female employment rate controls for policies that increase women's economic independence.

Democracy has an important role in the determination of how resources are distributed among a population. Therefore, the Polity IV democracy index from the Center for Systemic Peace (2017) represents democracy (or lack thereof) in a given country. The Polity IV is based on scoring countries according to democratic and authoritarian principles related to elections, the transition of power after elections, constraints on the chief executive of the state, political participation, and competition between political parties (Marshall, Gurr, & Jaggers, 2017). This data is available for most countries for several decades, with some countries having data as far back as the year 1800.

This study also includes the Gini index, representing country income inequality. The Gini index represents a deviation from a perfectly equal income distribution (The World Bank Group, 2017b). Gini index values range from zero, representing perfect equality, to 100, representing perfect inequality (The World Bank Group, 2017b). Gini index values are available for most countries from 1984 to 2010, although some countries have values as far back as 1978.

The final control variable to be introduced to the model is GDP per capita. GDP per capita controls for the overall level of development in a country, and it is available from the World Bank Group (2017b) for most countries from 1990 to 2016.

5.6 Methods

5.6.1 Sample

The sample for this study includes all countries for which data is available for at least one year for public social protection expenditure, MCV1, and MCV2. Data includes the years 1995, 2000, 2005, 2010-2015, as these are the years that public social protection data was collected. This includes 157 countries (see table 5.1).

5.6.2 Statistical Analysis

Once the final dataset was collected, missing values were replaced with Markov Chain Monte Carlo simulations using predictive mean modeling in SPSS (IBM Corporation, 2016). Nine simulations were completed. Initial work was done with the first simulation, and the remaining simulations were checked for similar outcomes. Outliers were removed based on measles rates within each year for each region. Countries were removed if the simulations produced the same value for each year because the lack of variability would produce errors in the statistical models. Means, standard deviations, relative frequencies, and scatter plots were used to summarize the data, and maps, Moran's I test for global spatial correlation, and local indicators of spatial autocorrelation (LISA) tests were used to summarize the spatial distribution of the data.

5.6.2.1 Model building.

Generalized linear mixed models (GLMM) regression was applied to the data relating to welfare spending and measles immunization. GLMMs are appropriate because these models can account for variables that have non-normal distributions and variables that are correlated (IBM Corporation, 2012). GLMMs allowed us to account for the correlation between countries that lie within the same world region and repeated measures of data by year. Initially, bivariate negative binomial models were computed in SAS studio (SAS Institute Inc., 2020). The dependent variable is counts of measles cases in a country within a given year. To account for population size, the model offset is set as the population size of the country within the same year.

Due to differences in scale of variables, GDP, GINI, MCV1, MCV2, and PSP variables had to be transformed with the natural log and standardized before the models would converge. The natural log transformation and standardization preserve the relationships among the variables because the order of the data from smallest to largest values does not change. However, the degree of difference between data points may have changed. Hence, these transformations and the purpose of the research must be considered when interpreting the results. The purpose of this research is to explore relationships among variables, and not to make predictions. Therefore, the interpretation of these results focuses on the direction of the relationship, rather than the exact coefficient result. The Polity coefficient is the exception because no transformation was needed to aid in its analysis by the statistical programs used for this analysis. All of the model coefficients were converted to standardized beta coefficients so that the independent variables' associations with the dependent variable were comparable.

Variables that had a p-value of 0.20 or less in bivariate models were included in the multivariate fixed-intercept model. Interactions were tested between the variables of interest (MCV1, MCV2, and PSP) and reported if they were significant at 0.05. Then, a multivariate model with random intercepts for countries and world regions was computed. The significance level for interpreting these models was set with $\alpha = 0.05$. Models were compared with the Bayesian Information Criterion (BIC) and the -2 log likelihood (-2LL) value. The model chosen for Bayesian analysis was selected based on BIC, -2LL, how additional variables and random intercepts impacted the overall model.

5.6.2.2 Bayesian analysis.

Once models were completed in SAS (SAS Institute Inc., 2020), parameters and random effects were re-examined in OpenBUGS (Spiegelhalter, Thomas, Best, & Lunn, 2014). In the non-spatial model, random effects were included for country (*u*) and world region (*v*). In the spatial model, a random effect for spatial error was also added (*sp*). All parameters and random effects were estimated with non-informative priors that were set to a normal distribution with a mean of zero and a precision of 0.001. The spatial random effect was modeled with a Gaussian conditional autoregressive (CAR) distribution. The Gassian CAR model allowed countries to be defined as a neighbor or not for any given country, which is the proper choice for spatially distributed random effects (Spiegelhalter et al., 2014). The spatial precision was structured with a gamma distribution having a mean of 0.5 and a precision of 0.0005. The non-spatial model had the following for the country *i*: $\ln y_i = \ln POP_i + \alpha + \beta_1 X1 + \beta_2 X_2 + \ldots + \beta_m X_m + u + v$. The spatial model had the following for the department *i*: $\ln y_i = \ln POP_i + \alpha + \beta_1 X1 + \beta_2 X_2 + \ldots + \beta_m X_m + u + v + sp$. In these models, the population (POP_i) was the offset, α represented the intercept, and the betas (β_1, β_2, … β_m) represented the coefficient estimates for the independent variables X_1, X_2, … X_m. The exponentiated value of ($\ln (y_i) - \ln (POP_i)$) represents the measles rate in a country in a given year.

To run the Bayesian models, a burn-in period (T=175,000 time-steps) was selected based on the Brook-Gelman-Rubin plots (Gelman & Rubin, 1992). The time between independent samples was 17,500 (burn-in period/10) (Sokal, 1989). To ensure that the burn-in period did not have undue influence on the estimates, the length of the simulation was calculated so that the burn-in period would be five percent of the total length of run, and the length of run was increased until convergence was confirmed (see below) (T= 20,020,000 time-steps) (Sokal, 1989). This provided 1144 data-points with independent samples every 17,500 time-steps for each of three chains. The final model produced a value for the error's precision that lied outside the credible interval. Because of this result, outliers were removed and the model was rerun. However, the models with and without outliers produced statistically consistent results. Therefore, the model that includes the outliers is presented in this paper. To confirm that chains had converged and were sampling from stationary distributions, convergence diagnosis and output analysis (CODA) data were analyzed with R Studio software package (RStudio Team, 2016). The Gelman and Rubin (1992), Geweke (1992), Raftery and Lewis (1992), and Heidelberger and Welch Heidelberger and Welch (1981) tests were the diagnostic tests performed.

5.6.2.3 Spatial models.

The above analysis provided residuals that were examined for spatial correlation in each year with spatial descriptive statistics, including global and local Moran's *I* statistics and cluster maps. The results of spatial testing on the residuals from the non-spatial model were used to determine if neighbouring countries' welfare spending might impact measles immunization in a given country. These spatial tests on the residuals justified the development of a GLMM that included a spatial random effect (as discussed above). The spatial analysis was used to determine if the influence of welfare spending on measles immunizations and disease rates is more alike in countries that are geographically close to one another than those that are far apart (Cressie, 1993).

To conduct spatial analysis, the relation between countries must be defined with a neighborhood matrix. Various neighborhood matrices were considered, including defining neighbors based on shared borders and neighbors based on distance from a country's centroid. There are many more ways to define spatial relationships that are beyond the scope of this paper. However, defining neighbors by distance reduces the influence of countries that are large, with centroids far from their borders, and defining neighbors by contiguity neglects the influence of countries that are separated by water. Therefore, a neighborhood matrix was created based on contiguity, but it was altered to allow for the influence of neighbors that were separated by 200km or less by water. This conservative distance was chosen based on the average speed of a sailboat (5 knots) and how far it can travel in one day (Anderson, 2008). This neighborhood matrix was used to structure the spatial error in the Bayesian model with spatial random effects. Model selection between the Bayesian model without spatial effects and the Bayesian model without spatial effects was based on the BIC value.

5.7 Results

5.7.1 Descriptive Results

Initial testing of the data was completed with non-parametric Friedmans' analysis of variance (ANOVA) and descriptive statistics, including spatial maps. A Friedman's ANOVA test revealed that there were significant differences in measles rates between world regions (χ = 1142.1, df = 1040, p-value = 0.014). Descriptive statistics showed that Africa and Oceania have the highest mean measles rates over the period of the study, while Europe, Asia, and the Americas have the lowest mean measles rates throughout the study (see table 5.2). Friedman's ANOVA showed significant differences between regions based on MCV1 (χ = 209.78, df = 69, p-value < 0.001) and MCV2 (χ = 148.80, df = 80, p-value < 0.001). Africa and Oceania have the lowest mean immunization rates for MCV1 and MCV2 and Europe, Asia, and the Americas have the highest mean immunization rates for MCV1 and MCV2. Interestingly, there was not a significant difference between regions based on PSP (χ = 985.86, df = 966, p-value = 0.321).

Spatial maps and spatial correlation statistics focused on the main variables of interest: measles rates, MCV1, and PSP (see figures 5.1 to 5.6 and table 5.3). The results of the choropleth maps and cluster maps for measles rates, MCV1, and PSP complement the descriptive statistics described above. Figure 1 shows high concentrations of measles in Africa and Oceania, while Figure 5.2 shows that low levels of MCV1 were administered in some areas of Africa and Oceania. Figure 5.3 complements the measles rates and MCV1 findings, showing that the lowest PSP levels are in parts of Africa and south Asia.

One might expect spatial clustering tests to be significant for measles rates, MCV1, and PSP. However, table 5.3 indicates that measles rates had significant global spatial clustering only in the years 1995 ($I = 0.086$, p-value = 0.038), 2014 ($I = 0.236$, p-value = 0.006), and 2015 ($I = 0.219$, p-value = 0.002), while MCV1 and PSP had significant global spatial clustering in all years (see figures 5.4 to 5.6). These results justify the use of models with spatial random effects and spatial error.

5.7.2 Models in SAS

Models were initially computed in SAS with a negative binomial model. These models were chosen because the mean of measles is not equal to its variance, $t = -6865900$, $df = 7259$, p-value < 0.001. Bivariate models for each independent variable and control variable indicated that MCV1 ($B = -0.42$, p-value < 0.001), MCV2 ($B = -0.19$, p-value = 0.005), PSP ($B = -0.44$, p-value < 0.001), GINI ($B = 0.27$, p-value = 0.001), GDP ($B = -0.35$, p-value < 0.001), and POLITY ($B = -0.04$, p-value = 0.007) variables should be included in the overall model because they had a significance level of less than 0.20, while FLF ($B = 0.05$, p-value = 0.493) was not included in the overall model because it had a p-value greater than 0.20 (see table 5.4).

5.7.3 GLMM

Once the variables were chosen based on the criteria outlined above, a negative binomial model was computed, and the interaction between PSP and MCV1 was added to the model, as this interaction was the relationship of interest in the research. Finally, random intercepts were added. Models were completed with random intercepts for countries only, random intercepts for world region only, and countries being nested within world regions. This process was repeated for each of the nine imputed data sets, and results from the final model were compared. None of the coefficient estimates for each of the nine models differed in direction and confidence intervals overlapped between all nine models. Therefore, only results from the first imputation will be displayed (see table 5.5).

The models computed in SAS consistently showed that measles counts have a negative relationship with MCV1. However, MCV2 has a positive relationship with measles counts in all the models. PSP has a negative relationship with measles counts, and the interaction between PSP and MCV1 also has a significant and negative relationship with measles counts. The control variable GDP consistently has a negative relationship with measles counts, but those relationships are not significant in all models. The control variables GINI and POLITY are inconsistent in the direction and significance of the relationship with measles counts. The country-only random intercept model shows that the random intercept is significant ($u = 3.76$, p-value < 0.001), but the region-only random intercept model showed that the random intercept is not significant ($v = 2.83$, p-value $= 0.194$). The model with random intercepts for country and region show that both random intercepts have an overall positive influence on the fixed intercept, but both are not significant ($u = 1.90$, p-value $= 0.233$; $v = 1.86$, p-value $= 0.242$). Hence, the random intercept model is the preferred model because of the reduction in the unexplained error due to including these random intercepts. Furthermore, the addition of region as a random intercept changed the relationship that country had as a random intercept with measles cases. Therefore, we chose model 5 (see table 5.5) to check with Bayesian methods in OpenBUGS and test for a spatial relationship.

5.7.4 OpenBUGS Models

The final model was reassessed with Bayesian statistical methods in OpenBUGS. Both formal and informal convergence analysis of the Bayesian model satisfied criteria suggesting that the three Markov chains had reached their stationary distributions and the samples from these chains were sufficient. The Gelman and Rubin (1992) diagnostic test showed that the potential scale reductions estimated for the models were below 1.05, indicating that the simulations emerged from a stationary distribution. The Raftery and Lewis (1992) diagnostic showed that the run-length was sufficient, as the dependence factor values were lower than 5. The p-values in Geweke (1992) and Heidelberger and Welch (1981) tests were greater than 0.05 for 95% of the coefficient estimates and random intercepts that significantly differed from zero.

5.7.4.1 Final spatial and non-spatial models.

Once the non-spatial model was developed from OpenBUGS, residuals were obtained and tested for spatial clustering. Global spatial clustering was significant in the years 1995 (I = 0.099, p-value = 0.038), 2010 (I = 0.161, p-value = 0.004), 2013 (I = 0.017, p-value = 0.002), 2014 (I = 0.184, p-value = 0.004), and 2015 (I = 0.245, p-value = 0.002) (see table 5.6 and Figure 5.7). Since more than half of the years studied showed significant spatial clustering, a spatial model was developed with a neighborhood matrix (described above) through a Gaussian CAR model (see table 5.7). The spatial random effects are not included in the final model because the Bayesian Information Criterion (BIC) was higher in the spatial model (BIC = 24225.730) than the non-spatial model (BIC = 19743.090). Therefore, the model that does not account for the spatial effects of neighboring countries was chosen as the final model for interpretation (also see table 5.7 and table 5.8).

The final model (without spatial error) shows fascinating results both in the independent and control variables. All variables included in the model are significant, except the Gini coefficient (B [unstandardized coefficient] = 0.159; 95% Cr. I. = -0.003, 0.321, β [standardized coefficient] = 16.174). As expected, MCV1 has a negative impact on log measles count (B = -0.835; 95% Cr. I. = -0.975, -0.699; β = -70.284). However, MCV2 has an unexpected positive relationship with log measles count (B = 0.202; 95% Cr. I. = 0.090, 0.313; β = 14.001). Finally, our model indicates that PSP has a negative relationship with log measles count (B = -0.936; 95% Cr. I. = -1.132, -0.744; β = -111.291). When the negative influence of both MCV1 and PSP on log measles count are taken into consideration with their significant, negative interaction (B = -0.239; 95% Cr. I. -0.319, -0.156; β = -12.181), our results indicate that welfare spending may have a modifying effect on the relationship between measles vaccination and log measles count. In other words, for every unit increase in PSP, the coefficient representing the relationship between MCV1 and log measles count decreases by an additional 0.239.

In addition, GDP and Polity are significant control variables that are worthy of further review. GDP has a significant negative influence on log measles count (B = -1.219; 95% Cr. I. = -1.694, -0.966; β = -297.796) with a relatively large influence on the model compared to the other variables' standardized beta coefficients. Interestingly, Polity's significant and negative relationship with log measles count (B = -0.065; 95% Cr. I. = -0.094, -0.036; β = -1.173) has comparatively very little influence on measles rates when considering the standardized beta coefficient. These results indicate that PSP and MCV1, along with their interaction have negative influences on measles rates, but GDP's negative relationship with measles rates may be the most influential.

The random effects in the final model are meant to account for the variability that comes from each country and region. As discussed above, the models developed in SAS justified including random intercepts for country and region. While none of the random intercepts for each region differ significantly from the fixed intercept (see figure 5.8), approximately half of the random intercepts for country are significant (see figures 5.9 to 5.13 and table 5.8). In spite of many insignificant random intercepts, it is important to include them in the final model because the random intercepts account for the nested structure of the data and accounted for the similarity of data points within the same country or region. These random intercepts allow the years of data to be more representative of the underlying population.

The significance of the random intercepts in the final model is difficult to interpret. The mean value for the error's precision lies outside its credible interval, indicating that there are some extreme outliers in the precision samples. Therefore, Variance Partition Coefficients (VPC) were calculated based on the mean and median precision for the random error, error explained by country effects, and error explained by region effects. The VPC values calculated based on the mean precisions indicate that country and region may explain a large amount of the variation in the model error. However, the VPC values calculated based on the median indicate that country and region may explain a very small amount of the model error. The VPC values based on median precision values are in agreement with the SAS models. Due to the extreme outliers found in the precision, we interpreted results based on the median precision value because it is more representative of the center of the distribution of errors.

5.8 Discussion

This study provides evidence to suggest that national public policies may play an important role in enhancing primary prevention interventions. The variables discussed in the results section were chosen to represent concepts in the conceptual model. The conceptual model uses primary prevention's specific protection from the Levels of Prevention model (Clark & Leavell, 1965) and public policy from the Ecological Model for Health Promotion (McLeroy et al., 1988). More specifically, it tests the influence of welfare spending (represented by PSP) on the effectiveness of immunization (represented by MCV1 and measles rates).

As presented in the results above, MCV1, PSP, and their interaction have significant negative influences on measles rates. Therefore, these findings suggest that greater levels of welfare spending (decommodification) may increase the effectiveness of primary prevention. These results are congruent with the Daku et al. (2012) study that found children had higher vaccination rates in countries with longer duration of maternity leave and higher income replacement while on maternity leave. The Daku et al. study is an example of how specific welfare benefits can bolster primary prevention efforts. Conversely, MCV2 has a positive and significant relationship with the log of measles counts. This surprising finding may be due to the time lag of the second dose of measles vaccine, the variability in the timing of the second dose of measles vaccine between countries, or that countries with high measles rates respond by increasing the second dose of measles vaccine. Future research may consider the interacting relationships between other specific welfare benefits and primary prevention efforts.

Our finding that GDP had the largest influence on the model in comparison to the other variables is congruent with expectation that development improves health outcomes (Patterson & Veenstra, 2016). However, even after controlling for the large effect of GDP, PSP and its interaction with MCV1 still had a significant effect on log measles cases. It is noteworthy that the standardized beta coefficient for GDP is almost three times more influential on the measles rates than PSP, the next most influential variable in the model, and over four times more influential on log measles count than MCV1, the third most influential variable in the model. MCV2 is the next most influential significant variable in the model. POLITY has the smallest amount of influence on the model. It is surprising that the Gini coefficient is not significant in the model, as income inequality is often found to be a significant influence on health and access to healthcare (Coburn, 2004). Future research could investigate how the Gini coefficient interacts with welfare spending. Ultimately, GDP may be an important control variable to include in research that investigates how welfare spending influences health interventions.

Primary prevention efforts and welfare spending need to account for diverse country situations. While none of the region effects are significant, many of the country effects are significant. Including these random intercepts is important because they account for the nested structure of the data (years of data within countries within regions) and allow the model to represent the population, rather than the sample (Ntzoufras, 2009). More specifically, this random intercept model represents the years and countries that are not analyzed along with the years and countries that are included. This advantage of random intercept models comes from its ability to let the intercepts vary according to an appropriate distribution (Ntzoufras, 2009). Using a random intercept GLMM allowed this research to be a good representative of the relationships studied.

Spatial relationships were hypothesized to be an important influence on the concepts being tested in this research. While the residuals from the non-spatial model show significant global spatial correlation in four out of the nine years studied, the model fit statistics show that the added complexity of including spatial error in the model is not justified. However, most of the residuals that have significant spatial correlations are in the latter years studied. Examining data that includes years beyond those included in this study may reveal if spatial relationships are becoming more significant over time. Hence, follow up research may be warranted when more data becomes available. Furthermore, alternative methods of defining neighbors may provide differing results.

5.8.1 Strengths and Limitations

This study has many strengths which make it valuable to the nursing and health literature. This study's primary strength is that it uses an analytical approach that considers geography and time. Furthermore, this study addresses validity in many ways. In relation to internal validity, the study uses data over time to decrease the influence of temporal ambiguity and account for history. Construct validity is addressed with consideration of the strengths and weaknesses of available theory constructs. Variables were chosen to represent decommodification and defamilialization in relation to welfare state theory, primary prevention in relation to the Levels of Prevention model, and public policy in relation to the Ecological Model for Health Promotion. Furthermore, previous research was considered in choosing possible control variables. Concerning statistical conclusion validity, the study includes all countries for which data is available, making the sample as close to the population as possible. The use of a sample that is close to the population also provides the study with greater external validity.

A limitation of country level analysis is the lack of consideration toward within-country variation. Results represent the average outcome in a country and ignore extreme values that may be hidden in the average. Furthermore, research at the country level may fail to account for supra-national influences, like globalization, neoliberalism, and multinational corporations, for example. The region and country effects need to be explored further in future research that tests alternative distributions of the model's error term (as discussed above).

Further challenges to country-level studies include differences in the quality and methods of data collection between countries, which may threaten validity. However, the World Health Organization attempts to verify the accuracy of their data with the reporting process described above. In addition, there is a possibility of missing data or omitted variables influencing the results. The use of quantitative methods to analyze abstract ideas and policy nuances is another challenge to this study. Welfare benefits can be provided in many ways with various policy approaches and investigated in relation to various outcomes. Another limitation is related to the challenges in accounting for the impact that false information related to the measles vaccine has had on measles immunization rates, especially the now retracted Wakefield et al. (1998) article in which a link was made between the measles vaccine and developmental disorders in children. Finally, because this is an ecological, correlational study, and no causality can be determined from its results. However, despite these limitations, the strengths of the study make it a valuable addition to the nursing and health literature.

5.8.2 Conclusion

This research uncovered some valuable insights that have the potential to inform public policy decisions about primary prevention and welfare spending. The methods used in this research revealed findings suggesting that higher levels of national welfare spending enhance the relationship between measles immunizations and measles infection. While this result requires further research, it suggests that welfare spending may have a beneficial impact on prevention interventions. Therefore, welfare spending policies have the potential to significantly impact people's health and daily life. As nurses, we must consider how the national policies in which we live and work impact the populations we serve.

5.9 References

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5.10 Tables

Table 5.1. List of countries included in analysis by world region.

Africa	Algeria Angola Benin Botswana Burkina Faso Burundi Cabo Verde Cameroon Central African Republic Chad Congo, Dem. Rep. Congo, Rep. Cote d'Ivoire Egypt, Arab Rep. Equatorial Guinea Eritrea	Ethiopia Gambia, The Ghana Guinea Guinea-Bissau Kenya Lesotho Liberia Libya Madagascar Malawi Mali Mauritania Mauritius Morocco Mozambique Namibia	Niger Nigeria Rwanda Sao Tome and Principe Senegal Sierra Leone South Africa Sudan Swaziland Tanzania Togo Tunisia Uganda Zambia Zimbabwe
Americas	Belize Bolivia Brazil Canada Chile Colombia Costa Rica Cuba	Dominican Republic Ecuador Guatemala Haiti Jamaica Mexico Nicaragua Panama	Paraguay Peru Saint Kitts and Nevis Saint Lucia United States Uruguay Venezuela, RB
Asia	Afghanistan Armenia Azerbaijan Bahrain Bangladesh Bhutan Brunei Darussalam Cambodia China Cyprus Georgia India	Japan Jordan Kazakhstan Korea, Rep. Kuwait Kyrgyz Republic Lao PDR Lebanon Malaysia Maldives Mongolia Myanmar	Pakistan Philippines Qatar Saudi Arabia Singapore Sri Lanka Syrian Arab Republic Thailand Timor-Leste Turkey United Arab Emirates Uzbekistan

	Indonesia Iran, Islamic Rep. Israel	Nepal Oman	Vietnam Yemen, Rep.
Europe	Albania Austria Belgium Bulgaria Byelarus Croatia Czech Republic Denmark Estonia Finland France Germany Greece	Hungary Iceland Ireland Italy Latvia Lithuania Luxembourg Malta Moldova Netherlands Norway Poland	Portugal Romania Russian Federation San Marino Serbia Slovak Republic Slovenia Spain Sweden Switzerland Ukraine United Kingdom
Oceania	Australia Fiji	Kiribati New Zealand	Papua New Guinea Samoa

Table 5.2. Descriptive statistics for main variables of interest.

		N	Missing	Mean	Median	Std. Dev.	Variance	Min	Max
Measles count	Africa	424	17	4827.2	213.5	188744.1	356232834.4	0.0	212183.0
	Americas	294	3	42.3	0.0	189.5	35892.4	0.0	2631.0
	Asia	370	17	4163.7	206.5	12527.6	156940951.7	0.0	124219.0
	Europe	301	32	938.2	20.0	4331.1	18758646.1	0.0	54239.0
	Oceania	58	14	315.5	0.0	1093.2	1195051.9	0.0	7135.0
	All data	1447	83	2695.6	36.0	12344.6	152389989.9	0.0	212183.0
Measles rate per 100,000 people	Africa	420	21	25.1	2.1	73.9	5459.3	0.0	782.7
	Americas	294	3	0.2	0.0	1.0	1.0	0.0	11.6
	Asia	370	17	13.4	1.4	78.2	6116.4	0.0	1203.9
	Europe	301	32	3.9	0.3	19.7	389.1	0.0	297.5
	Oceania	58	14	38.3	0.6	151.0	22811.3	0.0	1008.1
	All data	1443	87	11.9	0.4	57.8	3344.0	0.0	1203.9
MCV1	Africa	432	9	79.7	85.0	17.3	297.7	19.0	99.0
	Americas	294	3	91.5	93.5	9.0	81.5	32.0	99.0
	Asia	380	7	90.8	95.0	11.2	125.5	27.0	99.0
	Europe	310	23	92.2	94.0	8.2	68.0	50.0	99.0
	Oceania	68	4	81.8	85.0	14.5	209.5	39.0	99.0
	All data	1484	46	87.6	93.0	13.7	188.1	19.0	99.0
MCV2	Africa	103	338	75.3	84.0	25.1	630.7	3.0	99.0
	Americas	172	125	81.4	88.0	16.9	285.6	11.0	99.0
	Asia	267	120	86.7	95.0	19.0	361.2	9.0	99.0
	Europe	233	100	90.5	93.0	11.5	131.8	0.0	99.0
	Oceania	38	34	78.2	85.0	20.3	412.5	9.0	99.0
	All data	813	717	84.8	92.0	18.5	340.5	0.0	99.0
PSP	Africa	204	237	4.6	3.9	3.0	9.2	0.3	16.3
	Americas	174	123	8.9	7.1	5.0	25.2	1.1	19.3
	Asia	275	112	6.0	4.1	5.3	28.5	0.1	24.2
	Europe	289	44	20.8	20.7	4.9	23.9	9.3	31.7
	Oceania	51	21	9.5	7.6	7.0	49.4	0.9	22.9
	All data	993	537	10.7	8.2	8.2	67.9	0.1	31.7

Table 5.3. Spatial cluster results for each year of data analyzed.

	Measles rate		MCV1		PSP	
	Moran's I	p-value	Moran's I	p-value	Moran's I	p-value
1995	0.086	0.038	0.330	0.002	0.732	0.002
2000	0.026	0.062	0.535	0.002	0.752	0.002
2005	0.034	0.120	0.378	0.002	0.755	0.002
2010	-0.010	0.438	0.127	0.014	0.730	0.002
2011	0.062	0.076	0.185	0.004	0.702	0.002
2012	0.012	0.090	0.227	0.002	0.655	0.002
2013	0.044	0.162	0.273	0.002	0.606	0.002
2014	0.236	0.006	0.303	0.002	0.599	0.002
2015	0.219	0.002	0.274	0.002	0.652	0.002

Table 5.4. Coefficient estimates from bivariate negative binomial models of independent variables and control variables. Coefficients with a p-value of < 0.20 were included in the overall model.

	Coefficient Estimate	Standard Error	DF	t-value	p-value	Confidence Limits	
FLF	0.05	0.07	1413	0.69	0.493	-0.09	0.18
GDP	-0.35	0.06	1413	-6.01	<0.001	-0.47	-0.24
GINI	0.27	0.08	1413	3.29	0.001	0.11	0.43
MCV1	-0.42	0.06	1413	-6.52	<0.001	-0.55	-0.30
MCV2	-0.19	0.07	1413	-2.81	0.005	-0.33	-0.06
POLITY	-0.04	0.01	1413	-2.72	0.007	-0.06	-0.01
PSP	-0.44	0.06	1413	-7.08	<0.001	-0.56	-0.32

Table 5.5. Multivariate models computed in SAS, including a fixed model (model 1), a fixed model with an interaction term (model 2), a model with random intercepts for country (model 3), a model with random intercepts for region (model 4), and a model with random intercepts for country nested within region (model 5). † = significant at 0.05.

	Intercept	MCV1	MCV2	GDP	GINI	PSP	POLITY	MCV1*PSP	Country	Region	Error	BIC	-2LL
Model 1	-9.09†	-0.48†	0.22†	-0.18	-0.14	-0.48†	0.03				5.92†	17852	17794
Model 2	-9.07†	-0.61†	0.22†	-0.24†	-0.24†	-0.53†	0.03†	-0.28†			5.83†	17831	17765
Model 3	-10.13†	-0.92†	0.22†	-0.59†	-0.15	-0.68†	-0.04	-0.24†	3.76†		3.75†	17387	17337
Model 4	-9.72†	-0.59†	0.21†	-0.08	0.04	-0.45†	0.05†	-0.23†		2.83	5.18†	17595	17578
Model 5	-10.13†	-0.92†	0.23†	-0.59†	-0.15	-0.67†	-0.04	-0.24†	1.90	1.86	3.75†	17392	17336

Table 5.6. Global Moran's I spatial clustering statistics for residuals from the OpenBUGS non-spatial model.

	Moran's I	p-value
1995	0.099	0.038
2000	0.092	0.072
2005	-0.017	0.450
2010	0.161	0.004
2011	0.064	0.106
2012	0.053	0.160
2013	0.017	0.002
2014	0.184	0.004
2015	0.245	0.002

Table 5.7. Coefficient estimates and variance partition coefficients for model without spatial effects and with CAR normal spatial effects. * Calculation based on mean precision values. **Calculation based on median precision values.

Model	Variables	Standardized Coefficients	Coefficient estimates	sd	MC_error	val2.5pc	median	val97.5pc
Non-spatial	Intercept		-10.220	1.613	0.054	-13.320	-10.250	-6.752
	GDP	-297.796	-1.319	0.186	0.003	-1.694	-1.314	-0.966
	GINI	16.174	0.159	0.084	0.001	-0.003	0.158	0.321
	MCV1	-70.284	-0.835	0.069	0.001	-0.975	-0.834	-0.699
	MCV1*PSP	-12.181	-0.239	0.042	0.001	-0.319	-0.240	-0.156
	MCV2	14.001	0.202	0.057	0.001	0.090	0.202	0.313
	POLITY	-1.173	-0.065	0.015	0.000	-0.094	-0.064	-0.036
	PSP	-111.291	-0.936	0.098	0.002	-1.132	-0.935	-0.744
	VPC error*		0.027					
	VPC country*		0.396					
	VPC region*		0.577					
	VPC error**		0.995					
	VPC country**		0.002					
	VPC region**		0.003					
	-2LL		18510.000					
	BIC		19743.090					
Spatial CAR Normal	alpha		-10.410	1.220	0.152	-13.870	-10.210	-8.488
	GDP		-1.365	0.187	0.008	-1.748	-1.366	-1.007
	GINI		0.143	0.079	0.004	-0.006	0.141	0.295
	MCV1		-0.833	0.070	0.003	-0.970	-0.835	-0.698
	MCV1*PSP		-0.239	0.041	0.002	-0.318	-0.239	-0.162
	MCV2		0.208	0.056	0.002	0.095	0.210	0.313
	POLITY		-0.064	0.015	5.824E-04	-0.092	-0.064	-0.038
	PSP		-0.949	0.100	0.004	-1.144	-0.951	-0.758
	VPC error*		0.221					
	VPC country*		0.396					
	VPC region*		0.172					
	VPC spatial*		0.211					
	VPC error**		0.997					
	VPC country**		0.001					
	VPC region**		0.001					
	VPC spatial**		0.001					
	-2LL		18510.000					
	BIC		24225.730					

Table 5.8. Random effects for final model.

Random effect	mean	sd	MC_error	Val2.5pc	median	Val97.5pc
Afghanistan	-2.621	0.523	0.010	-3.609	-2.621	-1.603
Albania	-1.329	0.502	0.011	-2.310	-1.343	-0.334
Algeria	0.751	0.467	0.008	-0.148	0.739	1.691
Angola	2.415	0.470	0.009	1.549	2.404	3.415
Armenia	-0.334	0.459	0.009	-1.247	-0.335	0.562
Australia	1.371	0.865	0.017	-0.289	1.361	3.094
Austria	0.288	0.485	0.010	-0.636	0.281	1.267
Azerbaijan	-0.039	0.554	0.012	-1.082	-0.046	1.082
Bahrain	-0.485	0.512	0.010	-1.494	-0.483	0.534
Bangladesh	-2.674	0.528	0.010	-3.685	-2.669	-1.633
Belgium	2.381	0.456	0.009	1.489	2.370	3.289
Belize	-0.318	0.742	0.016	-1.810	-0.316	1.114
Benin	0.518	0.441	0.009	-0.361	0.506	1.413
Bhutan	-0.888	0.479	0.010	-1.830	-0.888	0.083
Bolivia	0.263	0.560	0.012	-0.855	0.276	1.349
Botswana	3.258	0.483	0.010	2.350	3.244	4.227
Brazil	1.799	0.545	0.011	0.797	1.790	2.895
Brunei Darussalam	4.568	0.537	0.011	3.524	4.569	5.640
Bulgaria	2.542	0.461	0.009	1.629	2.535	3.468
Burkina Faso	0.257	0.452	0.009	-0.638	0.263	1.128
Burundi	-0.185	0.478	0.009	-1.092	-0.198	0.758
Byelarus	-1.775	0.527	0.009	-2.818	-1.781	-0.757
Cabo Verde	-2.873	0.623	0.011	-4.119	-2.880	-1.635
Cambodia	-2.618	0.538	0.009	-3.676	-2.620	-1.576
Cameroon	-1.088	0.451	0.008	-1.918	-1.091	-0.190
Canada	5.593	0.565	0.010	4.491	5.577	6.719
Central African Republic	-2.181	0.501	0.011	-3.136	-2.184	-1.184
Chad	-1.521	0.470	0.010	-2.415	-1.525	-0.545
Chile	-0.308	0.613	0.015	-1.471	-0.317	0.889
China	-0.720	0.461	0.009	-1.594	-0.723	0.171
Colombia	-0.094	0.548	0.011	-1.126	-0.095	0.991
Congo, Dem. Rep.	0.590	0.497	0.010	-0.366	0.609	1.563
Congo, Rep.	-0.064	0.462	0.009	-0.945	-0.076	0.879
Costa Rica	0.790	0.563	0.011	-0.313	0.788	1.865
Cote d'Ivoire	-0.764	0.451	0.009	-1.646	-0.763	0.159
Croatia	-0.356	0.469	0.008	-1.314	-0.353	0.550
Cuba	-2.894	0.950	0.019	-4.895	-2.843	-1.169
Cyprus	0.307	0.530	0.010	-0.715	0.295	1.372
Czech Republic	-0.705	0.489	0.009	-1.649	-0.723	0.258

Denmark	-0.426	0.487	0.009	-1.375	-0.422	0.546
Dominican Republic	0.267	0.541	0.011	-0.784	0.264	1.335
Ecuador	1.174	0.541	0.012	0.125	1.165	2.269
Egypt, Arab Rep.	0.696	0.480	0.010	-0.191	0.689	1.668
Equatorial Guinea	0.556	0.649	0.013	-0.739	0.560	1.818
Eritrea	-1.496	0.465	0.009	-2.371	-1.488	-0.542
Estonia	-2.001	0.502	0.010	-3.004	-1.983	-1.013
Ethiopia	-0.837	0.475	0.010	-1.783	-0.842	0.086
Fiji	1.702	0.839	0.016	0.024	1.696	3.366
Finland	3.785	0.471	0.009	2.851	3.781	4.741
France	2.398	0.461	0.009	1.501	2.400	3.343
Gambia, The	-1.415	0.478	0.009	-2.350	-1.433	-0.450
Georgia	2.903	0.453	0.009	2.032	2.902	3.811
Germany	0.891	0.480	0.010	0.024	0.877	1.913
Ghana	0.991	0.439	0.010	0.127	0.978	1.885
Greece	-1.182	0.473	0.008	-2.104	-1.178	-0.222
Guatemala	-2.805	0.598	0.013	-4.008	-2.808	-1.648
Guinea	-1.918	0.474	0.009	-2.843	-1.921	-1.020
Guinea-Bissau	-1.631	0.469	0.009	-2.512	-1.643	-0.664
Haiti	-2.330	0.642	0.012	-3.587	-2.319	-1.089
Hungary	-3.923	0.540	0.011	-4.954	-3.932	-2.870
Iceland	-2.795	0.771	0.013	-4.380	-2.790	-1.385
India	-1.156	0.498	0.009	-2.133	-1.159	-0.189
Indonesia	-0.880	0.474	0.008	-1.782	-0.895	0.084
Iran, Islamic Rep.	0.461	0.464	0.009	-0.433	0.451	1.359
Ireland	1.568	0.475	0.009	0.639	1.555	2.486
Israel	1.052	0.500	0.009	0.100	1.045	2.034
Italy	0.752	0.483	0.009	-0.159	0.742	1.715
Jamaica	-0.566	0.600	0.012	-1.725	-0.570	0.637
Japan	2.670	0.505	0.008	1.682	2.667	3.690
Jordan	-1.163	0.466	0.009	-2.058	-1.172	-0.237
Kazakhstan	1.913	0.455	0.009	1.056	1.897	2.837
Kenya	-1.389	0.465	0.009	-2.288	-1.411	-0.419
Kiribati	-4.256	0.978	0.019	-6.236	-4.275	-2.382
Korea, Rep.	2.309	0.476	0.009	1.336	2.321	3.266
Kuwait	1.211	0.550	0.011	0.147	1.203	2.316
Kyrgyz Republic	2.531	0.503	0.009	1.559	2.522	3.520
Lao PDR	-2.347	0.493	0.008	-3.301	-2.349	-1.365
Latvia	-2.519	0.515	0.009	-3.540	-2.523	-1.512
Lebanon	-0.423	0.480	0.010	-1.358	-0.440	0.534
Lesotho	1.141	0.490	0.010	0.198	1.129	2.147

Liberia	-1.126	0.510	0.010	-2.121	-1.139	-0.123
Libya	3.673	0.529	0.012	2.637	3.661	4.716
Lithuania	-1.031	0.487	0.009	-1.951	-1.036	-0.041
Luxembourg	2.625	0.500	0.009	1.664	2.611	3.610
Madagascar	-0.330	0.471	0.011	-1.251	-0.327	0.617
Malawi	-0.015	0.533	0.013	-1.074	-0.014	1.039
Malaysia	0.431	0.463	0.010	-0.440	0.412	1.398
Maldives	3.829	0.435	0.008	2.999	3.821	4.705
Mali	-1.111	0.453	0.009	-2.013	-1.115	-0.211
Malta	3.557	0.473	0.007	2.674	3.555	4.555
Mauritania	-0.323	0.462	0.009	-1.207	-0.329	0.603
Mauritius	4.343	0.507	0.011	3.387	4.327	5.341
Mexico	-0.593	0.544	0.012	-1.608	-0.611	0.468
Moldova	-1.388	0.559	0.011	-2.512	-1.394	-0.303
Mongolia	4.950	0.463	0.008	4.051	4.954	5.882
Morocco	0.231	0.468	0.009	-0.638	0.220	1.167
Mozambique	-0.576	0.511	0.011	-1.574	-0.581	0.445
Myanmar	-3.559	0.489	0.009	-4.521	-3.567	-2.594
Namibia	2.881	0.467	0.009	2.012	2.870	3.814
Nepal	-1.486	0.544	0.010	-2.545	-1.479	-0.444
Netherlands	1.631	0.470	0.009	0.724	1.625	2.578
New Zealand	2.363	0.856	0.017	0.677	2.358	4.032
Nicaragua	-3.224	0.714	0.015	-4.662	-3.196	-1.839
Niger	0.677	0.507	0.010	-0.325	0.683	1.647
Nigeria	-0.381	0.479	0.010	-1.300	-0.387	0.574
Norway	-0.629	0.510	0.011	-1.604	-0.636	0.402
Oman	-1.197	0.518	0.012	-2.192	-1.200	-0.107
Pakistan	-4.011	0.573	0.010	-5.164	-4.008	-2.904
Panama	-0.360	0.598	0.011	-1.548	-0.364	0.853
Papua New Guinea	-1.494	0.854	0.016	-3.175	-1.494	0.157
Paraguay	-0.918	0.561	0.012	-2.016	-0.905	0.186
Peru	-0.447	0.551	0.011	-1.544	-0.455	0.655
Philippines	-0.703	0.487	0.010	-1.666	-0.688	0.245
Poland	-1.874	0.470	0.009	-2.793	-1.878	-0.957
Portugal	-0.946	0.478	0.009	-1.830	-0.959	0.055
Qatar	1.594	0.590	0.012	0.456	1.587	2.752
Romania	1.464	0.473	0.009	0.526	1.462	2.400
Russian Federation	-0.742	0.500	0.009	-1.715	-0.752	0.249
Rwanda	-0.834	0.495	0.011	-1.784	-0.841	0.130
Saint Kitts and Nevis	0.988	1.183	0.025	-1.569	1.074	3.040
Saint Lucia	-0.062	0.867	0.016	-1.878	-0.026	1.530

Samoa	0.986	0.873	0.017	-0.731	0.977	2.675
San Marino	3.193	0.500	0.008	2.218	3.192	4.191
Sao Tome and Principe	-2.044	0.525	0.011	-3.055	-2.052	-0.983
Saudi Arabia	-0.142	0.524	0.011	-1.150	-0.154	0.916
Senegal	-1.123	0.478	0.009	-2.058	-1.127	-0.197
Serbia	-0.534	0.474	0.009	-1.480	-0.514	0.405
Sierra Leone	-0.444	0.479	0.008	-1.380	-0.449	0.487
Singapore	0.182	0.523	0.009	-0.837	0.178	1.211
Slovak Republic	-4.942	0.683	0.014	-6.376	-4.915	-3.670
Slovenia	0.796	0.470	0.008	-0.101	0.769	1.735
South Africa	1.802	0.545	0.010	0.781	1.779	2.904
Spain	1.281	0.459	0.009	0.407	1.278	2.197
Sri Lanka	1.295	0.447	0.008	0.464	1.281	2.166
Sudan	0.201	0.451	0.010	-0.633	0.191	1.123
Swaziland	-0.009	0.513	0.010	-0.959	-0.020	1.026
Sweden	-0.292	0.494	0.009	-1.254	-0.306	0.662
Switzerland	1.350	0.485	0.009	0.431	1.348	2.333
Syrian Arab Republic	-1.337	0.464	0.009	-2.205	-1.343	-0.447
Tanzania	-0.420	0.494	0.010	-1.374	-0.428	0.597
Thailand	0.569	0.449	0.009	-0.285	0.556	1.490
Timor-Leste	-2.282	0.520	0.011	-3.288	-2.288	-1.284
Togo	-1.799	0.465	0.009	-2.684	-1.801	-0.876
Tunisia	-0.351	0.456	0.010	-1.215	-0.371	0.572
Turkey	1.828	0.464	0.009	0.943	1.808	2.762
Uganda	-0.075	0.456	0.009	-0.952	-0.072	0.822
Ukraine	-0.351	0.512	0.009	-1.311	-0.365	0.628
United Arab Emirates	1.147	0.517	0.012	0.137	1.132	2.194
United Kingdom	0.952	0.468	0.009	0.085	0.935	1.922
United States	2.764	0.580	0.012	1.628	2.767	3.912
Uruguay	-0.033	0.687	0.014	-1.371	-0.019	1.297
Uzbekistan	-2.263	0.518	0.010	-3.257	-2.278	-1.224
Venezuela, RB	-0.861	0.574	0.013	-1.958	-0.869	0.257
Vietnam	-0.968	0.482	0.009	-1.889	-0.984	0.005
Yemen, Rep.	-1.077	0.477	0.009	-1.987	-1.089	-0.100
Zambia	2.328	0.452	0.009	1.465	2.320	3.258
Zimbabwe	0.454	0.448	0.009	-0.409	0.443	1.385
Africa	-0.896	1.697	0.071	-4.602	-0.834	2.410
Americas	-3.038	1.733	0.069	-6.842	-2.989	0.340
Asia	0.380	1.693	0.069	-3.350	0.405	3.754
Europe	2.306	1.699	0.069	-1.317	2.311	5.818
Oceania	0.915	1.812	0.070	-2.962	0.906	4.650

5.11 Figures

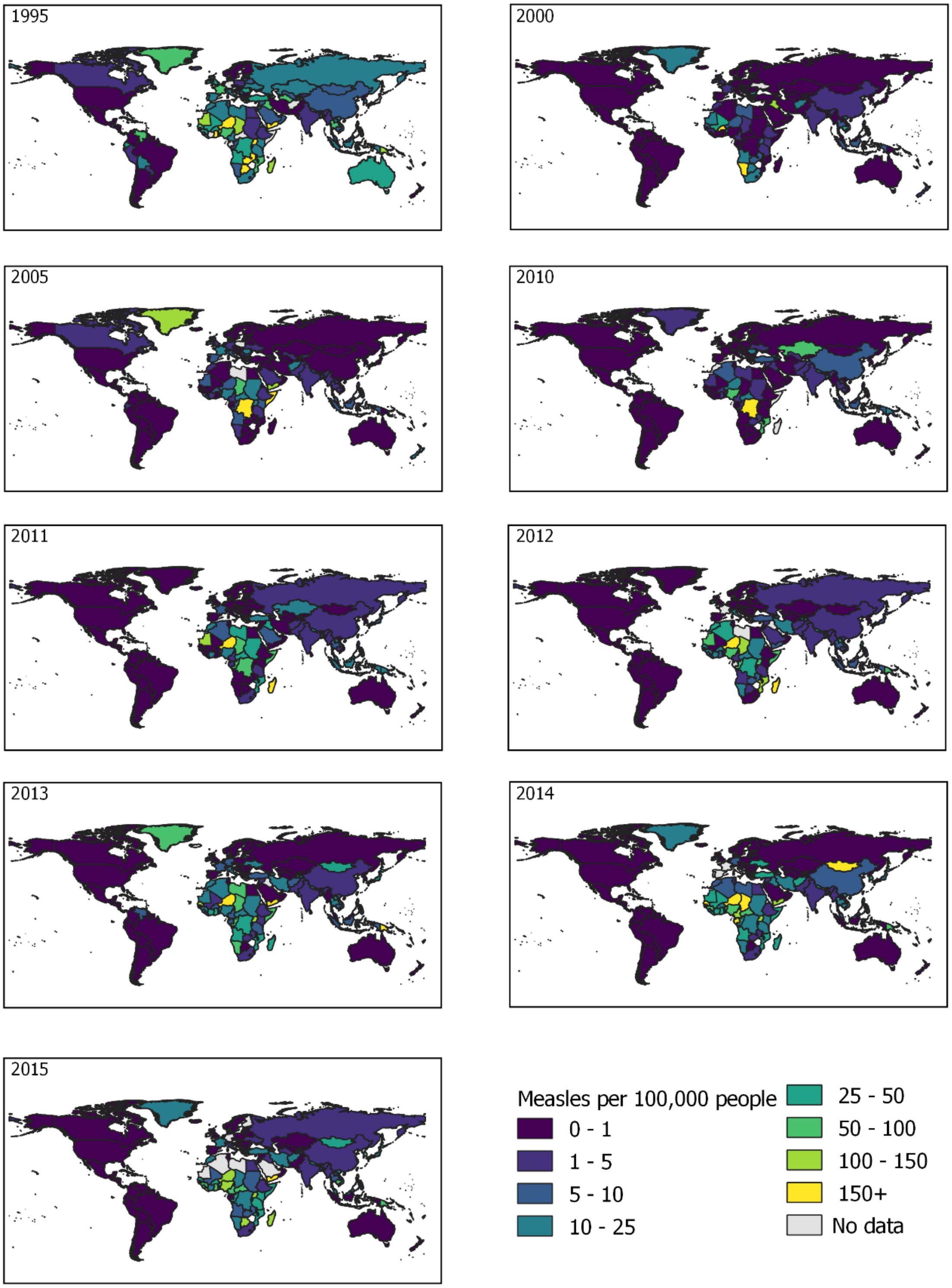

Figure 5.1. Choropleth maps for measles rates per 100,000 people for each year analyzed.

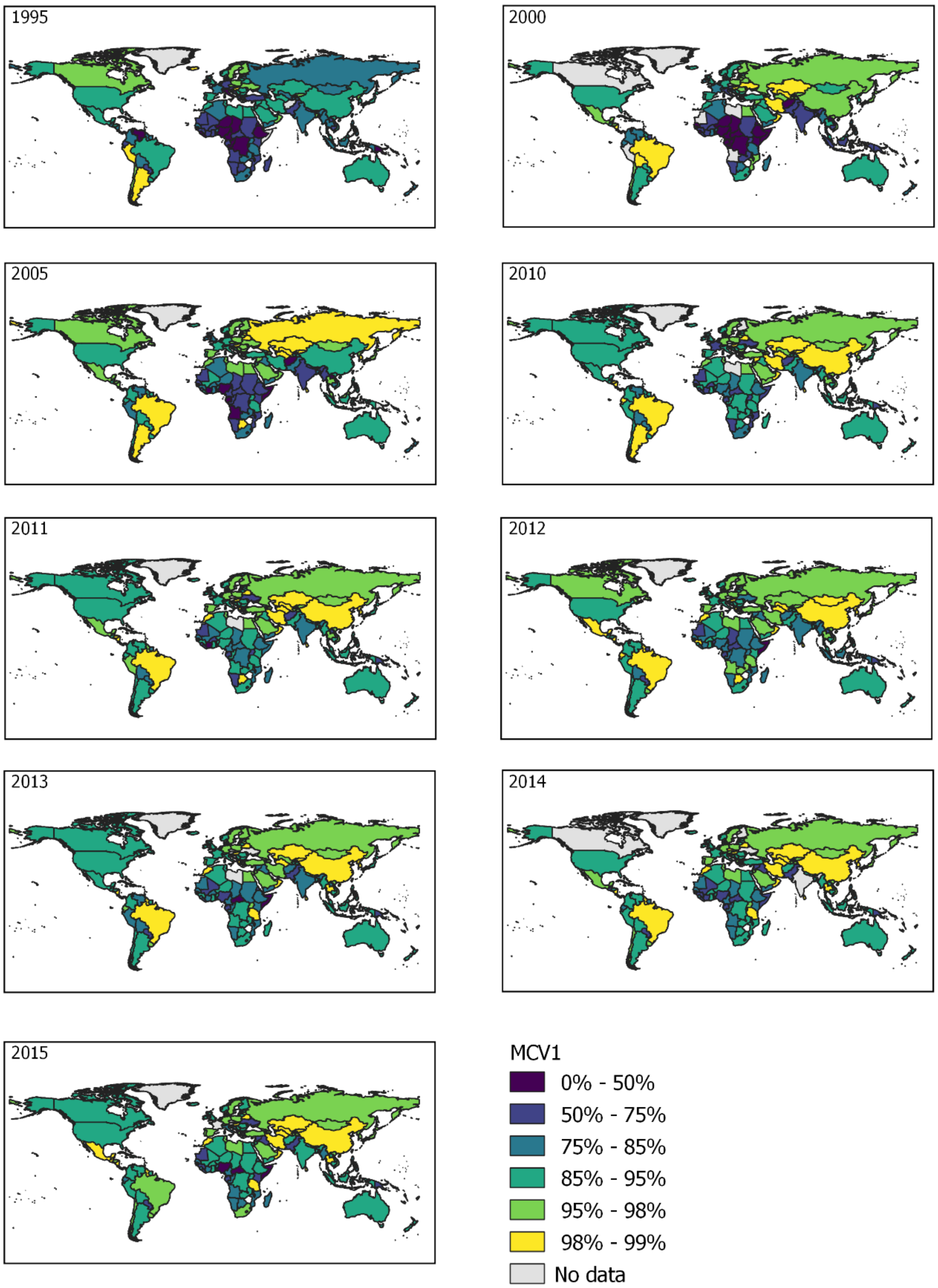

Figure 5.2. Choropleth maps of MCV1 rates for each year that was analyzed.

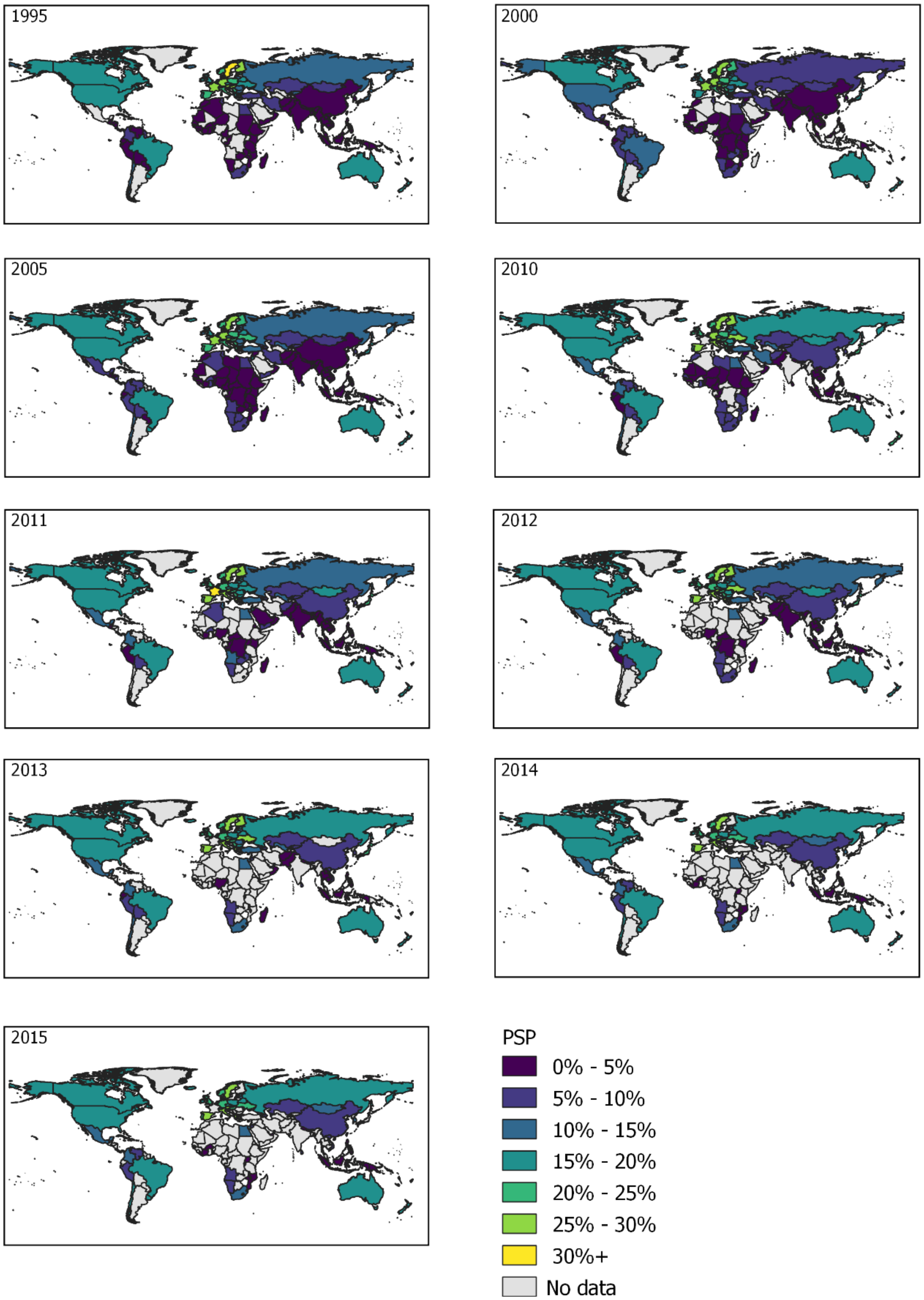

Figure 5.3. Choropleth maps for PSP levels as a percentage of GDP for each year was analyzed.

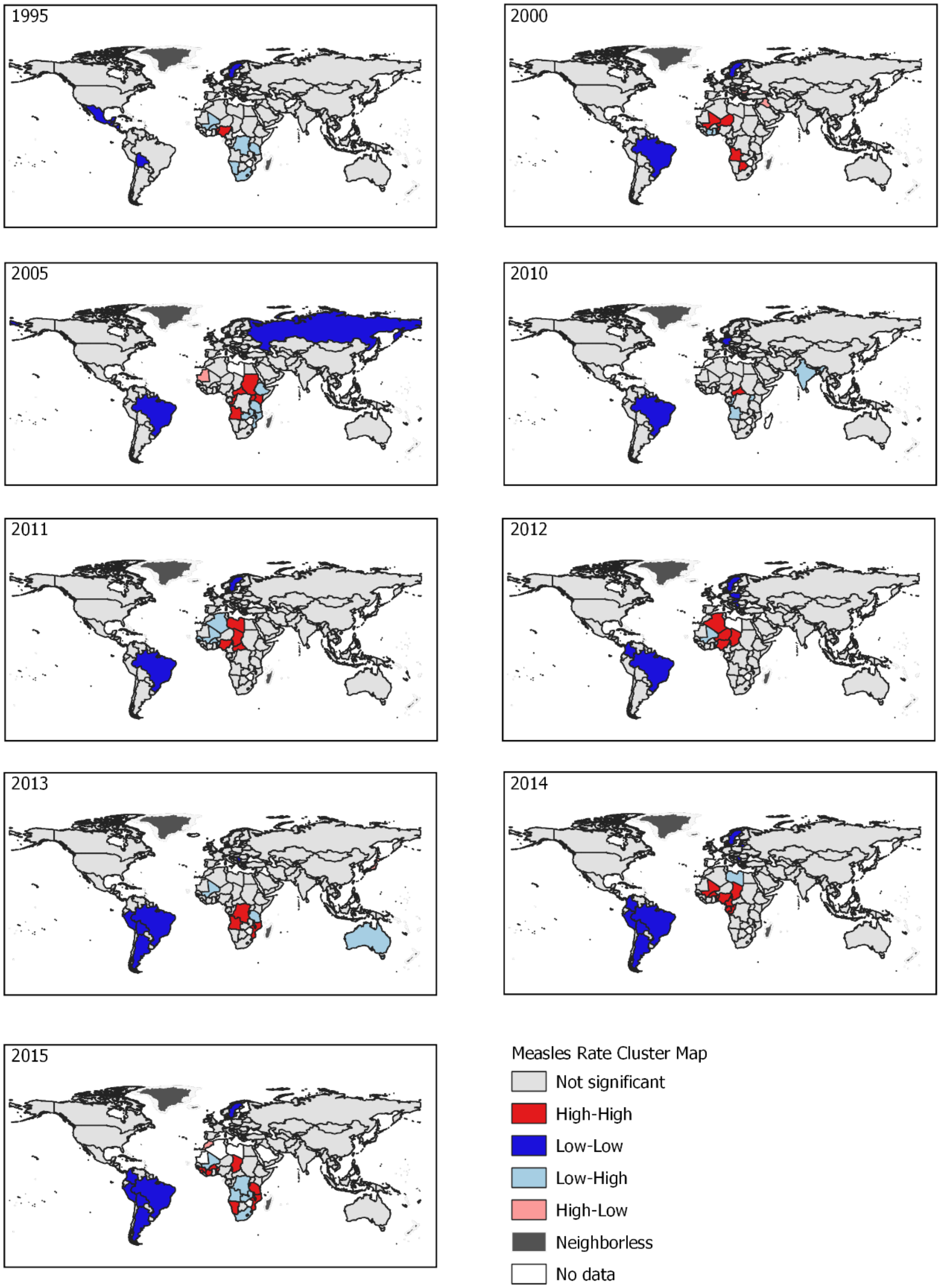

Figure 5.4. Spatial cluster maps for measles rates per 100,000 people for each year that was analyzed.

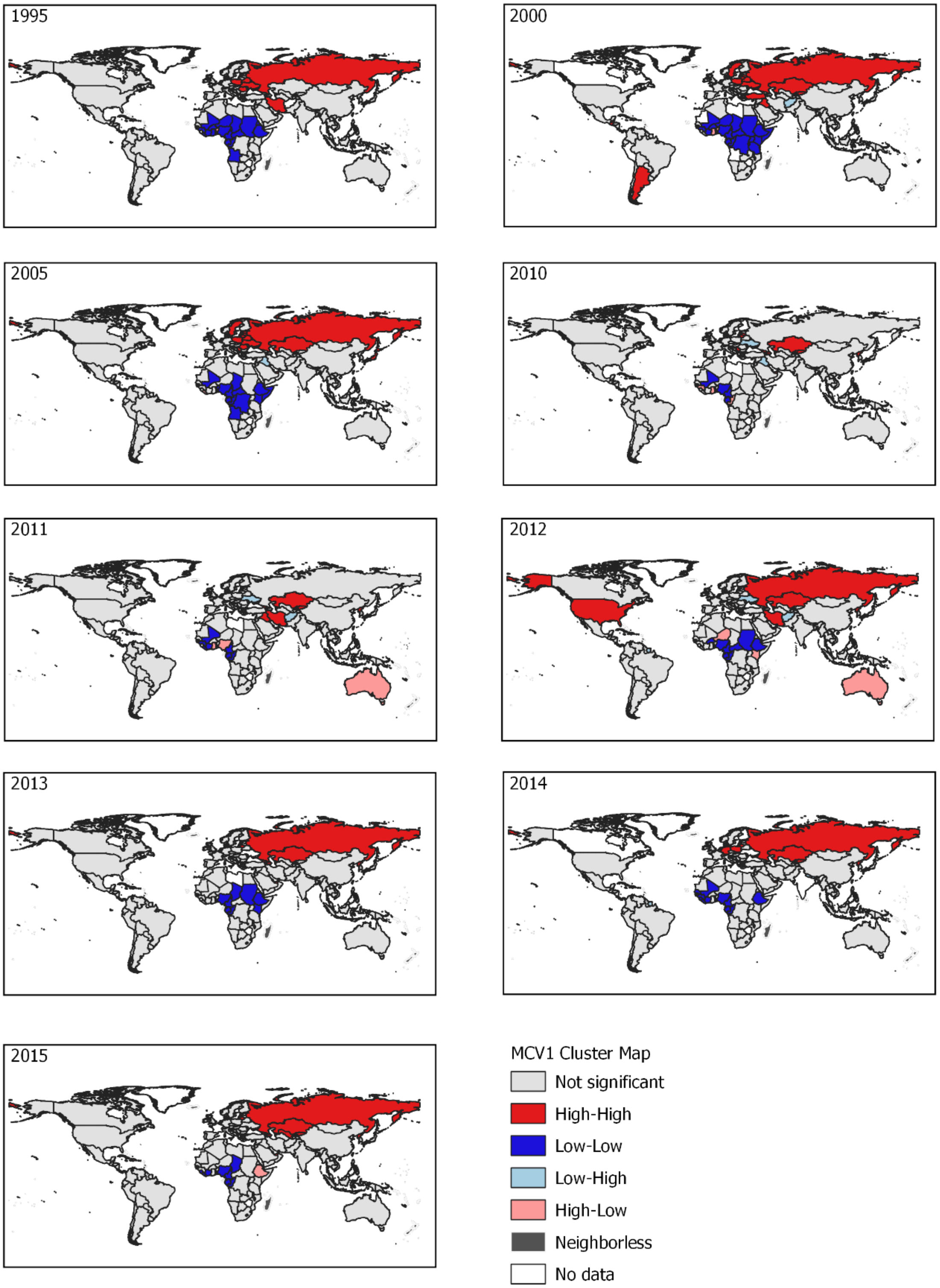

Figure 5.5. Spatial cluster maps of MCV1 rates for each year that was analyzed.

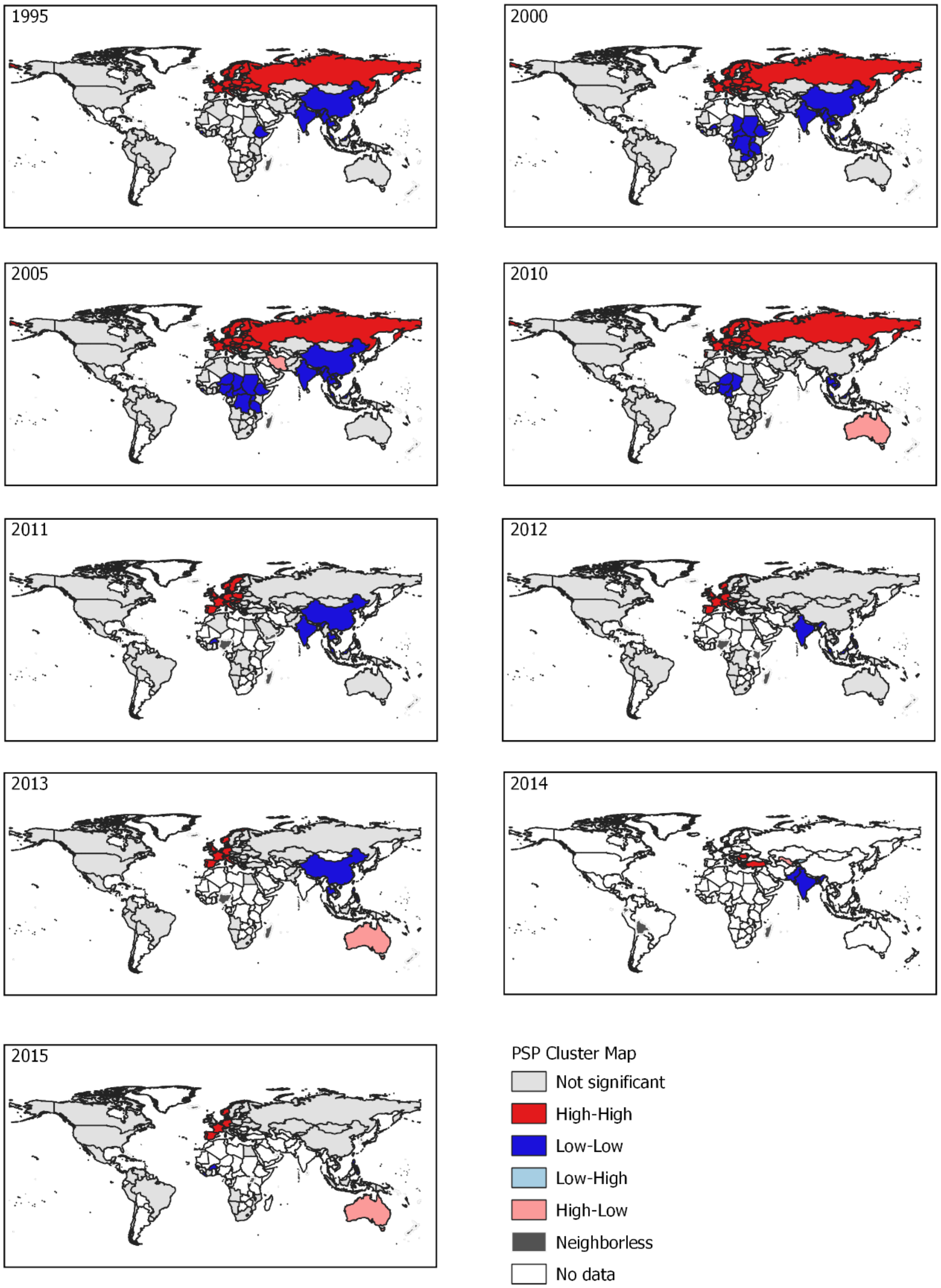

Figure 5.6. Spatial cluster maps for PSP levels as a percentage of GDP for each year that was analyzed.

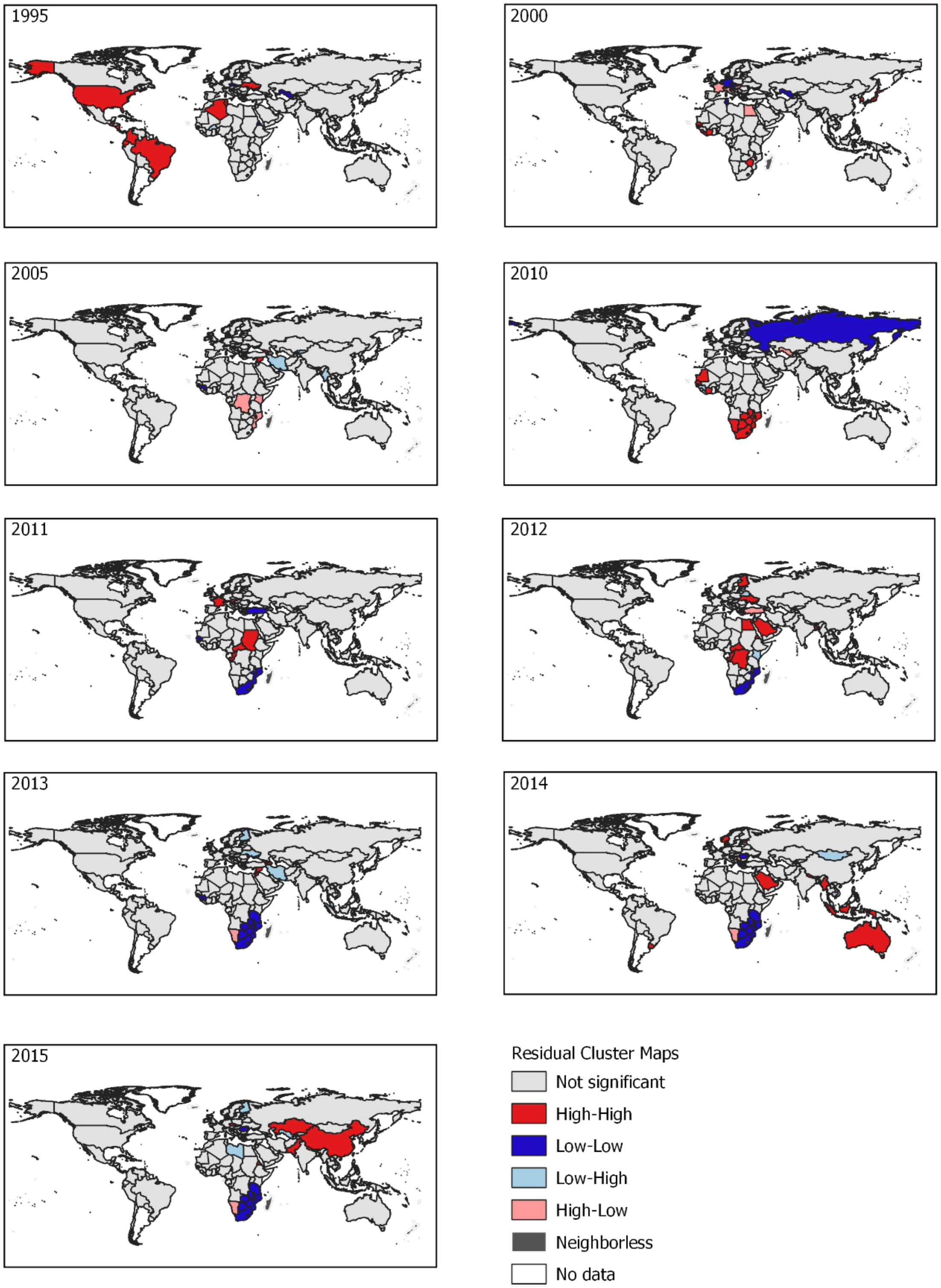

Figure 5.7. Spatial clustering maps for non-spatial OpenBUGS model.

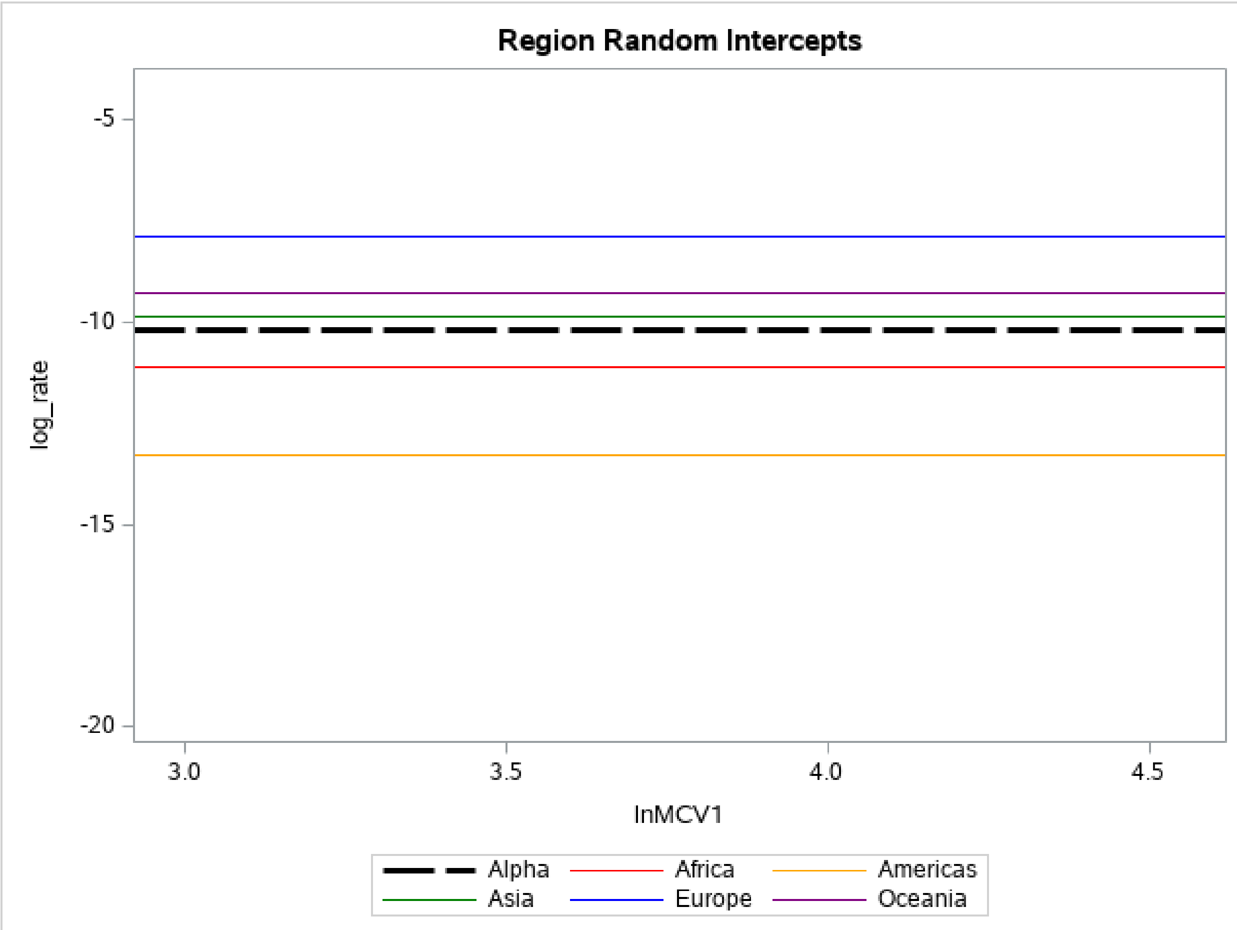

Figure 5.8. Random intercepts plots for regions.

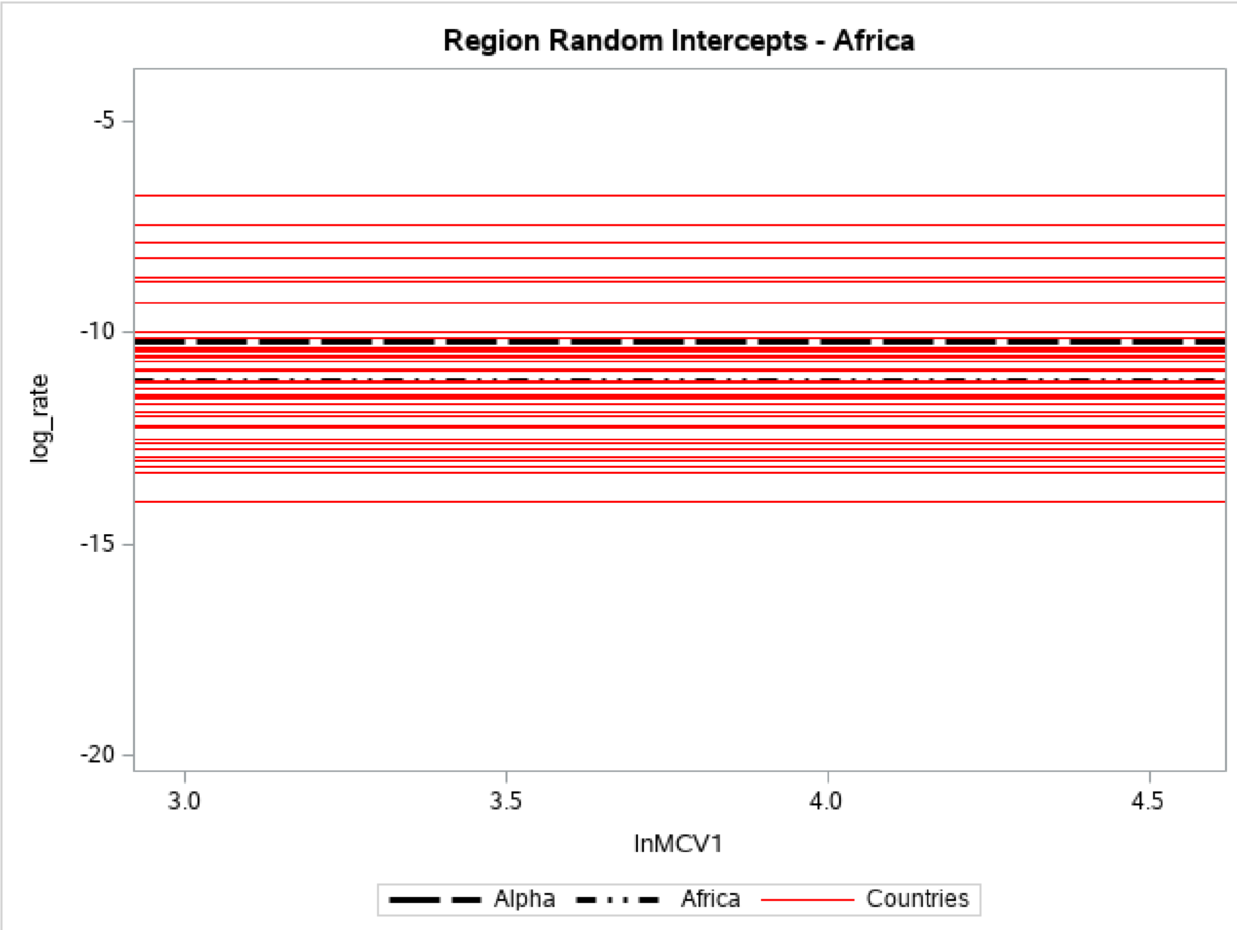

Figure 5.9. Random intercept plots for African countries.

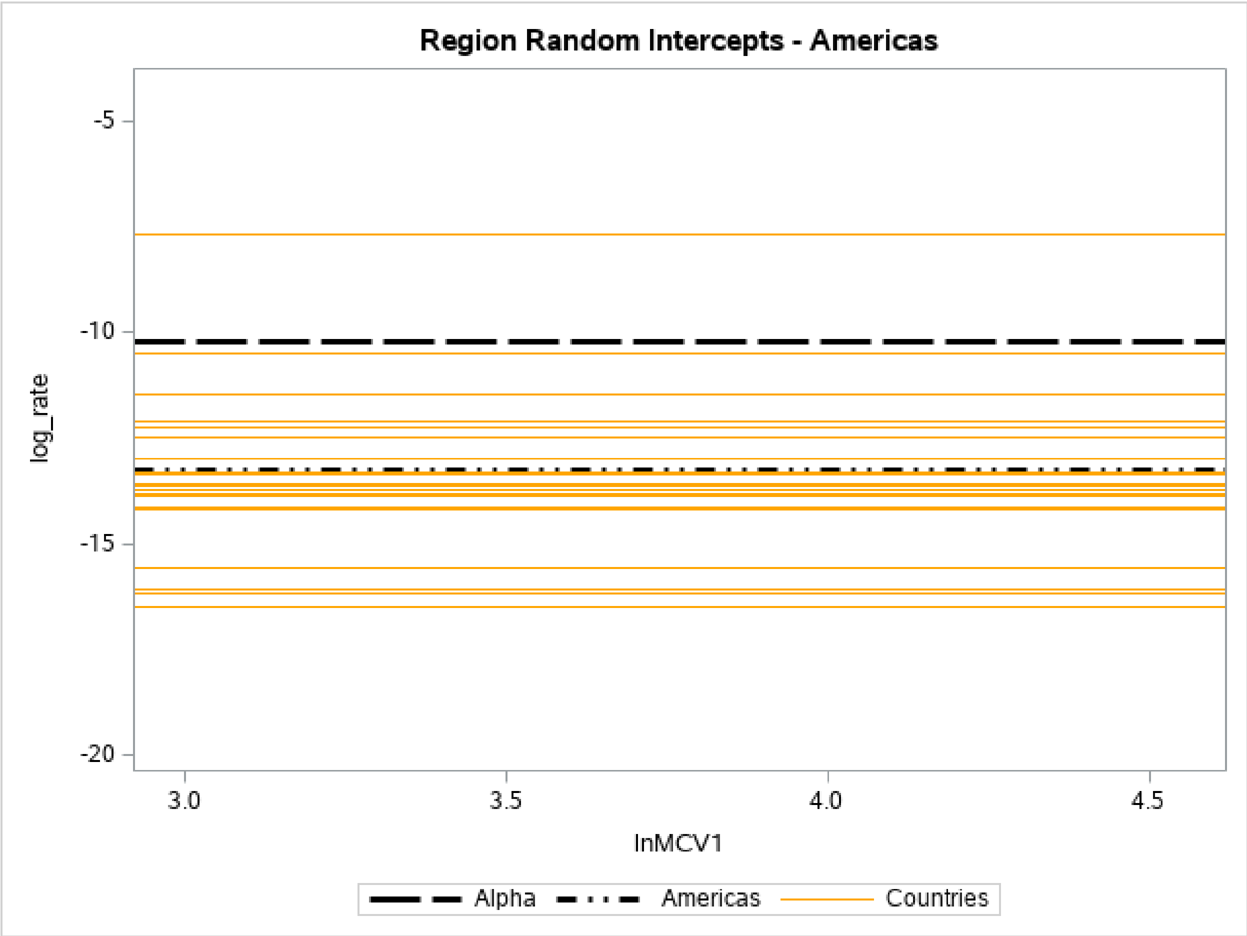

Figure 5.10. Random intercept plots for countries in the Americas.

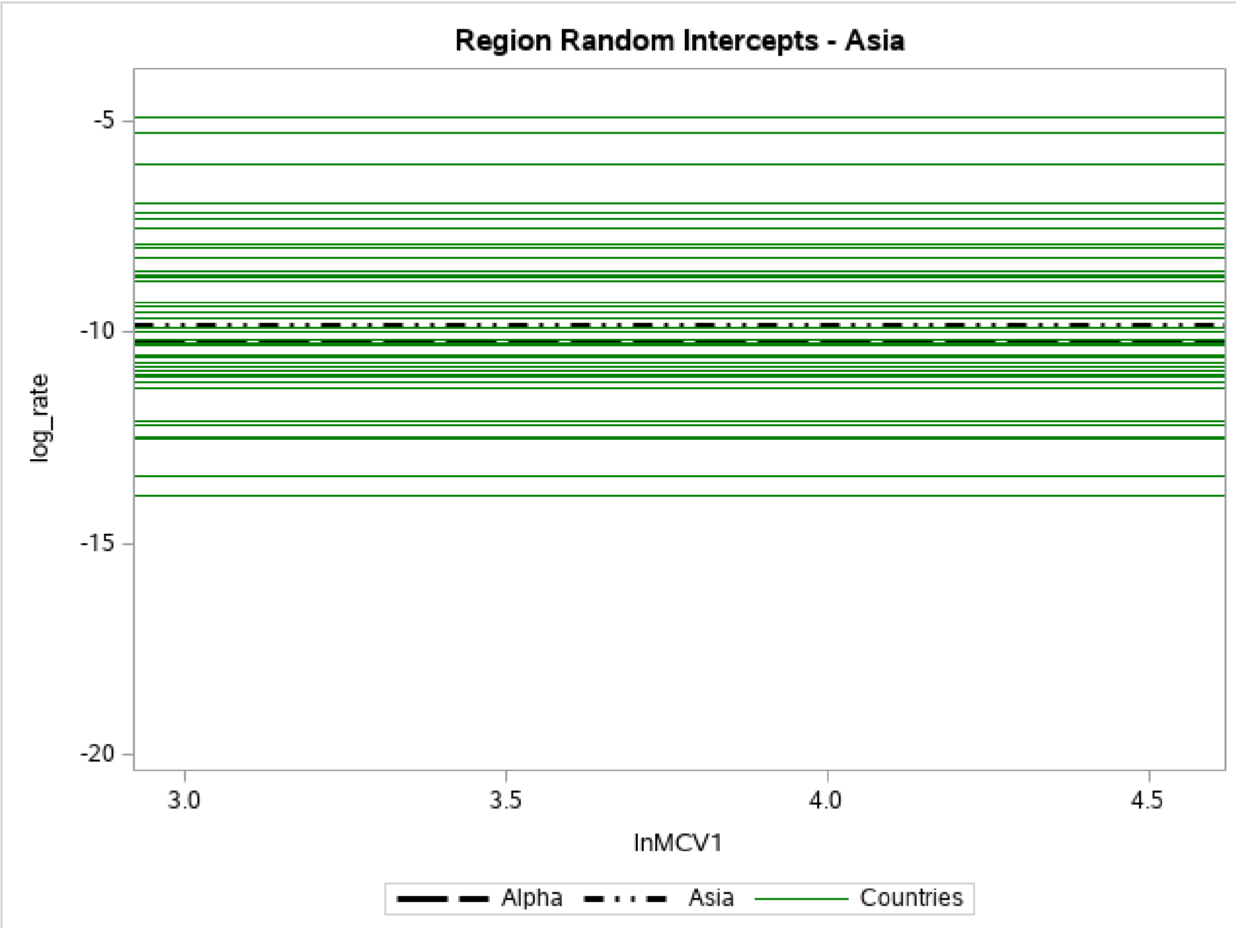

Figure 5.11. Random intercept plots for Asian countries.

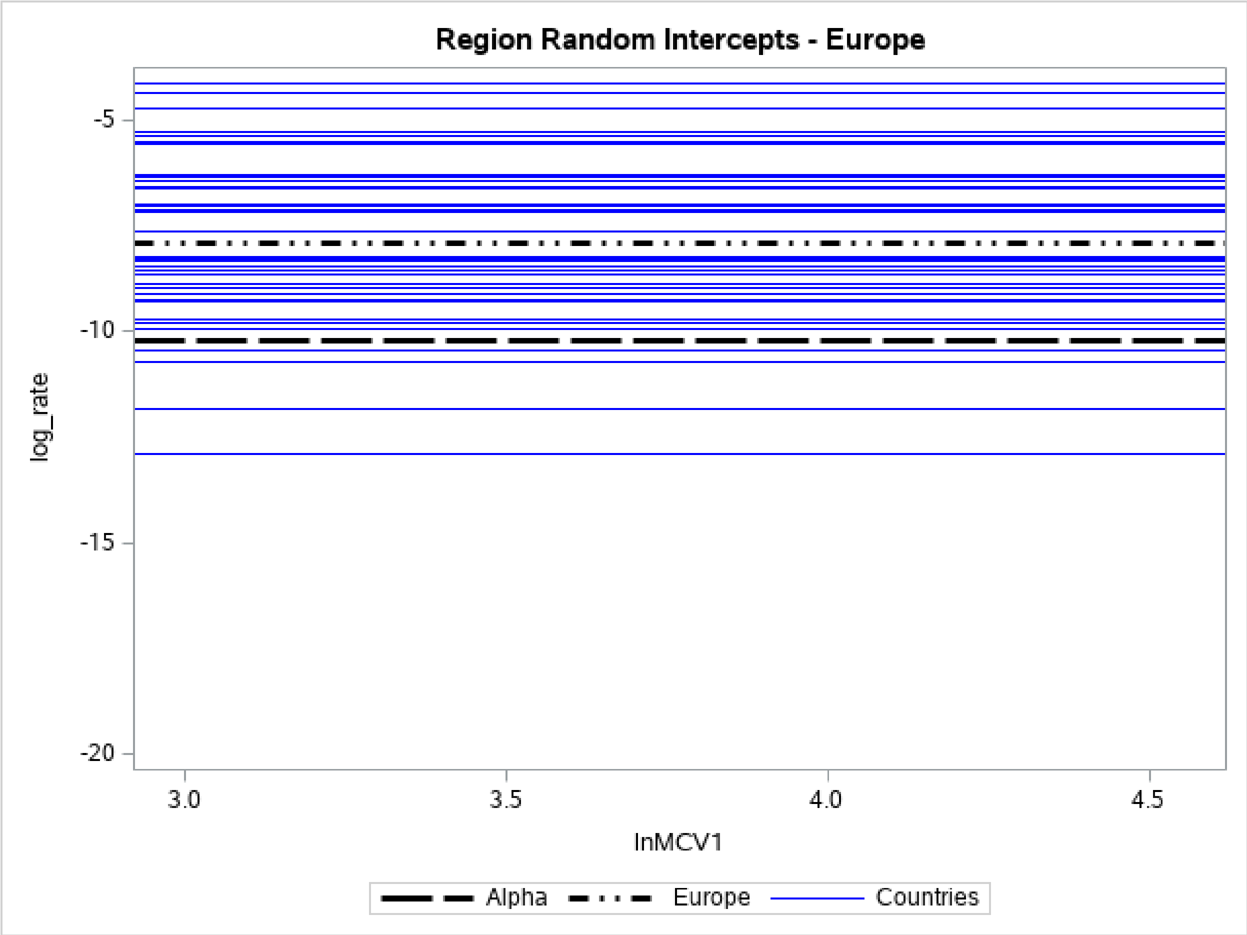

Figure 5.12. Random intercept plots for European countries.

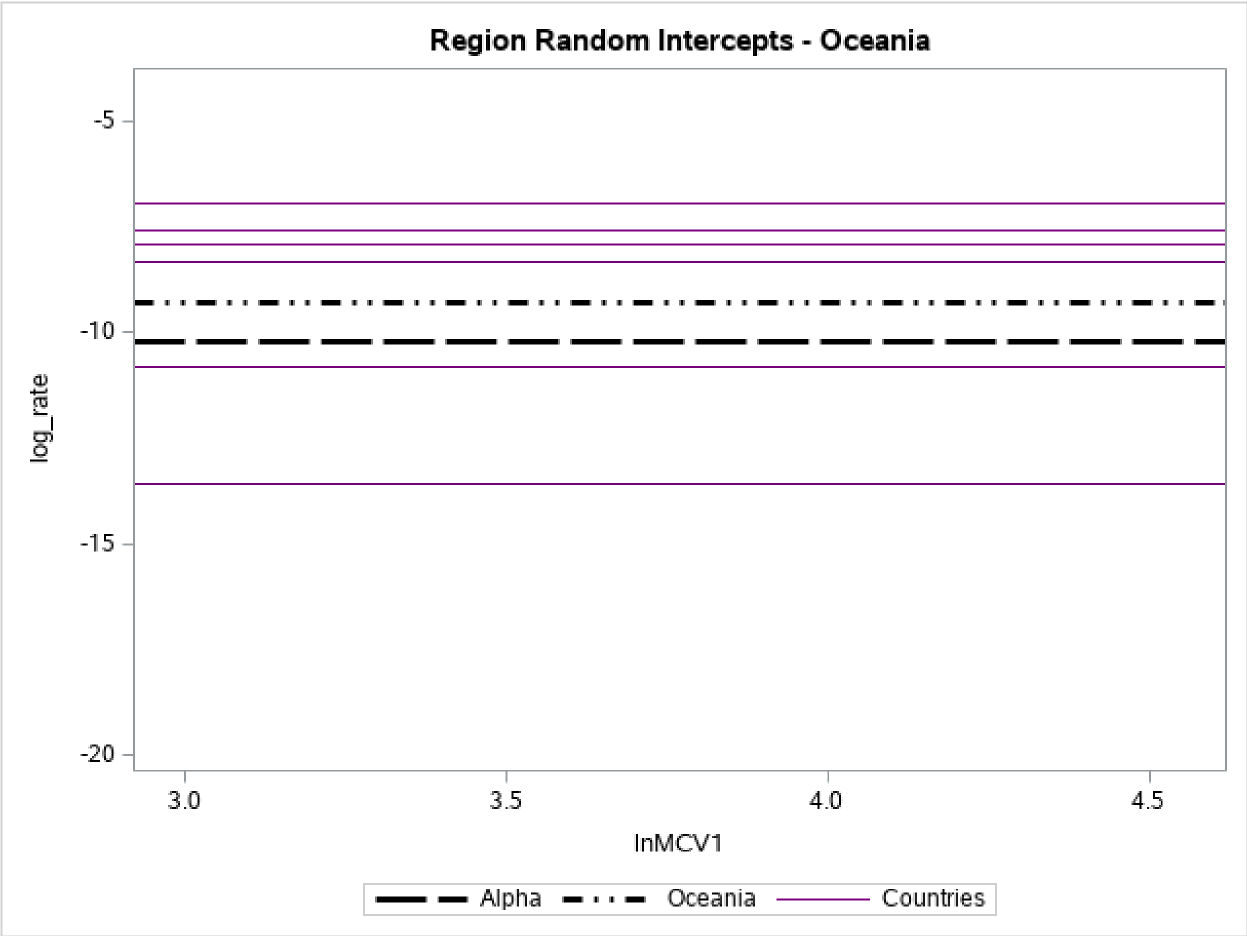

Figure 5.13. Random intercept plot for countries within Oceania.

6.0 DISCUSSION AND CONCLUSION

6.1 Introduction

The work presented in this dissertation has important implications for nursing research, and its topic is highly relevant to the current health context, nationally and internationally. The objectives of this dissertation are to develop an analytical approach to study data considering geographic location and use the analytical approach to determine the influence that welfare spending has on the relationship between a childhood immunization and its associated disease rate. These objectives were met throughout the chapters of this dissertation. In this dissertation, a scoping review (chapter 2) highlights a gap in the literature related to the relationship between welfare spending and vaccinations at national levels; a conceptual model (chapter 3) is developed that captures the influence of social ecology on primary prevention; and an analytical approach (chapter 4) is developed and implemented to address the research questions outlined. Finally, the findings that are produced from use of the analytical approach are presented in a results manuscript (chapter 5).

Findings from the scoping review indicate that there is inconclusive evidence about the influence that welfare spending has on health outcomes, including immunization rates. This inconclusive evidence justify research examining welfare spending's influence on immunization because it would expand the current state of knowledge on the topic. While the scoping review provides evidence that completing the research would be beneficial, the conceptual model provides a base for explaining the relationships among the concepts of interest. The theoretical models used to develop the conceptual model included the Levels of Prevention model by Clark and Leavell (1965) and the Ecological Model for Health Promotion by McLeroy, Bibeau, Steckler, and Glanz (1988). This conceptual model provides a means to contextualize the results generated from the analytical approach. Learning and implementing methods and computer programs relevant to spatial regression analysis can be a daunting task. Researchers often have to comb through several very abstract resources in order to determine how to implement the spatial analysis; at times, utilizing the information in these resources results in what seems to be adhoc and trial-and-error, leaving the researcher confused and frustrated. The analytical approach presented in this dissertation is a resource that collates the information from these different, more abstract sources into a single, concrete, step-by-step process that a non-statistician researcher can use to perform spatial analysis. The analytical approach developed in this dissertation makes spatial analysis accessible to other nursing researchers which will allow them to address more diverse and complex research problems.

The application of the analytical approach to exploring how welfare spending influences measles vaccination counts helps expand the knowledge of welfare spending's influence on primary prevention interventions. Overall, this study finds evidence to suggest that higher levels of national welfare spending may increase the effectiveness of measles immunization at preventing measles. This finding suggests that greater levels of welfare spending, or decommodification, increase the effectiveness of primary prevention, which is consistent with the findings of the scoping review. However, despite the analytical approach being developed to implement spatial regression, the spatial effect is not included in the final model because it explains very little of the variation in the model. We include random intercepts for countries and regions to account for the nested structure of the data and using a random intercept GLMM allows this research to be a good representative of the relationships studied.

This study may be especially relevant in the current context of the global spread of disease and anti-vaccination movements. For example, measles outbreaks have happened in Canada and the United States as recently as 2018 and 2019 (Sanyaolu et al., 2019). Global travel, lack of vaccination, inadequate vaccine dosing, and clusters of intentionally unimmunized children are all cited as possible reasons for these outbreaks (Sanyaolu et al., 2019). Furthermore, future research may explore how welfare spending influences other vaccinations and other prevention interventions. For example, the investigation of coronavirus disease 2019 and the various government approaches related to welfare spending may be an important research topic relevant to this field of enquiry. Recent world events highlight the importance of considering research that explores the social and political influences on primary prevention outcomes, like immunization. The research in this dissertation has uncovered areas for further study. For example, welfare spending is a broad concept that includes many components impacted by welfare policies. Exploring research topics that focus on specific types of welfare spending and their influence on primary prevention interventions could further add to the research literature in this area. Daku, Raub, and Heymann (2012) have explored maternity leave length and income replacement's relationship with child immunization rates. However, there are many more welfare support programs and primary prevention interventions that could be examined. Furthermore, spatial regression could address many more topics beyond those presented here that are of interest to nurse researchers. Some examples of nursing research that could use spatial analysis include spread of infections between patient rooms, control of patent symptoms based on location in a nursing unit, impact of location on homecare nurses' work, or disease risk in relation to factors that encourage or discourage healthy behaviours. All types of nursing take place in a spatial plane. Therefore, the possibilities for spatial analysis research in nursing are endless.

6.1.1. Strengths and Limitations

This study has many strengths which make it valuable to the nursing and health literature. This study's primary strength is that it aims to develop an analytical approach that makes research considering geography and time more accessible to other researchers. Furthermore, this study addresses validity in many ways. In relation to internal validity, the study uses data points over a 20-year period to decrease the influence of temporal ambiguity and account for history. Construct validity is addressed with consideration of the strengths and weaknesses of available theory constructs. Variables were chosen to represent decommodification and defamilialization in relation to welfare state theory, primary prevention in relation to the Levels of Prevention model, and public policy in relation to Ecological model. Furthermore, previous research was considered in choosing possible control variables. In relation to statistical conclusion validity, the study includes all countries for which data is available, making the sample as close to the population as possible. The use of a sample that is close to the population also provides the study with greater external validity.

This study also has limitations that need to be considered in relation to its strengths. A limitation of country level analysis is the lack of consideration toward within-country variation. Results represent the average outcome in a country and ignore extreme values that may be hidden in the average. Furthermore, research at the country level may fail to account for supra-national influences, like globalization, neoliberalism, and multinational corporations, for example.

Another limitation to this research was that the model produced a precision term for the error that was outside the 95% credible interval. This makes conclusions about the amount of error explained by region and country difficult. Future research could consider alternative distributions for the error term that may help find a more conclusive answer about how well country and region categorizations explain the error in the model.

Further challenges to country-level studies include differences in the quality and methods of data collection between countries, which may threaten validity. However, the World Health Organization attempts to verify the accuracy of their data with the reporting process described above. In addition, there is a possibility of missing data or omitted variables influencing the results. The use of quantitative methods to analyze abstract ideas and policy nuances is another challenge to this study. Welfare benefits can be provided in many ways with various policy approaches and investigated in relation to various outcomes. Furthermore, there are multitude of preventative health interventions that could be explored in relation to welfare spending. This research only investigates one type of immunization, and results may vary if other immunizations or other preventative interventions were analysed. Another limitation is related to the challenges in accounting for the impact that false information related to the measles vaccine has on measles immunization rates, especially the now retracted Wakefield et al. (1998) article in which a link was made between the measles vaccine and developmental disorders in children. Finally, because this is an ecological, correlational study, no causality can be determined from this study. However, despite these limitations, the strengths of the study make it a valuable addition to the nursing and health literature.

6.2 Contribution to Nursing

This study has the potential to significantly contribute to the nursing literature. This research takes nursing's environment metaparadigm concept and explores it in ways not found in the literature. This lack of consideration for the political environment has presented nursing as apolitical and leaves nurses without the theoretical or scholarly resources to engage politically (Cameron, Ceci, & Santos Salas, 2011; O'Byrne & Holmes, 2009). Exploring the influence of welfare spending on nursing work helps examine how the broader ecological effects of a country influence nurses' abilities to implement prevention interventions. This allows nurses to consider their practice in relation to the influence of the political economy, consider what role nurses believe they should have in society, and advance their ideas of how nurses can address the larger ecological factors that influence their work and their patients. This research uses measles immunization as a health intervention that nurses are commonly responsible for administering. Providing a concrete example of nursing responsibility may aid nurses in understanding the importance of socio-political concepts, like welfare spending, to their work. Community health nurses may find this information particularly valuable, especially when considering how policy influences health when working in international or global contexts, because community health nurses work with people in the contexts of their daily lives, including the socio-political context. Furthermore, this study contributes to nursing with the addition of advanced statistical methods, including spatial regression, which was not found in an exhaustive search of nursing journals. While nurses may have done spatial analysis work not published in nursing journals, this analytical approach may encourage more interest in spatial analysis among nurse researchers and lead to more spatial research being published in nursing journals. The analytical approach developed in this dissertation provides nurses and their interprofessional colleagues with an educational tool to develop their ability to analyze spatial-temporal data. Developing an analytical approach to help other nurses explore research questions that take place over space and time will aid the nursing discipline in advancing itself.

6.3 Conclusion

The study aims to explore how welfare spending levels influence the relationship between a primary prevention intervention and its associated outcome while considering geographic location. This aim is achieved through the development of an analytical approach meant to make spatial analysis more accessible to nurse researchers and apply that analytical approach to the above-stated relationship of interest. The exploration of welfare spending's influence on the relationship between measles disease and its vaccination, as well as the development of an analytical approach that promotes spatial regression, addresses research and methodology gaps relevant to nursing and health professionals. The influence of spatial relationships and welfare spending on primary prevention interventions is relevant to nurses because nurses throughout the world work in a variety of geographic, political, and economic contexts that impact their work and the health of the people they serve. The research presented in this dissertation highlights the importance of understanding the larger geographic and policy contexts on health.

6.4 References

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GLOSSARY

Bayesian statistics – consider the probability of unknown model parameters taking on certain values given the data and the probability model (Waller & Gotway, 2004). Bayesian statistics are based on a posterior distribution (the distribution of model parameters given the observed data) (Cressie, 1993), the likelihood function (the distribution of the data given the model parameters), and the prior distribution (the distribution of the parameters set by the researcher based on previous findings) (Waller & Gotway, 2004).

Choropleth maps – maps that use combinations of colors and patterns to depict values associated with an area in a map (Waller & Gotway, 2004).

Decommodification – when the state takes responsibility for welfare through the provision of benefits and services independent of one's ability to work (Esping-Andersen, 1985; Esping-Andersen, 1990).

Defamilialization – when the state takes over the costs and burdens associated with having a family (Esping-Andersen, 1999).

Generalized linear mixed models – an extension of GLMs that account for nested, hierarchical, or multilevel data (Healy, 2001). To allow for grouped data to be analyzed this way, one or more extra error terms are added to account for the grouping variables (Healy, 2001). For example, an error term for the *j*th region will account for the variability between each country within the *j*th region. The intercept for the *j*th region will then be the model intercept plus the error for the *j*th region. The model's intercept and any other coefficients will be the fixed part of the model, and the extra error terms to account for grouping variables will be the random part of the model (Healy, 2001).

Generalized linear models (GLM) – regression models that allow for a variety of distributions. GLMs use a link function to define the relationship between the systematic and random components of the model (Waller & Gotway, 2004).

Global spatial autocorrelation – a summary of the spatial similarity between neighbors over the whole study area (Waller & Gotway, 2004).

Gross domestic product (GDP) – the gross value added by all residents a country's economy (The World Bank Group, 2017).

Local indicators of spatial autocorrelation (LISA) – look for areas of similar deviations from the overall mean, suggesting spatial similarity. LISA statistics detect and identify clusters within the data (Waller & Gotway, 2004).

Polygons – closed shapes with three or more sides and angles (Waller & Gotway, 2004).

Primary prevention – a means to protect against a disease before it reaches a human (Clark & Leavell, 1965).

Principal component analysis (PCA) – is a dimension reduction technique that groups themes together into factors to explain the maximum amount of variance in the data (Polit & Beck, 2012).

Specific protection – a means to prevent the causes of specific diseases before they reach humans, such as immunizations (Clark & Leavell, 1965).

Welfare spending – represented by social protection expenditure in this research proposal, welfare spending will be defined as the extent to which a country spends their income to reduce and prevent poverty, vulnerability, and social exclusion (International Labour Organization, 2017).

Welfare policy – policy related to the society's promotion of physical and material well-being for people in need (Oxford Living Dictionaries, 2018).

Welfare state – a country with a set of institutional structures where the state takes responsibility for the basic welfare of citizens, protecting them from risks, and advancing equal opportunities (Esping-Andersen, 1990; Esping-Andersen, 2009; Kolberg & Esping-Andersen, 1992; Korpi, 2001). Welfare state institutions redistribute material resources between people in various socioeconomic positions and life stages (Ferrarini, 2006).

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