Fall 9-13-2021

Making The Case to Improve the Availability and Reliability of Public Health Spending Data: An Examination of Preventive Care Expenditures among High-Income Countries from 2000 to 2019

Kristy Hayes

Making the case to improve the availability and reliability of public health spending data: An examination of preventive care expenditures among high-income countries from 2000 to 2019

by

Kristy Thottumkal Hayes

B.S., St. Joseph's University
M.A., Georgia State University

A Dissertation Submitted to the Graduate Faculty
of Georgia State University in Partial Fulfillment
of the
Requirements for the Degree

DOCTOR OF PUBLIC HEALTH

ATLANTA, GEORGIA
30303

APPROVAL PAGE

Making the case to improve the availability and reliability of public health spending data: An examination of preventive care expenditures among high-income countries from 2000 to 2019

by

Kristy T. Hayes

Approved:

Sarah Ann McCool
Committee Chair

Karen Nielsen
Committee Member

Susan Snyder
Committee Member

September 13, 2021

Acknowledgments

I would like to acknowledge the following individuals for their limitless support and encouragement in developing this dissertation. Drs. Sarah Ann McCool, Karen Nielsen, and Susan Snyder, who served as my dissertation committee, with special thanks to Karen for giving me a renewed appreciation in statistics; and Dr. Harry Heiman for his guidance when it was most needed.

I would be remiss to not acknowledge our current circumstances of living through a global pandemic. I am grateful to the dedication and bravery of first responders globally and public health champions who continue to fight the good fight.

I would also like to thank my family - my brother, Robbie, for making time to give me a lesson in the art of writing; my sister, Leena, and my parents who are my foundation; and my dear husband, Conor, for always believing in me.

Author's Statement Page

In presenting this dissertation as a partial fulfillment of the requirements for an advanced degree from Georgia State University, I agree that the Library of the University shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to quote from, to copy from, or to publish this dissertation may be granted by the author or, in his/her absence, by the professor under whose direction it was written, or in his/her absence, by the Associate Dean, School of Public Health. Such quoting, copying, or publishing must be solely for scholarly purposes and will not involve potential financial gain. It is understood that any copying from or publication of this dissertation which involves potential financial gain will not be allowed without written permission of the author.

Kristy T. Hayes

Signature of Author, Kristy T. Hayes

ABSTRACT

Making the case to improve the availability and reliability of public health spending data: An examination of preventive care expenditures among high-income countries from 2000 to 2019

By

Kristy T. Hayes

September 13, 2021

Background: Averting the onset of disease or detecting disease early through preventive care can improve overall population health. It is well recognized in the literature that preventive care has been historically undervalued and underinvested, despite a growing body of evidence on the impact of total health funding on economic growth and health outcomes. The relationship between health outcomes and public funds spent on prevention has not been thoroughly investigated. The purpose of this dissertation is to examine the relationship between government funds spent on preventive care and health outcomes. To do this, an examination of preventive care expenditures was conducted using data from countries in the Organization of Economic Cooperation and Development (OECD).

Methods: A three-phased methodological approach was used to gather evidence on preventive care expenditures. The first phase was a descriptive analysis of preventive care spending. The second phase investigated four paired relationships between preventive care expenditures and health outcomes among OECD countries. A cross-correlation function was

used to examine the temporal association of these relationships from 2000 to 2019. Lastly, economic and demographic factors were applied to delineate between country differences.

Results: On average, OECD countries spent approximately 3% of total health funds on preventive care. Ten countries had positive cross-correlations, five countries had negative cross-correlations, and the remaining 15 had inconclusive results. This dissertation could not determine a relationship between health outcomes and public funds spent on preventive care.

Conclusion: These results indicate the importance of high-quality data and consistent reporting to build evidence on government expenditures on public health on health outcomes. Without credible and reliable health spending data, it is challenging to study the possible relationship between preventive care spending and health outcomes. Establishing a global minimum standard of public health programs can serve as a key input to developing benchmarks to meet a basic public health standard. This may offer a pathway for more consistent, reliable and regular reporting of expenditure data. Lastly, there is a need for available, accessible, and actionable expenditure data from economically and geographically diverse countries to strengthen fiscal capacity.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

ACRONYMS AND SYMBOLS

ACF	Autocorrelation Function
ADF	Augmented Dickey Fuller
AR	Autoregression
ARIMA	Autoregressive Integrated Moving Average
DAH	Development Assistance for Health
GDP	Gross Domestic Product
HALE	Health-adjusted Life Expectancy
HCI	Human Capital Index
LE	Life Expectancy
MA	Moving Average
OECD	Organization of Economic Co-operation and Development
PACF	Partial Autocorrelation Function
PPP	Purchasing Power Parity
QALY	Quality-adjusted Life Years
SHA	System of Health Accounts
USPSTF	United States Preventive Services Task Force
WHO	World Health Organization
X^2	Chi-square
τ	Tau
ρ	Ro

Introduction

Background

Governments have a responsibility to promote health and prevent disease. The need arises as a result of market failures, ubiquity of unhealthy products, or inequitable public policies that adversely affect health, among other reasons.[1] Governments are responsible to protect the population's health based on three accepted norms.[2] Government's first responsibility is to disseminate free and transparent information to promote healthier lifestyles, such as front-of-pack labeling on food items or cigarette packages.[2] The second is to protect people from harm caused by others, such as impaired driving or second-hand smoking, which can lead to changes in social norms.[2] The third responsibility is to use their authority to protect entire populations regardless of socioeconomic status, like regulating air quality or eliminating artificial trans-fats from food.[2] These obligations aim to prevent diseases and disabilities as a result of health factors or social determinants of health.[3] Fulfilling these obligations depends on political will and funding, but both factors can fluctuate with election cycles and the political climate because, despite the population level gains, the individual-level benefits are perceived to be too small.[4]

Governments can measure, report, and monitor health spending to become better stewards of public funds and ensure sustainability of the health system.[5] Fiscal stewardship of public funds is the ability to maintain the viability of the financial condition of effective and efficient public

health functions, institutions and systems, and articulate their financial conditions in terms that are familiar to decision makers and the public.[5,6] Ensuring sustainability is the ability to maintain and manage service coverage from local to national levels. This is critical during a surge for resources during natural and humanitarian emergencies.[5,6] To achieve fiscal stewardship and sustainability, a uniform chart of accounts and standard financial management practices and systems are essential to validate the magnitude and impact of public health actions. This allows health leaders to be sound fiscal stewards and ensure a strong public health system.

An internationally accepted standardized framework called the System of Health Accounts (SHA) was developed by the Organization of Economic Co-operation and Development (OECD) in 2000 to support countries in accounting for expenditures in health.[7] Founded in 1961, the OECD consists of 38 mostly high-income countries, representing 80% of the world's trade and investment.[8] The OECD collaborates with other member countries to set standards and support policy development to strengthen economies and to establish more equitable societies.[9] The SHA is one of the tools established by the OECD to account for health expenditures in support of its mission and goals. It is considered the gold standard for monitoring health spending because it provides a governance framework to report health expenditures from diverse and complex health systems.[10] Data on health expenditures are easily accessible and regularly updated from OECD countries. These countries are economically and demographically similar and have advanced fiscal capacity.[11] Expenditure data from low- and middle-income countries are hosted online but are in formats that do not allow for easy retrieval and are not regularly reported or updated.

Before the emergence of SARS-CoV-2, the causative agent of COVID-19, the average annual total health expenditure across OECD countries was approximately 8% of GDP and 2.8% of annual health expenditures were spent on prevention.[1,12] Though not a formal recommendation, the literature suggests that countries should spend 5% of their GDP on health.[13,14] However, none of the normative setting agencies, like the World Health Organization (WHO), have formally adopted this approach.[13] A recognized optimal or minimum level of funding for preventive care is not currently available or recommended in the literature.

Purpose

While it is well recognized in the literature that public health has been historically undervalued and underinvested, the relationship between government spending on preventive care and health outcomes has not been thoroughly investigated.[15–17] The government has the responsibility to prevent disabilities and diseases through programs, policies, and strategies for the sake of public health protection.[2] Therefore, the purpose of this dissertation is to build evidence on the relationship between government spending on public health and health outcomes. This dissertation does not account for private expenditures or individual out-of-pocket expenses for preventive care services. This study uses health expenditures reported by OECD countries following the SHA framework, which has its limitations in portraying spending in public health. The SHA uses the traditional definition of prevention of averting injuries, diseases, and their complications. This definition excludes the evolution of public health in its 3.0 era which is inclusive of cross-sectoral collaboration to address social determinants of health.[18] While SHA circumvents the challenges to account for funds that address social determinants of

health, the SHA definition of preventive care expenditures also limits the depth of public health practice.[1] Because expenditure data that characterizes the breadth of public health and represents an array of countries is not currently available, this study attempts to make inferences on public health spending using existing data to examine the extent of government expenditures on prevention and its relationship with health outcomes. As a result, preventive care, government, and public health spending or expenditures are used synonymously throughout this paper. This study uses descriptive analyses to examine results from a cross-correlation function. This function investigated the temporal association between preventive care expenditures and health outcomes among OECD countries from 2000 to 2019.

Undertaking this analysis provided a process to consider the reasons for the limited empirical analysis on public health expenditures. This could be the result of the complex multisectoral nature of health promotion and disease prevention activities. The prevailing definition of prevention addresses social determinants of health, which are social and economic factors that influence health.[3,18–20] Programs that address social determinants of health inherently partner across sectors.[3] Extracting funding levels or determining sources of funds can be overly complicated and difficult to collect if multiple stakeholders are involved. Another possibility for the lack of robust evidence on public health expenditures is the time lag from prevention to population impact.[21] Because the benefits of preventive measures accrue over a long period of time, it is challenging to attribute any improvements in population health or health outcomes to them. Having available and reliable expenditure data provides the basis to translate the

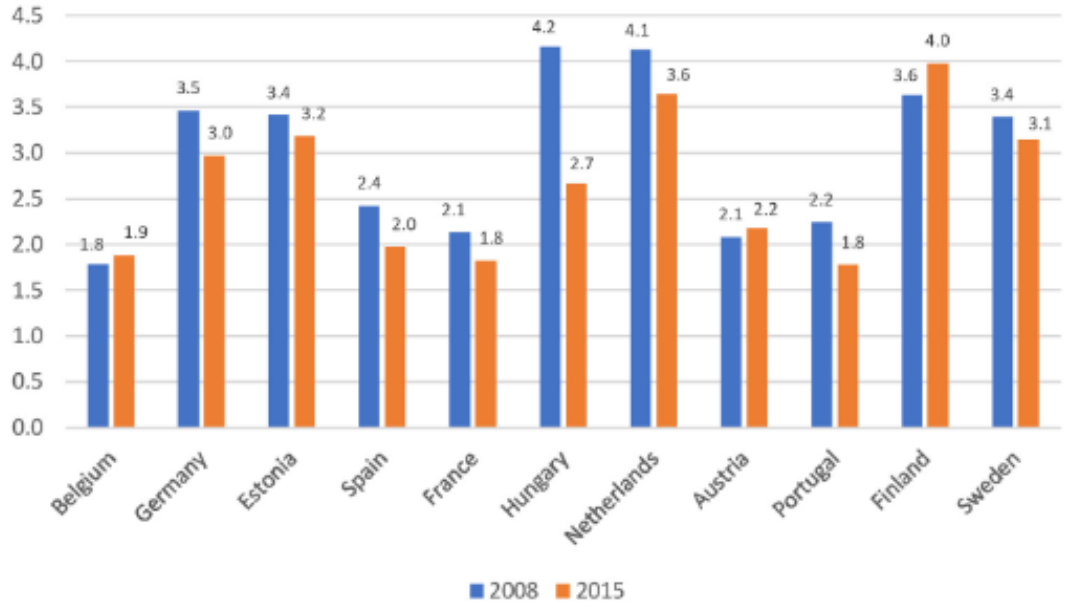
magnitude and impact of public health actions which can be used to justify sustainable and predictable funding.

Significance

Prevention measures are critical because it is inevitable for a portion of the population to develop a disease, whether a result of genetics (a direct pathway) or social determinants of health (an indirect pathway).[15] The public has the responsibility for their own health, but the role of government is to implement public health action to make the healthy choice the default option.[2]

It is especially difficult for governments to earmark funds for prevention during an economic crisis. For example, during the Great Recession, 2007 to 2009, high-income countries put into place austerity measures making significant cuts to public health budgets and condensed or closed public health offices.[11] Figure 1 compares preventive care spending as a percent of total health expenditures among European countries in 2008 and 2015. In eight of the 11 countries, there was a decline in the share of funding dedicated to prevention. This was a result of a tradeoff in funding public health and other industries to boost economic growth.[11] Similarly, U.S. prevention spending struggled to recover from budget cuts during the Great Recession in which it was reduced from 3.2% in 2002 to 2.7% of total health spending in 2014.[22]

Figure 1. Preventive care as a percent of current health expenditures, 2008 and 2015[11]



The emergence of COVID-19 revealed fault lines within public health. Persistent underinvestment in public health structures, capacity, and resources as well as mismanagement brought on significant challenges to control the pandemic. It impeded the implementation of primary and secondary prevention measures to properly and rapidly screen and surveil the population for the virus.[23] The lack of a strong public health infrastructure may have contributed to the misinformation regarding prevention measures, like the use of face masks, social distancing, and COVID-19 vaccine hesitancy.[24,25] The aftermath of the COVID-19 pandemic can usher in a sea change for public health. It can be the catalyst to significantly fortify public health in its mission to prevent and control chronic conditions, mitigate the susceptibility to infectious diseases, and improve capacity for emergency response.[26] But for a meaningful upgrade of its capacity and infrastructure, public health needs to be impervious to budget cuts. Providing the economic and epidemiological justification can influence policy makers to secure sustainable and predictable financing for public health.

Economic evidence may offer a rationale to safeguard public health from being snubbed from prolonged sustainable public funding. The COVID-19 pandemic exposed how public health and the economy are intertwined. The economic disruption from the pandemic has had a global impact. Some models estimate the total impact of lockdown restrictions at approximately 9% of the global GDP. The economic loss in the U.S. is approximately $16 trillion or more than twice as much as the money spent on all wars, including in Afghanistan, Iraq, and Syria, the U.S. has fought since September 11, 2001.[27] The global cost of premature deaths from COVID-19 is approximately $5.9 trillion, with high-income countries bearing most of the burden of at least $3,700 per person.[28]

Investing in preventive care can make an impact beyond geopolitical borders. The pandemic provides an opportunity for high-income countries to recognize their own ineffectiveness in preventing, detecting, and responding to highly communicable diseases, like COVID-19. In OECD countries, infectious diseases account for a small share of the overall disease burden, but they can reconcile their failure to adequately control the virus because of underinvestment in public health. In doing this, they can achieve their goals of stimulating economic progress and recommending equitable social policies in low- and middle-income countries.[8] OECD countries have the platform to encourage the adoption of public health prevention policies, practices, and systems to combat emerging infectious diseases, interrupt the growth of chronic conditions, and prepare for the next pandemic.

The COVID-19 pandemic laid bare the fragility of public health systems globally. With chronic underfunding, politicization of public health, and resulting economic ramifications, it is clear there is a need for further analysis of prevention expenditures and outcomes. Linking monetary data with non-monetary data provides an opportunity to generate information on preventive care spending and the implications for allocating scarce resources. This dissertation aims to build evidence on the relationship between preventive care spending and health outcomes. This analysis attempts to provide the basis in supporting the case for available and reliable public health spending data.

Literature Review

Background

Population health and health spending have an iterative relationship with human capital, individual income, and workforce productivity.[29] The seminal theory on the demand for health, developed by Michael Grossman in 1971, modeled health as a commodity which naturally depreciates over time with age.[30] The model posits investments in health increase the health stock of individuals. Investing in someone in poor health yields a greater marginal benefit relative to healthy individuals because they have more health to gain. Grossman assumes that more education shifts marginal benefits upwards so that the better educated have more time being productive and less time in poor health. From this theory, improvements in health strengthens workforce productivity and positively influences economic growth, thus sustaining spending on health increases health stock.[30]

The theory is supported by research by Bloom and colleagues (2019) that studied the effects of health on economic growth based on wages.[31] Their results indicate that a 10% increase in adult survival rates is associated with a 9% increase in labor productivity with health status influencing differences in wages between countries. Bloom (2004) also estimates a one-year improvement in a population's life expectancy increases GDP by 4%.[29,32] Their findings suggest public health

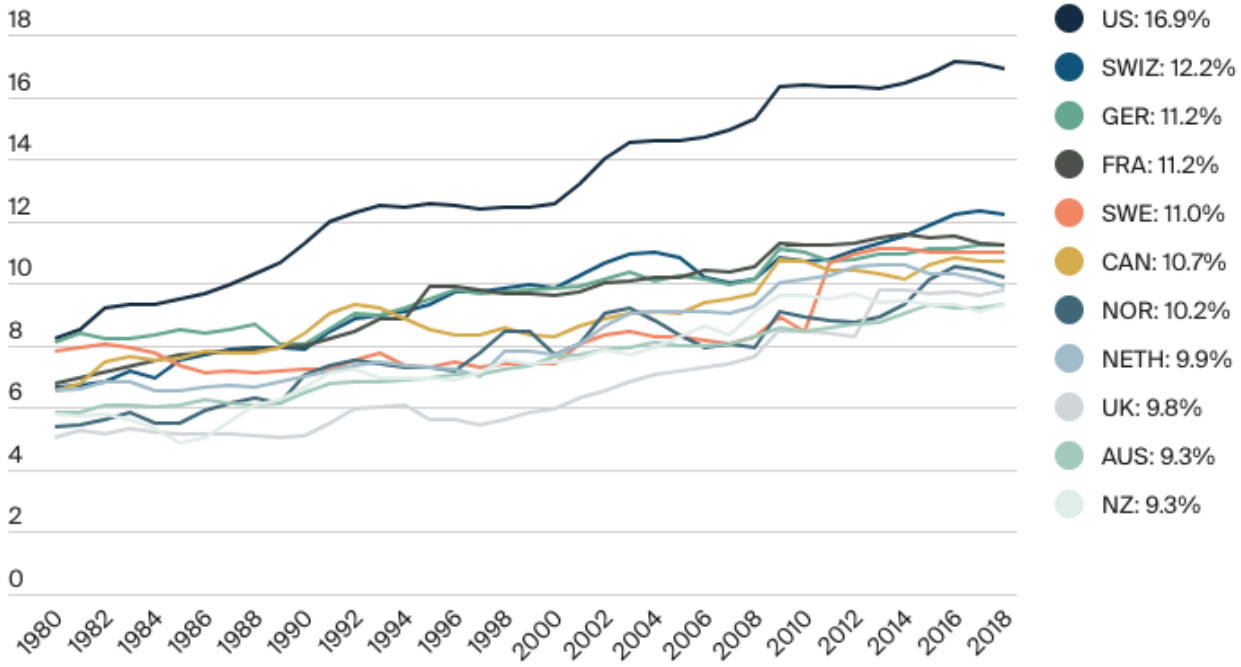
prevention measures contribute to economic development. This incentive of improving overall economic growth should motivate governments to want to invest in public health.[29]

There is a constant struggle to advocate for public funds within health, like between preventive and curative care, or between health and social programs, such as education or social protection. This competition is a zero-sum game since preventing a disease contends for the same limited resources that address social determinants of health or treatments for illnesses.[17] Securing ongoing and predictable government support for preventive care is often mired in politics and can be exacerbated by election cycles. Appealing to public officials to invest in public health is difficult because the cumulative benefits from public health interventions occur over time and across administrations.[21] It is also challenging to count and report the number of deaths or disabilities averted as a result of a public health intervention.[21] This makes it difficult to attribute its benefit to the intervention. For example, fluoridation in drinking water contributes to the reduction of tooth decay.[21] But it is difficult to credit water fluoridation to good dental health or to count the number of people who benefit from it as a result of other factors supporting good dental health. [21] Consequently, public health budgets and political will stagnate, leading to chronic underinvestment in the health system for preventive care.

High overall government spending in health does not always correlate to better health outcomes. It is well documented that the U.S. spends more on health than any other country but continues to produce poor health outcomes.[33,34] The Commonwealth Fund's comparison of health expenditures in countries in the Organization of Economic Cooperation and Development

(OECD) found that the U.S. spends more than twice as much on health than any other OECD country but has worse health outcomes.[35] The most recent survey suggests that the U.S. has the lowest life expectancy, highest burden of chronic disease, its obesity rate is twice that of the OECD average, and the U.S. has the highest number of preventable hospitalizations.[35] Figure 2 presents health expenditures as a percent of GDP among OECD countries. A cross-sectional analysis using 2016 data found that the 10 next highest income countries spent a range of 9% (Australia) to 12% (Switzerland) of their GDP on health. The U.S. is an outlier, spending nearly 17% of its GDP in 2018 on health, due to high administrative costs and pharmaceutical spending.[33]

Figure 2. Health Spending as a percent of GDP among OECD Countries[35]



Note: GDP is adjusted for differences in cost of living, legend shows 2018 data

Health expenditure as a share of GDP and per capita are two measures that summarize the overall availability of funding for health. However, health expenditure as a portion of GDP may

have a distorted appearance due to external factors. In a perspective piece, Brian Turner (2018) explains this distortion from two angles based on an experience in Ireland in 2008 and 2015.[36] In 2008, in the midst of the Great Recession, it appeared that Ireland spent more on health as a proportion of GDP compared to other OECD countries. But the measure was misleading, as it was a result of a contracted economy and not because Ireland increased their health spending.[36] In 2015, because their GDP increased by 26%, health spending as a proportion of GDP declined, despite a 9% increase in health spending. Health spending as a share of GDP may not provide an accurate picture on the state of health expenditures in a country and could have implications on health equity.[37] A per capita measure of health spending is a better indicator of health expenditures, translated in purchasing power parity (PPP), because it regards population size and mitigates externalities that could distort between country comparisons.[36] The average per capita health expenditure among OECD countries was US$3,994 in 2018.[38] The U.S. remains an outlier with a health spending per capita of over US$10,000 that same year. Other high-income countries like Canada, Germany, France, and Japan spend 50% less than the U.S. per capita health spending.[38]

Given the tightening of public funds as a result of the Great Recession, studies emerged to assess health spending and return on investment in health. Despite growth in health spending in 2015 and 2016 of approximately 3.3%, there was a significant reduction in overall per capita spending in OECD countries by an average of 2.0% in 2017.[38] This is particularly relevant in countries hardest hit by the Great Recession. Austerity measures, which resulted in sustained annual reductions in overall health spending in subsequent years resulted in unintended negative

effects on the public health system in many European countries.[39] Declines in health spending in high-income countries have been associated with stunting economic growth.[39–41] In 2017, Masters and colleagues (2017) review of return on investments of public health interventions in high-income countries found that any reductions to public health budgets at the national level in the form of savings represents a "false economy".[4] This is because any short-term economic advancements will falter driven by future costs of a weakened health sector and lost economic productivity.[4]

Publications on cross-country comparisons of health spending are typically based in OECD countries. This is because expenditure data are publicly available, easily accessible, and updated regularly. OECD countries follow the System of Health Accounts (SHA), a standard framework to report health expenditures. The SHA links the pathway of health expenditures by the financers (who pays), health providers (who uses the funds), and the purpose for the funds (what is consumed).[7] It accounts for consumption of health as curative care, rehabilitative care, long-term care, ancillary services, medical goods, preventive care, governance and health system administration, and other health services. The proceeding section provides an overview of the literature on total health spending and its relationship on various measures of health outcomes. This is followed by a review of the available literature on preventive care spending.

Health Spending

Cross-country comparisons of health expenditures assess the efficiency in spending public funds. It examines whether countries spend less and achieve the same health outcomes or spend the same level and achieve better health outcomes.[42] Researchers use a number of indicators as a proxy for health, such as death statistics like mortality rate, infant mortality, or years of life lost (YLLs).[42] It can also be expressed as longevity indicators like life expectancy (LE), years lived with disability (YLDs), disability-adjusted life years (DALY), or healthy adjusted life expectancy (HALE).[42]

A limited number of studies use HALE as a proxy for health outcomes. HALE is a summary measure of the average number of healthy years lived at different ages in a given country.[43] It is calculated using life tables and accounts for disease prevalence that lead to death and disability. The Global Burden of Disease use HALE as their outcome measure to account for the severity of a wide range of health states.[44] It is also a key indicator for WHO's impact measurement to monitor inequality and improve equity.[45] Poullier and colleagues (2003) studied the relationship between health spending and HALE in 191 countries.[46] They found that the range of health spending and HALE vary among countries which suggests that the level of funding and the efficiency in which funds are spent could affect health outcomes.[46] These results A Canadian analysis of health expenditures from 1980 to 2012 found that health spending per capita increased between 1.0% to 2.2% per year, but HALE, on average, increased 0.3% during that

time period.[47] This indicates that the yearly incremental increase in spending produces little improvements in health outcomes.[47]

LE is a common measure of health outcomes to assess health systems and resources. Results from studies examining this relationship are mixed and, at times, contradictory on the role health spending plays in improving LE. Jaba and colleagues (2014) found a significant positive relationship between health expenditures and LE in high-income countries.[42] They suggest that differences in health financing systems, like a national health system compared to multiple insurance schemes, explain discrepancies in health outcomes between countries. Deshpande et al. (2015) also found a significant positive correlation between health expenditures and LE in developed countries, but this correlation was not found among developing countries.[48] They postulate that health spending in developed countries may be more efficient, whereas the quality of healthcare could matter more than funding levels in developing countries. Obrizan and Wehby (2018) analyzed health expenditure per capita in 175 countries and found that countries with lower LE have the greatest need for increased health spending.[49] Improvements in mortality have the potential to strengthen economic growth by inherent gains in human capital and therefore increased health spending in countries with low LE will see greater returns in longevity.[49] Similarly, Cutler and collaborators (2006) assessed the value of increased spending in health on gains in LE from 1960 to 2000 in the U.S.[50] They found that LE rose and the amount spent on health from birth increased from $14,000 to $83,000 in 1960 to 2000, respectively.[50] It suggests that the benefits received by the population are worth the increase in spending with LE increasing 6.97 years during the study period.[50]

Other studies allude to a more ambiguous relationship between health spending and LE. Nixon and Ulmann (2006) analyzed the relationship between health expenditures per capita as it relates to LE at birth and infant mortlity.[51] Their results indicate that health spending contributes to the reduction of infant mortality but marginally contributes to LE. Aísa and colleagues (2014) studied the influence of public and private health expenditures as a share of GDP on LE.[52] Their results were inconclusive because public health spending was significant at the 10% level of significance only when fixed effects were considered. They recommend taking into account the type of health system when assessing spending on health outcomes. Ven den Heuvel and Olaroiu (2017) studied the relationship between LE and spending as a share of GDP in health, education, and social protection controlling for the quality of healthcare system among 31 European countries.[53] Their results indicate that while all three types of expenditures have a statistically significant positive correlation, social protection spending contributes to longer LE more than health spending. Baltagi et al. (2012) found that health spending has a significant, but mild, effect on LE among OECD countries.[54] They suggest that the rise of health spending is driven by advances in medical technologies. Van Baal et al. (2013) denotes the difficulties in demonstrating the link between LE and health spending as a result of health system complexities and the inability to quantify the effects of technologies in advancing LE.[55] Indeed, advances in medical technology can contribute to increases in LE.[50,56] Technological innovations in curative care lead to long LE and an aging population as a result of reductions in mortality from cardiovascular disease and deaths in infancy.[50,56] Aging and long LE are seen as drivers for increases in health spending in developed countries, driven mostly by long-term care services.[53]

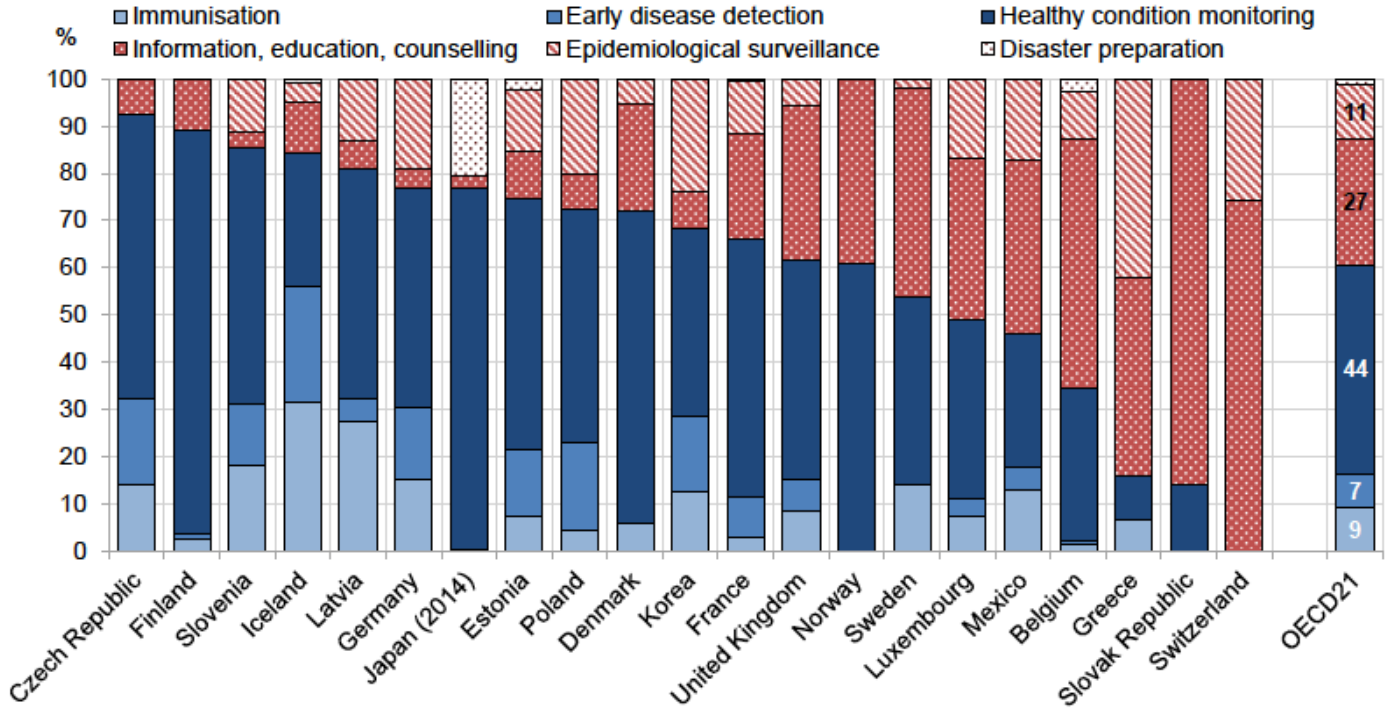
Most research on health spending focuses on total health expenditures and, of those, cross-country analyses are typically on high-income countries or exclusively on the U.S. Very little empirical research has been done to examine preventive care expenditures. The following presents economic and epidemiologic analysis of public health prevention and an exploration that may explain the deficiency of robust analysis.

Preventive Care Spending

A 2015 analysis found that OECD countries spend less than 3% of total health expenditures on preventive care and 60% on inpatient and outpatient curative care services.[1,38] Figure 3 illustrates the allocation of funds across preventive care among OECD countries in 2015. The variation is likely due to different measurement and accounting practices. More preventive care funds are spent on these individual-level services (60%) than population-based services (40%), though it is well established that population-level interventions have a greater impact than individualized efforts.[1,35] Of the funds spent in clinical preventive services, a large portion were allocated to activities that lack cost-effective evidence.[1] OECD countries spent over 40% of expenditures on healthy condition monitoring programs, which include wellness checkup visits and dental exams. These interventions have little evidence on their cost-effectiveness.[1] The absence of high-quality evidence implies that less should be spent on these programs or alternatively high costs could contribute to the large proportion spent on these programs.

Conversely, in 2015 countries spent less than 10% on immunization and screening programs, which are considerably more cost-effective.[1]

Figure 3. Prevention expenditure by service type among OECD countries, 2015[1]



With preventive care, there are epidemiologic and economic ramifications. The allocation of limited resources in health is essentially a policy issue that needs to weigh both sides. Due to limited public resources, there is an inherent tradeoff in the available funds allocated between preventive and curative care.[17,57] Because prevention is not always 100% effective in part due to social determinants of health or genetics, a portion of the population will ultimately develop preventable diseases.[15] Therefore, funds have to be allocated between curative care to treat an illness and preventive care to avert the disease.[17] Using the OECD expenditure data, Wang (2018) suggests a nonlinear relationship exists between preventive and curative care

expenditures as it relates to economic growth.[58] The relationship derives from the law of diminishing returns. Though prevention can improve health outcomes and workforce productivity—which, in turn, stimulates economic growth—too many resources dedicated to prevention may crowd out the available funds for curative care.[17] There is a point where too much funding for preventive care can reduce health outcomes overall because of its detrimental effect on spending for therapeutic innovations.[17] Consequently, Wang (2018) recommends an optimal level for prevention and curative care of 0.44% and 10.96% of GDP, respectively, to sustain economic growth.[17] This recommendation is not widely implemented. For example in a study by Ethgen and colleagues (2018), which estimated that the proportion spent on prevention was between 0.07% and 0.41% of GDP among seven OECD countries.[59] They acknowledged the limitations associated with OECD expenditure data relating to incompleteness and reliability of the cost components, and lack of consistent reporting. Additionally, Wang's recommendation is for sustaining economic growth, but no empirical research to date exists on the optimal or minimum level of preventive care to improve population health.

From an epidemiological standpoint, there is evidence for spending resources on public health. Between 1985 and 2012, seventeen articles were published studying the relationship between total public health spending and various health outcome measures in the U.S.[60] The evidence suggests that increases in spending lead to improvements in population health outcomes. For example, in an analysis of U.S. public health departments between 1993 and 2005, Mays and Smith (2011) found a positive relationship between public health spending and preventable deaths.[16] They saw that an increase of 10% in spending was associated with a 6.9% decrease in

infant mortality and 3.2% reduction in cardiovascular disease-related deaths.[16] Similarly, Ransom and colleagues (2012) found a positive association in improving childhood immunization coverage rates when state and federal levels align financing to local needs.[61]

Several studies and commentaries underscore the paradox of the value of preventive care and its expectation to deliver cost saving.[57,62,63] Louise B. Russell reviewed the cost-effectiveness of a wide range of prevention activities and estimated 80% of preventive services add to medical spending instead of achieving any cost-savings.[57] Frequency of care is one reason why preventive care adds to medical spending. For example, cervical cancer screening on an annual basis increases medical costs, but healthy women screened every 3-5 years is cost-effective compared to no screening.[57] By following approved guidelines for preventive clinical services does may not add to medical spending but also does not achieve cost savings. Targeting individuals at-risk who are more likely to benefit from prevention is another determinant of cost-effectiveness.[57] For example, increasing the frequency of screening young men who have sex with men for HIV to every 3 months compared to existing patterns of HIV screening has been shown to have an incremental cost effectiveness ratio of $4,500 per quality-adjusted life years (QALY), which is considered highly cost-effective, and gain 4.28 quality adjusted years.[64] Prioritizing cost-effective prevention activities and following evidence-based recommendations and guidelines from groups like the U.S. Preventive Service Task Force offer the ability to invest in prevention to reach those most likely to benefit.

From an economic perspective, the cost-effectiveness, and the less likely case of cost-saving, preventive care interventions depends on the intervention's effectiveness and implementation strategies, including targeting the population most likely to benefit.[57]From an epidemiologic perspective, preventive care overall is effective in improving population health. Some clinical preventive services, like childhood immunizations, smoking cessation, and counseling on daily aspirin-use among high-risk patients with cardiovascular conditions, have proven to do both – improve health and report a net savings.[65] Several articles state that prevention efforts are both undervalued and underinvested.[15,16,21,66,67] For example, tobacco cessation programs have proven to be effective interventions and reduce long-term costs. However, between 2008 to 2011, spending on tobacco cessation programs among states in the U.S. represented 13% of the CDC's recommended funding levels.[68] Funding for state and local health departments in the U.S. have declined by 17% over a decade.[69] However, amid the COVID-19 pandemic, the allocation of over $300 billion supplemented public health agencies to prevent infections and control its spread.[70] But the challenge of effectively and efficiently spending funds surfaces for agencies that have faced prolonged underfunding.[70] Consequently, there has been calls for mandatory funding from the government replacing annual discretionary appropriations in which public health agencies are vulnerable to budget cuts.[71] Whether public health receives mandatory funds or supplemental funding, a robust tracking system is needed to help build efficiencies in spending, develop good governance, and become strong fiscal stewards of public funds. [69,72] Without credible and reliable spending data undermines the development of evidence supporting prevention spending and the interplay between their value and investment.[16]

Conclusion

The societal benefits of public health prevention efforts echo throughout high-income countries. Successes in immunizations and water, sanitation and hygiene infrastructure have drastically reduced the burden of infectious diseases in high-income countries. Evidence for this success is most notable in the reduction of infant mortality falling from 3.3 to 0.6 deaths per 1,000 live births from 1960 to 1995 in the European Union.[51] However, more can be done within health systems and through public policies to promote healthier behaviors, reduce noncommunicable diseases, and safeguard for the next pandemic.

The current annual average of approximately 3% of total health spending on preventive care among OECD countries is relatively small considering its cost-effectiveness and societal benefits.[1] Chronic underinvestment and underutilization of preventive care indicates that governments may have normalized a reactionary response to health preferring to treat instead of preventing disease or disability. Governments have a tendency to invest in treatment over prevention due to the immediacy of results in curative approaches.[73] However, the current level of spending in preventive care may be untenable to manage the burden of chronic diseases that high-income countries are facing and the recurrent threats of emerging infectious diseases.

While there is a growing body of evidence on the relationship between overall health expenditures and health outcomes, albeit the direction of the relationship is ambiguous, the literature on preventive care spending and its relationship with health outcomes remains elusive.

This might be a result of the challenges to account for preventive care spending across multiple sectors, the failure to achieve cost-savings, or lack of evidence on the time lag for prevention to affect the population. The link between population health and preventive care spending requires more in-depth research to inform policy makers on the health status of the population and performance of health systems. This dissertation attempts to bridge that gap and offer evidence that addresses funding and its contribution to preventative care. In doing so, this study makes the case for the need for reliable and available spending data to make a robust investigation of preventive care expenditures.

Methodology

Introduction

The approach for the study is exploratory to build evidence for future work that can bring in more complex statistical techniques if more higher quality data is available. The following describes a three-phase methodological approach. The first phase is a descriptive analysis of preventive care spending to illustrate the share of healthcare-related spending dedicated to prevention. Second, this study hypothesizes a positive association between past government preventive care expenditures and health outcomes at the national level. This was tested using a discrete time series cross-correlation function which retrospectively examined the time lag during a 20-year period. The cross-correlation examined four paired relationships between preventive care spending and health outcomes Third, the differences between countries were examined using economic and demographic factors.

Country Selection

The Organization of Economic Co-operation and Development (OECD) consists of 38 high- or upper-middle income countries across the globe and was established to strengthen cross-country collaboration and promote sustainable economic growth policies.[12] OECD member

countries are presented in Figure 4.[9] OECD countries were selected for this analysis because expenditure data is publicly available, easily accessible, and regularly updated. Preventive care expenditure data from low- and middle-income countries during this study's period of analysis were unavailable or not easily retrievable. Accordingly, this study examined preventive care expenditures from OECD countries.

Figure 4. OECD member countries

OECD member countries:
Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Israel, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

Analysis

Given the nascent area of research in preventive care spending, this dissertation presents additional evidence to meaningfully study funds dedicated to health promotion and disease prevention. In 2017, the OECD released a report summarizing preventive care expenditures among OECD countries from 2005 to 2015.[1] The first phase of this analysis draws its motivation from this previously released report. A selection of their analysis was reproduced and extended to this study's period of analysis from 2000 to 2019.

The descriptive analysis includes the change in preventive care expenditure per capita compared to the annual economic growth rate and total health spending from 2000 to 2019. Using the most recent available year of data, the proportion of funding allocated to preventive care and its allocation to health promotion and disease prevention activities was assessed. Finally, prevention expenditure per capita and as a share of health expenditure by country in 2019 was illustrated. It is important to note that the number of countries varies between graphs as a result of inconsistencies within and between countries reporting preventive care expenditures.

The second phase was a discrete cross-correlation function which measures the temporal similarity between two independent time series variables.[74] Similar to the Pearson product-moment correlation coefficient, it measures the strength and direction of the relationship between two variables.[74] Often one series is shifted so that one variable lags or leads another variable. The lag or lead that has the best alignment results in the peak cross-correlation value.[74]

To illustrate, Figure 5a adapts Dean et al. (2016) description of a cross-correlation function.[75] It presents two hypothetical time series variables representing health outcomes and expenditures over 50 observations in length. These variables have seemingly no apparent relationship. Shifting the spending variable to the left achieves alignment by lagging health outcomes. A lag of five time periods maximizes the pairwise correlation as shown in Figure 5b. This means that both series increase and decrease together after five time periods, resulting in a strong positive cross-correlation.[75]

Figure 5a. Two independent time series variables [75]

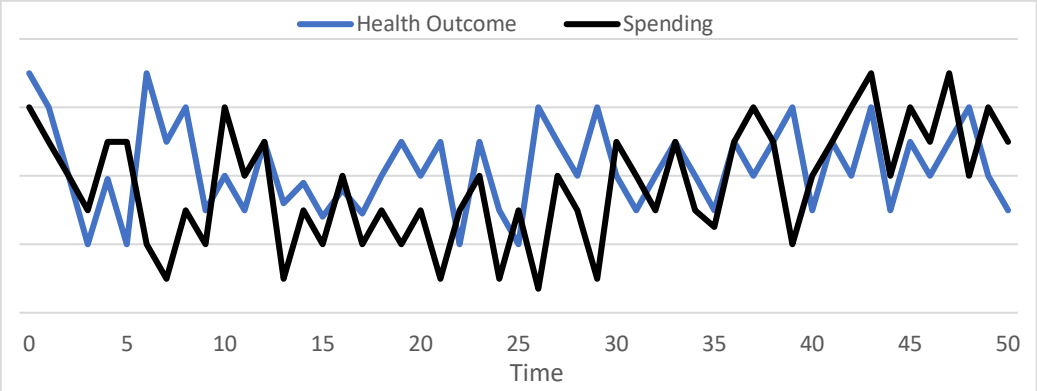
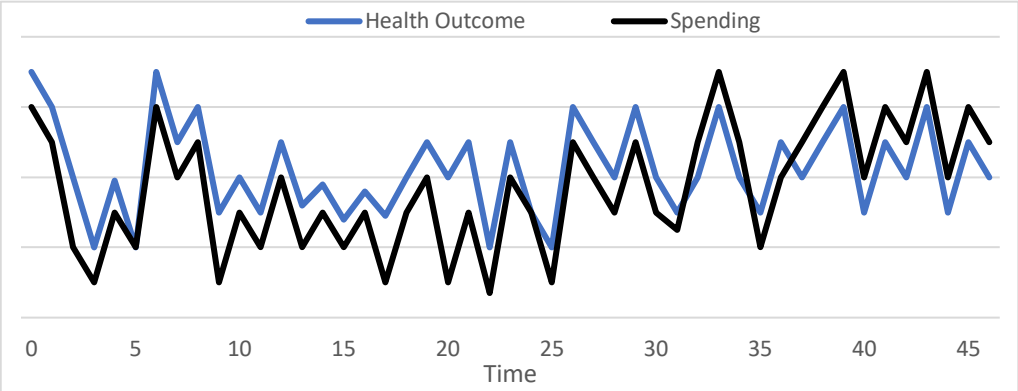


Figure 5b. Aligned at maximum cross-correlation, lag of 5 periods [75]



This procedure was used in this analysis to estimate the time-lagged relationship between preventive care spending and health outcomes from 2000 to 2019. A lagged association was considered because of the period needed for prevention measures to affect the population. The cross-correlation function examined four paired relationships between two health outcome measures and its relationship with two preventive care expenditure measures. Health outcomes were expressed as life expectancy (LE) and health-adjusted life expectancy (HALE). Preventive care spending was examined as a share of GDP and as a per capita measure.

The cross-correlation function was conducted in SAS 9.4. As a result of a large number of missing values, eight countries were not included in this analysis given the restrictions in SAS. Their inclusion would compromise the accuracy of results due to a small sample size. The following countries were excluded from this analysis: Chile, Colombia, Costa Rica, Israel, Ireland, New Zealand, Turkey, and the United Kingdom. The remainder of the analysis consisted of 30 OECD countries. Approximately 10 countries had four missing values or less, which occurred in the beginning or end of the study period. In these cases, missing values were excluded from the analysis.

Before conducting cross-correlation, the data is required to have stationarity and no autocorrelation.[76,77] Stationarity occurs when the mean and variance are constant over time.[76,78] Autocorrelation occurs when the time series variable has an association with a lagged version of itself. This can cause a spurious correlation between two independent time series variables.[79] An amended Box-Jenkins approach was used to estimate parameters for each variable to test and

correct these conditions. This strategy is commonly used in time series modeling that features the identification, estimation, and diagnostic checking of independent and dependent time series variables. [80,81]

Autocorrelation was checked using the Durbin-Watson test, which is typically used to test for autocorrelation in time series data. The test statistic provides a value between zero and four and the closer the value is to two, the data series is not autocorrelated.[82] Results from the Durbin-Watson test for the two spending measures and two health outcome measures for each country can be found in Appendix B. Conclusions were made based on a combination test statistic's value being close to two with a significant p-value of .05 or less and visual inspection of the histogram and QQ plots. All health outcome and prevention spending measures had autocorrelation. A pre-whitening process is done automatically in SAS which corrects autocorrelation.

The augmented Dickey Fuller (ADF) test was used to check for stationarity.[76,81] This is a commonly used unit root test for stationarity where the alternative hypothesis suggests the presence of stationarity. Results of the ADF test are presented in Appendix C showing the test statistic, tau, (τ) and p-value. Conclusions were based on the p-value of τ and trends greater than .05, visual inspection autocorrelation function (ACF), and partial autocorrelation function (PACF). All variables were found to have non-stationarity.

Each variable was differenced to correct non-stationarity. Differencing removes the value from the previous time period to obtain sequential changes in time.[76,77] If the p-value of chi-square

(X^2) is greater than .05, it suggests differencing does not reject the white noise hypothesis and the data has stationarity.[80] The white noise hypothesis tests whether the autocorrelation of the series, up to a certain number of lags, has information to model. [80] If lags are significantly different from zero, then no further modeling is needed and suggests stationarity. Visual inspection of the ACF, PACF and trend line was also examined to verify the results of the p-value of X^2. Approximately 28 variables needed further modeling, and all other variables resulted in stationarity as a result of differencing. Diagnostic results presenting the p-value of X^2 can be found in Appendix D.

The Box-Jenkins approach for variable estimation was used for the time series that required further modeling. Parameters were estimated using conditional least squares estimation to specify autoregression (AR), moving average (MA), or combined autoregression integrated moving average (ARIMA) model.[80] An autoregression of first difference (AR1,1) was attempted. If results were not significant, then a moving average of first difference (MA 1,1) was modeled and compared with the AR1,1. If neither AR1,1 or MA1,1 had significant results, then ARIMA of first or second differences was modeled. Significant results were based on 1) parameter estimate was less than one and had a significant p-value of less than .05; 2) A small value for the Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC), which suggests that the model has a better fit; and 3) X^2 p-value of .05 or greater, which rejects the white noise hypothesis that the autocorrelation in a given lag are not significantly different from zero.[80]

A summary of the parameters for each variable by country can be found in Appendix E. With these corrections to the individual time series, the cross-correlation of preventive care spending and health outcomes was estimated, expressed as equation 1.[76]

$$(1) \qquad \rho_k(X,Y) = \ Corr\ (X_{t-k}, Y_t)$$

In this equation, X represents preventive care expenditures and Y represents health outcomes. The time lag (*k)* establishes the cross-correlation between *X* at t years before *Y*. Given that health outcomes are the response variable, a negative lag and positive correlation was expected. The cross-correlation with the greatest absolute value was selected between zero and four lags. Thus, preventive care spending lagged health outcomes between 0 and -4 years. A four-year lag was used as a result of a sample size of 20 periods. A lag greater than 25% of the series length would have resulted in poor approximations in the correlation statistics. The four paired relationships used in the cross-correlation function included:

- HALE and preventive care expenditure per capita
- HALE and preventive care expenditure as a share of GDP
- LE and preventive care expenditure per capita
- LE and preventive care expenditure as a share of GDP

Countries were grouped based on similarity of cross-correlation results. These groups were used to further explore the constancy of the direction of cross-correlation coefficients within countries. The groups were used to examine differences of cross-correlations between countries using economic and demographic variables in the third phase of the analysis. The economic

indicators included the average annual GDP growth rate per capita and the average social protection expenditure and curative care expenditures per capita. The differences between country grouping based on variations in health financing systems were examined. The demographic indicators that were explored included overall population level, average rate of change in the proportion of youth and proportion of elderly, and the Human Capital Index (HCI). The description below provides further explanation for selecting these variables for the last part of the analysis.

Data Description

Most health spending empirical studies use LE as a proxy for health outcomes.[42,49,53,83,84] Though it has been suggested that HALE is a better alternative than LE,[42,46,47,51] HALE is a summary measure that quantifies the expected years of life spent in good health and addresses disability and death, allowing the measure to summarize LE with a full stock of health.[43,85] It is calculated by adjusting independent comorbidity, age, sex, and country to estimate the all-cause years lost due to disability rate per capita.[85] HALE is advantageous as an outcome measure because it is free from the influence of population size and age structure and avoids bias of setting population health goals. It also allows for cross comparability among countries.[45] It reflects health equity to show observable differences between countries.[45] This analysis requires a measure that assesses the length and quality of life in a country because as public health measures become more effective, the gains in LE should reflect quality of life. LE was included in this analysis because it is a common measure in the literature for health system efficiency, economic development, and

well-being. It also has a strong correlation with other population health indicators and therefore has been regarded as a good indicator for health outcomes.[83] HALE from birth is available on the Global Burden of Disease, and LE from birth was retrieved from the OECD.

Preventive care expenditure is based within the boundary of primary prevention – to avert diseases and their risk factors, and secondary prevention – to detect diseases early. The System of Health Accounts (SHA) accounts for preventive care spending on activities for primary and secondary prevention at the individual and population levels.[86] SHA defines preventive care as "any measure that aims to avoid or reduce the number of the severity of injuries and diseases, their sequelae, and complications".[86] SHA excludes tertiary prevention from preventive care because it is assumed that is covered under curative care.[86] Preventive care is further broken down into six subcategories: information, education and counseling programs; immunizations; early disease detection; healthy conditioning monitoring; epidemiological surveillance; and disaster and emergency response preparation.[86]

Information, education, and counseling services incorporate individual- and population-level programs. This can include mass-media campaigns, like tobacco cessation, and personal advice, such as daily aspirin use.[7] Immunization programs are vaccines that prevent the onset of diseases across all age groups and also include immunizations for travel or tourism. Early disease detection is related to screening for a single disease and usually targets a high-risk group, for example, cervical cancer screening among women ages 21-65.[86] Healthy condition monitoring targets healthy individuals who can be at risk for illness. It is comprised of annual wellness visits,

routine dental check-ups, workplace health monitoring campaigns, or antenatal check-ups. [86] Epidemiological surveillance and risk and disease control programs take into account the role of the health system to track and monitor disease.[7] This category includes information systems, epidemiological assessments, program monitoring and evaluation, and operational research.[7] Preparing for disaster and emergency response accounts for the response to human and natural humanitarian emergencies.

Expenditure data were based on constant Purchasing Power Parity (PPP) in U.S. dollars to allow for uniform comparisons across countries over time.[87] Constant expenditures adjusts for the effects of inflation and captures changes in volume of goods and services.[87,88] PPP is expressed in U.S. dollars and balances the purchasing power across countries by equalizing the price of the same basket of goods and services in different countries.[87,88] It uses a single base year to eliminate differences in price levels between countries. For this analysis the base year was 2015. Preventive care expenditures as a share of GDP and per capita are available on OECD statistics from 2000 to 2019. Comparing health expenditures as a share of GDP between countries may provide a distorted measure if countries experience large increases or declines in their economies.[36] Health expenditures may appear greater than they actually are if a country is experiencing an economic decline. Preventive care expenditures per capita regards population size and is a more accurate measure to compare health spending between countries.[36] Both measures were used in the cross-correlation function based on the literature suggesting the incongruity between the two measures.[36]

Demographic and economic variables considered for the analysis are found in Table 1, which provides a list of the variables and rationale for including them in the model.

Table 1. Demographic and economic variables and relationship to health expenditures

Variable	Relationship
GDP	A bi-directional relationship between GDP and health spending though previous analyses were not specific to preventive care.[40,83,84]
Curative Care expenditure	Competes for the same limited resources. Increases in curative care crowd out the available resources for preventive care.[17]
Social Protection expenditure	Redistribution of income through social benefits like unemployment benefits, pension payments, housing, etc. This type of spending has a stronger relationship with health outcomes than health spending.[53,89]
Finance System	System of financing responds differently to changes in health expenditures.[42,84]
Ratio of Youth in the Population	Ambiguous relationship between age and prevention. Rapidly aging populations affect health spending, but evidence indicates that age increases the demand on health services.[30,53,90]
Ratio of Elderly in the Population	
Human Capital Index	Proxy for workforce productivity and could be reflective of social determinants of health in a given country.[90–92]

Studies indicate a positive relationship between public health expenditures per capita and GDP as an absolute and per capita measure, suggesting the existence of bi-directional causality.[83,93–95] Examining the average annual GDP per capita growth rate from 2000 to 2019 could be meaningful given that previous studies, though not specific to preventive care, illustrate that investment in health cultivates economic growth.[31] GDP per capita for the study period are found from the OECD.[96] Other expenditures that compete for the same limited resources were

considered. Social protection and curative care spending were examined to explore if differences in the average per capita expenditure can be used to predict this study's relationship of interest.[17] Given that social protection programs can address social determinants of health, we anticipated a linear relationship between cross-correlation coefficients and social protection expenditures. We expected an inverse, or opposite, relationship with curative care expenditures as a result of the nonlinear association found in previous publications.[17]

Three types of health financing systems are recognized as multiple insurance schemes, national health care systems, or a single-payer model. A national health system is a system in which health providers and hospitals are publicly owned and financed with public funds in the form of taxes.[97] A multiple insurance scheme refers to a health system with multiple payers, which can include the government and private insurance companies that are financed through premiums paid by beneficiaries, employers, or the government.[97] The single-payer model is a public or quasi-public agency that takes responsibility for financing health services and physicians, but hospitals are private practices. Health systems based on this model experience lower administrative costs and spend a smaller share of the GDP on health.[97,98] Previous studies have found that financing systems show varying levels of effectiveness as it relates to health spending and outcomes.[52] A number of studies recommend including financing systems in empirical analyses to take into account the heterogeneity of health systems between countries.[42,52,84] They suggest that different types of health systems respond differently to changes in health spending. The Health Systems Characteristics Survey administered by the OECD has financing systems by country that were reported in 2016.

Because changes in health spending are affected by the size and structure of the population,[99] the size of the overall population and the proportion of youth and elderly in the population were examined. Age is a determinant to health spending because an aging demographic increases the demand for more health services, especially in rapidly aging populations.[53] However, the relationship is ambiguous because while older individuals have less incentive to invest in health, older individuals may demand more health services due to the depreciation of health capital with age.[30,90] This demand for health services is not specific to preventive care given that older populations demand more long-term and rehabilitative care. But some evidence suggests that older women seek preventive services because of the benefit from early disease detection.[90] When examining these variables, the average rate of change in the proportion of youth and elderly from 2000 to 2018 was considered. The proportion of youth and elderly in 2019 was not available. The ratio of youth in the population is the share of 15- to 24-year-olds and the ratio of elderly in the population is the share of 65 and older in a country. Population and ratios were retrieved from the OECD.[100]

The Human Capital Index (HCI) was developed by the World Bank to quantify progress in health and education and is used to determine how they drive economic growth.[92] The index measures child and adult survival rates and the quality and quantity of education.[92] It estimates the survival of children using mortality rates and the rate of stunting for children under age five.[92] Adult survival rate based on the fraction of 15 year-olds that survive to the age of 60.[92] HCI is used for cross country comparisons on the expected productivity of future workers. The index ranges from 0 to 1, where 1 is equivalent to full health and completion of high-quality education. This

indicator was explored given the reciprocal relationship human capital has on economic growth and demand for health. Based on Grossman's health investment theory, individuals in good health and more education have higher productivity leading to economic growth.[30] The HCI may reflect the conditions in which the population has improved social determinants of health, given that countries in this analysis already have advanced economies. The 2018 HCI used was retrieved from the World Bank.[92]

The following provides results of the analysis and a discussion on the possible factors that influence the relationship between preventive care spending and health outcomes. This is followed by limitations of the analysis and conclusion.

Results

The subsequent section presents results in three distinct phases: descriptive analysis of preventive care expenditures, cross-correlation coefficients of the four paired relationships, and descriptive analysis using economic and demographic indicators to explore differences between country specific cross-correlation.

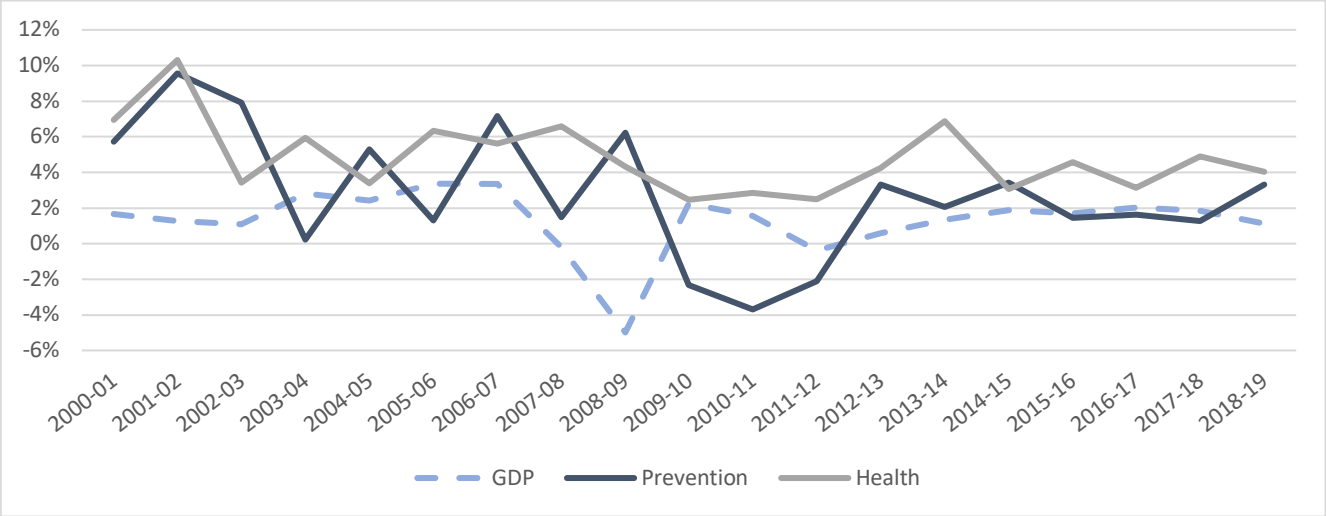
Phase 1. Descriptive Analysis

Employing expenditure data from the System of Health Accounts (SHA), a descriptive analysis of preventive care spending was conducted. A report published by the Organization of Economic Co-operation and Development (OECD) examining preventive care expenditures from 2005 to 2015 was used as the foundation for this part of the analysis.[1] The following presents the results of the descriptive analysis using prevention spending data from 2000 to 2019.

Trends in the growth rate of preventive care spending was much more volatile in the first half compared to the second half of our study period. Figure 6 presents the growth rate of GDP and preventive care and total health expenditures from 2000 to 2019. Because of the inconsistency of countries reporting prevention expenditure data regularly, the graph represents 23 of 37 OECD countries. The growth rate in prevention was 6% among OECD countries during the Great Recession from 2008-2009. However, there was a significant contraction following the economic crisis. This may indicate a lagged response over time in preventive care spending as a result of a

decline in the GDP growth rate. Despite multiple global outbreaks of infectious diseases since the Great Recession, spending on prevention has not recovered to its pre-economic crisis growth rate. The growth rate in prevention since 2012 have been between 2% and 3%. There has also been a consistent gap between the growth rate of prevention and total health spending since the Great Recession, except for a slight convergence in 2014-15.

Figure 6. GDP, preventive care, and health expenditures growth rate, in real terms, per capita

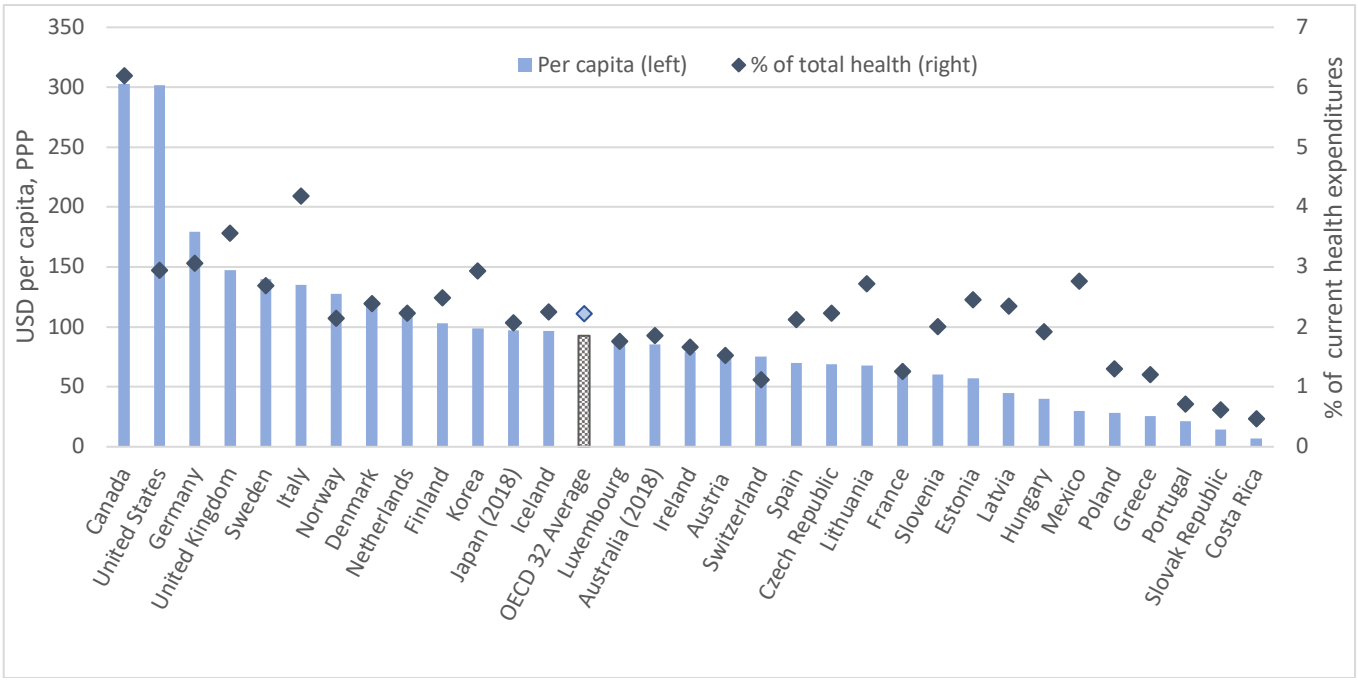


Note: Data refers to OECD 2000-2019 representing 23 countries

The range of preventive care spending per capita and as a share of total health expenditures varies widely among OECD countries in 2019, as shown in Figure 8. The graph represents 32 countries, which includes the 30 countries that reported preventive care expenditures in 2019, plus two countries from 2018 (Australia and Japan). Examining these countries follows the previous analysis published by the OECD using 2015 data.[1] The graph represents preventive care expenditures per capita, scaled on the left, and its share of total health spending, scaled on the right. In the previous report, 31 countries were represented but their results are similar with this analysis. Canada spent the most per capita on prevention and it accounts for a larger portion of

their health funds. In 2019, Canada and the U.S. had the highest per capita expenditures at approximately $300. This is almost three times the OECD average of $92 per capita. This contrasts slightly from 2015 in which the OECD average was $116 per capita, and Canada and the U.S. spent two-and-half times the OECD average.[1] On average, OECD countries spend 2.2% of total health spending on prevention. This is less than the OECD average of 2.8% reported in 2015. The share of prevention in Canada is double that of the US at 6% compared to approximately 3%, respectively. Conversely, Hungary and Mexico spent significantly less than the OECD average per capita at approximately $30 and preventive care accounts between 2% and 2.7% of their total health funds. These results are consistent with what was reported from 2015.

Figure 7. Prevention expenditures per capita and as a share of total health expenditure, 2019

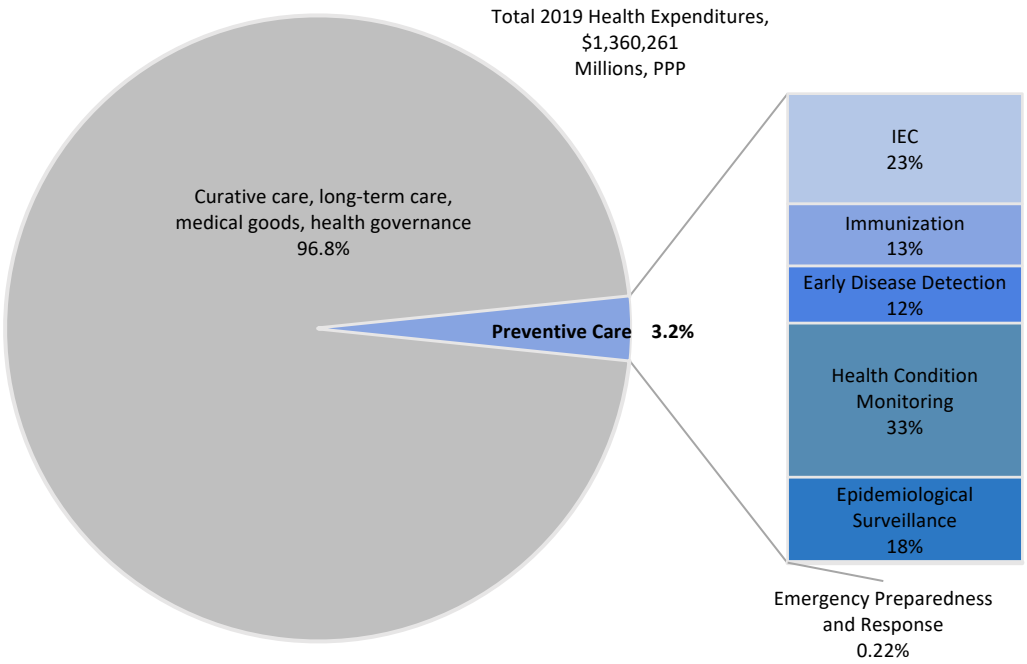


In 2019, 30 countries reported total spending on prevention, but only 21 countries reported by subcategories. Most notably, Canada and the U.S., the largest spenders on prevention, did not

report expenditures by subcategories. The pie chart shown in Figure 7 presents the allocation of health expenditures to preventive care and its associated activities in 2019 representing the 21 countries. Of those countries, based on the SHA framework of total health expenditures, a total of approximately $1.3 trillion were spent in health, of which a little over 3% were spent on prevention. The remaining funds were directed to curative or rehabilitative care, medical goods and devices, and health governance. Of the expenditures that were reported, a large proportion of preventive care funds, approximately a third, is spent in health condition monitoring, which are wellness programs like dental exams, prenatal care, and annual wellness checkups. Despite the large benefits, less is spent on population-level programs of approximately 40% compared to individual level clinical preventive services, spending a total of approximately 58% of preventive care funds.

Appendix F presents the distribution of preventive care expenditures by subcategory for the 21 countries. Expenditures for the subcategories were not uniform and mostly skewed to the right with a number of outliers over the maximum. The expenditures for information, education, and counseling; immunization, early disease detection, and epidemiological surveillance are skewed to the right. The median of health condition monitoring is the largest at almost $500 million. Emergency preparedness and response was an exception because of the 21 countries that reported preventive care expenditure subcategories, only six countries reported a value for emergency preparedness and response. The median amount spent in that category was $5.9 million, though the maximum expenditure was $60.4 million.

Figure 8. Proportion allocated to preventive care and associated activities in 2019



Note: Data refers to OECD average for 2019 representing 21 countries. IEC is information, education, and counseling. PPP is purchasing power parity

Phase 2. Cross-Correlation

The cross-correlation between two health outcome measures and two spending measures resulted in the following paired relationships:

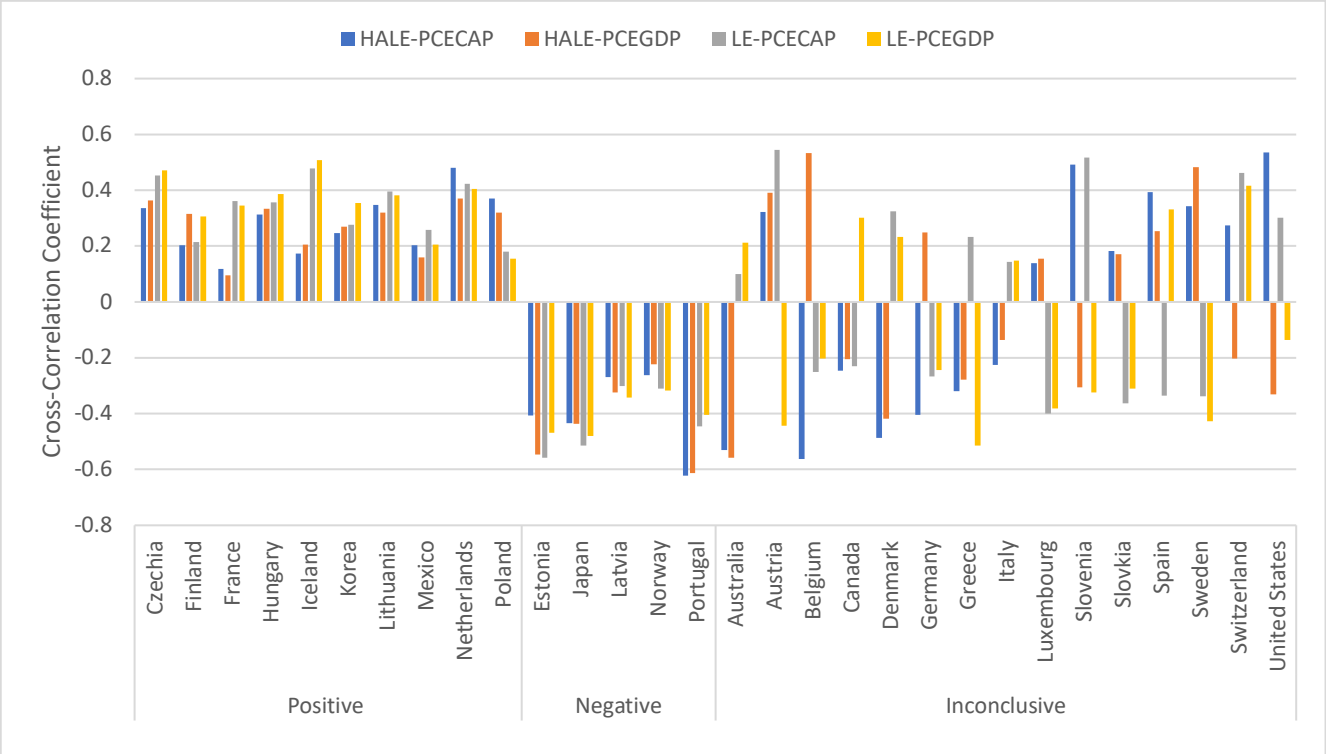
- HALE and preventive care expenditures per capita
- HALE and preventive care expenditures as a share of GDP
- LE and preventive care expenditures per capita
- LE and preventive care expenditures as a share of GDP

A strong positive association was anticipated between past government preventive care expenditures and health outcomes. A positive cross-correlation suggests that the direction of

health outcome and spending measure were the same. This could mean that spending and health outcomes increased or decreased together after a period of time. Conversely, a negative relationship suggests that health outcomes and spending change or move in opposite directions. Cross-correlation coefficients that have a value close to 1 or -1 suggests a stronger relationship and closer to 0 suggests a weaker relationship. The following presents the results of the cross-correlation function for the four paired relationships.

A total of 10 countries, or a third, had positive cross-correlation across all four relationships, and five countries, or 16%, had negative cross-correlations across all four relationships. The remaining 15, or half of the countries, resulted in inconclusive results to show whether a relationship exists between prevention spending and health outcomes. The time lag average and mode were approximately two years across all relationships. Figure 9 presents the cross-correlation between the four paired relationships by country.

Figure 9. Cross-correlations results by country



Note: HALE is healthy-adjusted life expectancy, LE is life expectancy, PCAP is preventive care expenditures per capita, PGDP is preventive care expenditures as a share of GDP

Table 2 presents countries grouped based on the cross-correlation results. Countries with four positive cross-correlations were grouped together, as well as countries with four negative relationships. The remaining countries were grouped together based on the inconclusive results between the four paired cross-correlations. Countries with consistent strength and direction across the four paired cross-correlations suggests that the relationships are capturing accordant information. Countries with varying strength or direction across the four paired cross-correlations may suggest that the relationship is capturing other information causing inconsistent results. The distribution of the four paired cross-correlation coefficients for 30 countries are similar regarding their spread, variation, and average of the coefficients. Results for country specific cross-correlations and their corresponding time lag can be found in Appendix G.

Table 2. Country groups

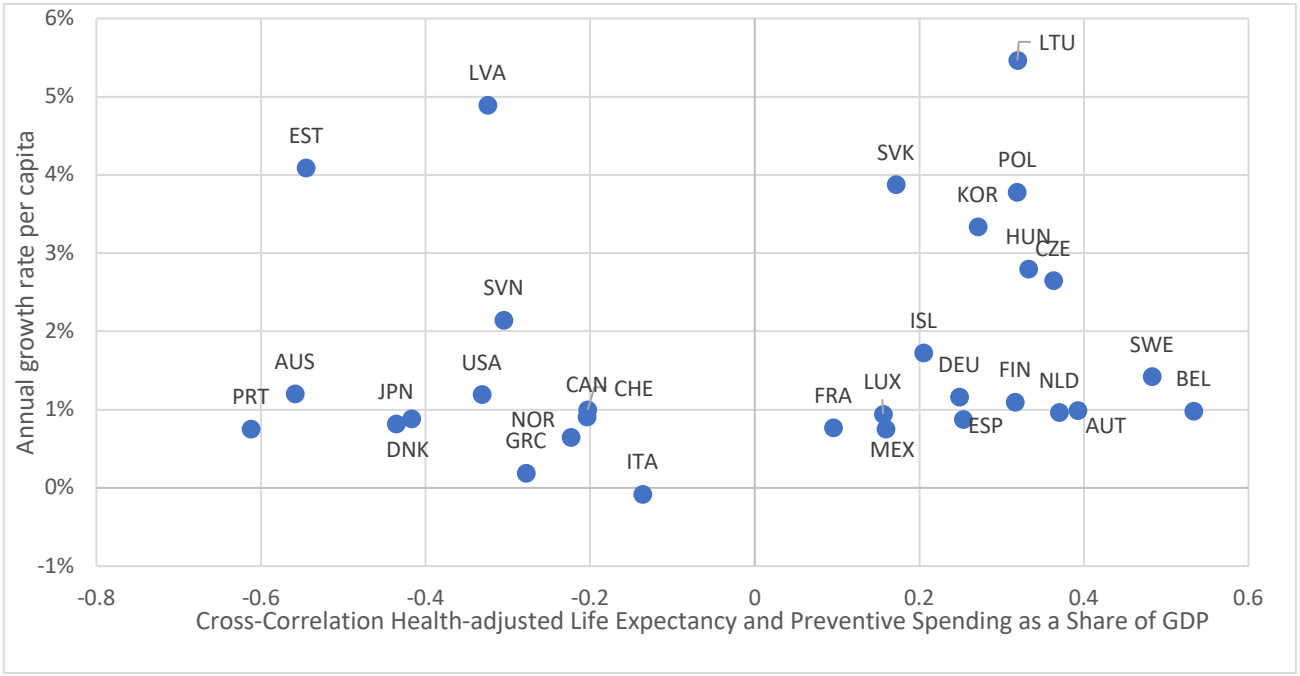
Positive	4 relationships with a consistent positive correlation	Czechia, Finland, France, Hungary, Iceland, Korea, Lithuania, Mexico, Netherlands, Poland
Negative	4 relationships with a consistent negative correlation	Estonia, Japan, Latvia, Norway, Portugal
Inconclusive	Inconsistent correlations between the 4 relationships	Australia, Austria, Belgium, Canada, Denmark, Germany, Greece, Italy, Luxembourg, Slovakia, Slovenia, Spain, Switzerland, Sweden, United States

Phase 3. Between Country Differences

Economic and demographic factors were included to delineate differences in the strength or direction of cross-correlation coefficients. Because of the possible lagged response of the decline of prevention spending after the Great Recession, as shown in Figure 5 above, a possible existence of a trend between the pairs of cross-correlation and GDP was investigated. We expected lower GDP growth rates among the negative group and high annual growth rates among the positive group. The average annual GDP per capita growth rate from 2000 to 2019 was used. The average annual GDP growth rate during the study period ranged from -0.08% (Italy) and 5.46% (Lithuania).

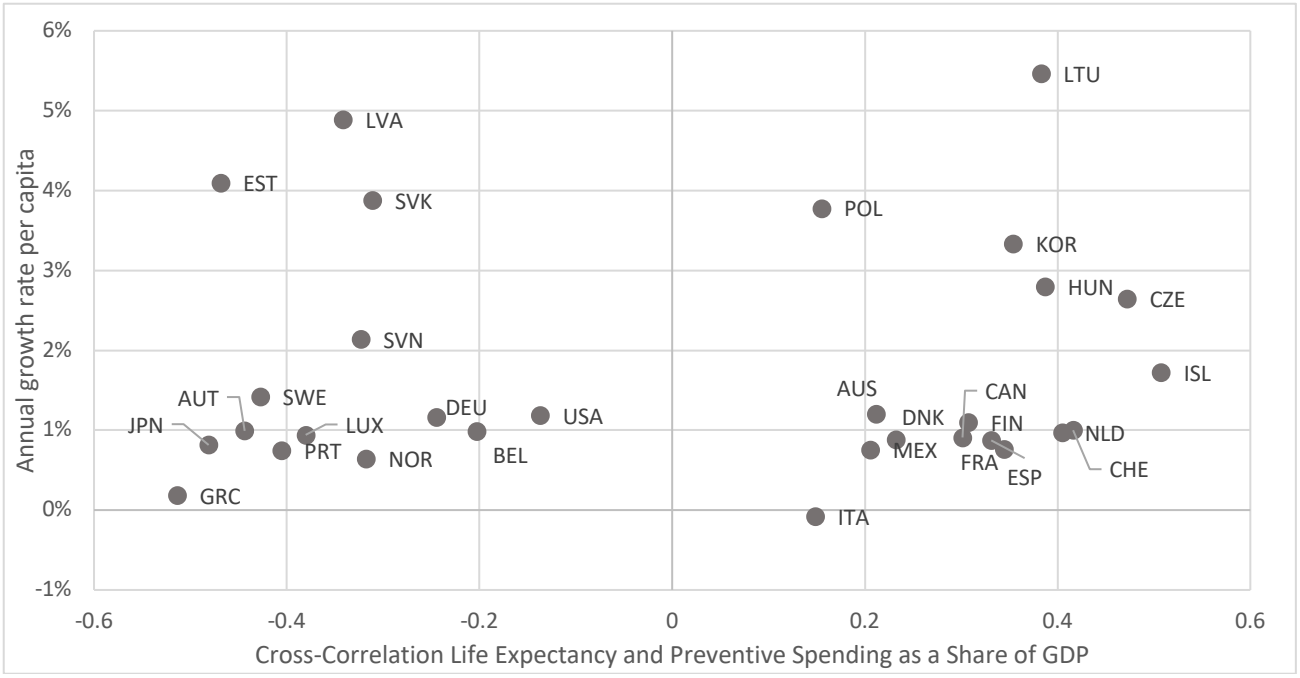
Figure 10a plots the correlations between HALE and preventive care expenditures as a share of GDP against the average annual GDP per capita growth rate. Figure 10b plots the correlation between LE and preventive care expenditures as a share of GDP against the average annual GDP per capita growth rate. Both scatter plots do not indicate a discernible trend with the average annual GDP per capita growth rate. The paired correlations with preventive care expenditures per capita against the average annual GDP growth rate can be found in Appendix H1 and H2, which shows similar results.

Figure 10a. Average annual GDP growth rate per capita by the cross-correlation of HALE and preventive care spending as a share of GDP



Note: Country acronyms can be found in Appendix A

Figure 10b. Average annual GDP growth rate per capita by the cross-correlation of LE and preventive care spending as a share of GDP



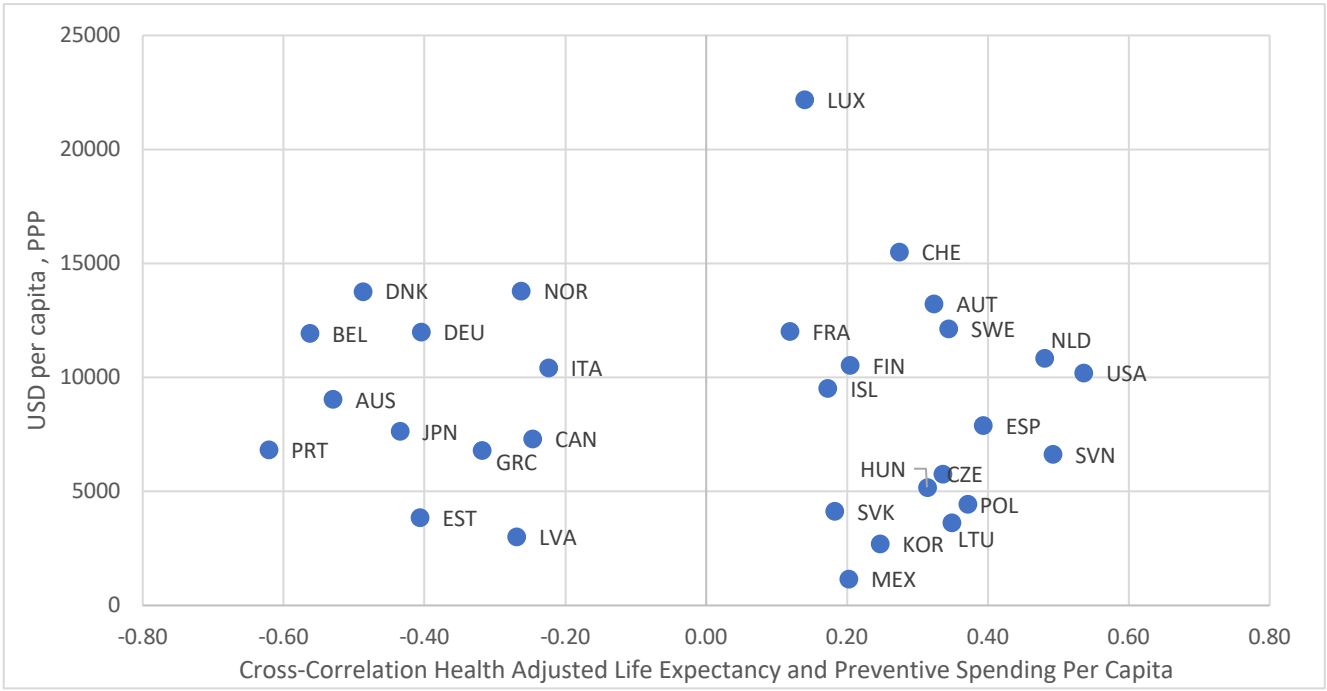
Note: Country acronyms can be found in Appendix A

Other types of public spending that compete for the same limited resources as preventive care were examined. A crowding out effect occurs between curative and preventive care.[17] Based on previous studies more funds allocated to prevention hinders progress in innovative therapeutics.[17] Spending more money in curative care weakens advancements in population health. Therefore, an inverse relationship was anticipated between the level of curative care spending and the cross-correlation coefficients. In 2018, on average, OECD countries spent almost $1,900 per capita in curative care, much greater than the average $300 per capita on prevention. However, there were no apparent differences in the level of funding for curative care to explain differences in the paired cross-correlations within countries or between groups.

Expenditures in social protection were then examined. These types of expenditures are social benefits like unemployment benefits, pension payments, housing allowances, etc. Because social

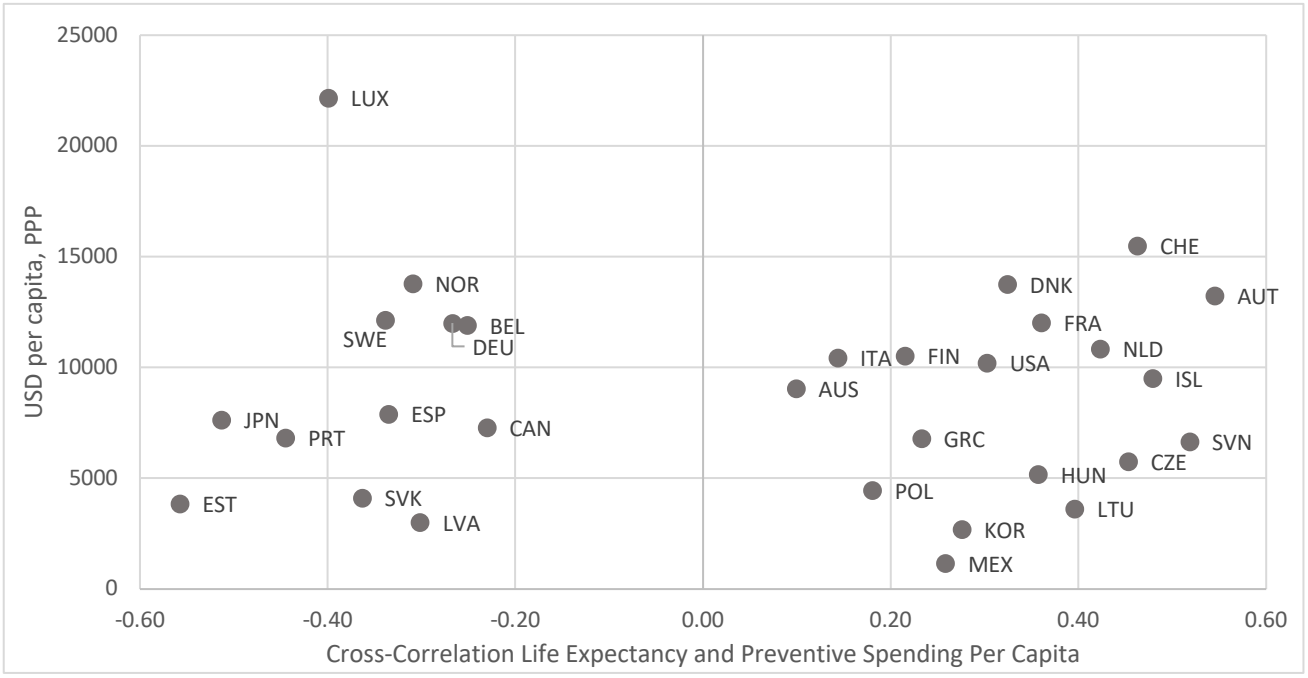
protection addresses some social determinants of health, a linear relationship with the paired cross-correlations was expected. Figure 11a plots the paired correlations of HALE and preventive care expenditures per capita against the average social protection expenditures per capita. Figure 11b plots the paired correlation of LE and preventive care expenditures per capita against the average social protection expenditures per capita. The scatter plots do not indicate a discernible relationship between the cross-correlation and average social protection expenditure per capita. The paired correlations of health outcomes with preventive care expenditures as a share of GDP against the average social protection expenditure per capita can be found in Appendix I1 and I2 showing similar results.

Figure 11a. Average social protection expenditure per capita by the cross-correlation of HALE and preventive care spending per capita



Note: Country acronyms can be found in Appendix A

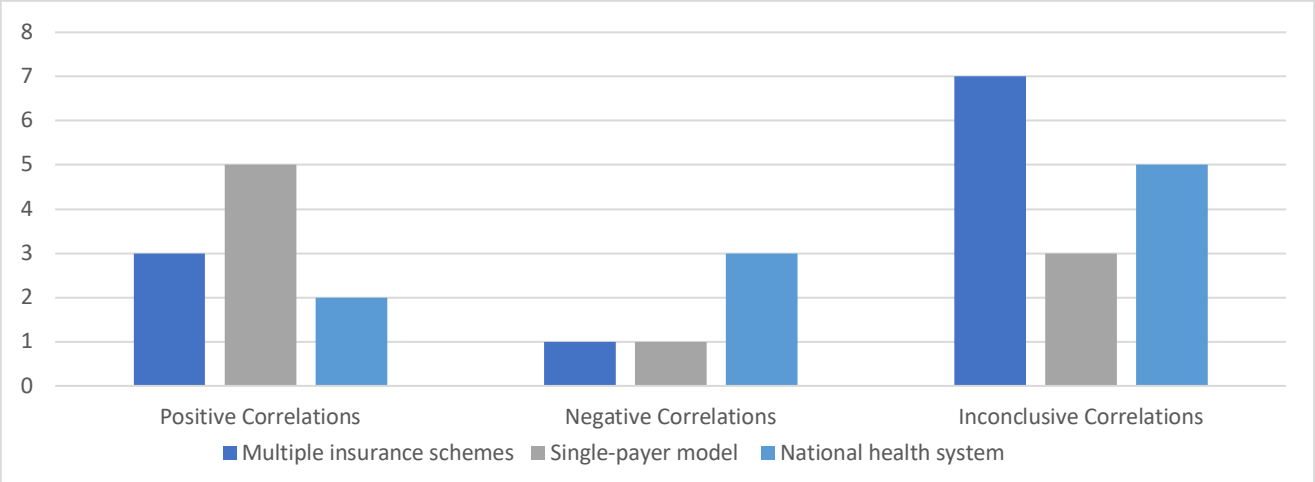
Figure 11b. Average social protection expenditure per capita by the cross-correlation of LE and preventive care spending as a share of GDP



Note: Country acronyms can be found in Appendix A

Health finance systems may also influence the coverage and financial protection in accessing clinical preventive care services. As shown in Figure 12, of the 30 countries in the analysis, half of the countries in the positive group had a single-payer model. Half of the countries in the negative group have a national health system, and nearly half of the countries in the inconclusive group had a multiple insurance scheme. These results are relative to a small sample of 30 total countries in the analysis, which became smaller once grouped by cross-correlation coefficients, e.g., the negative group has a total of five countries.

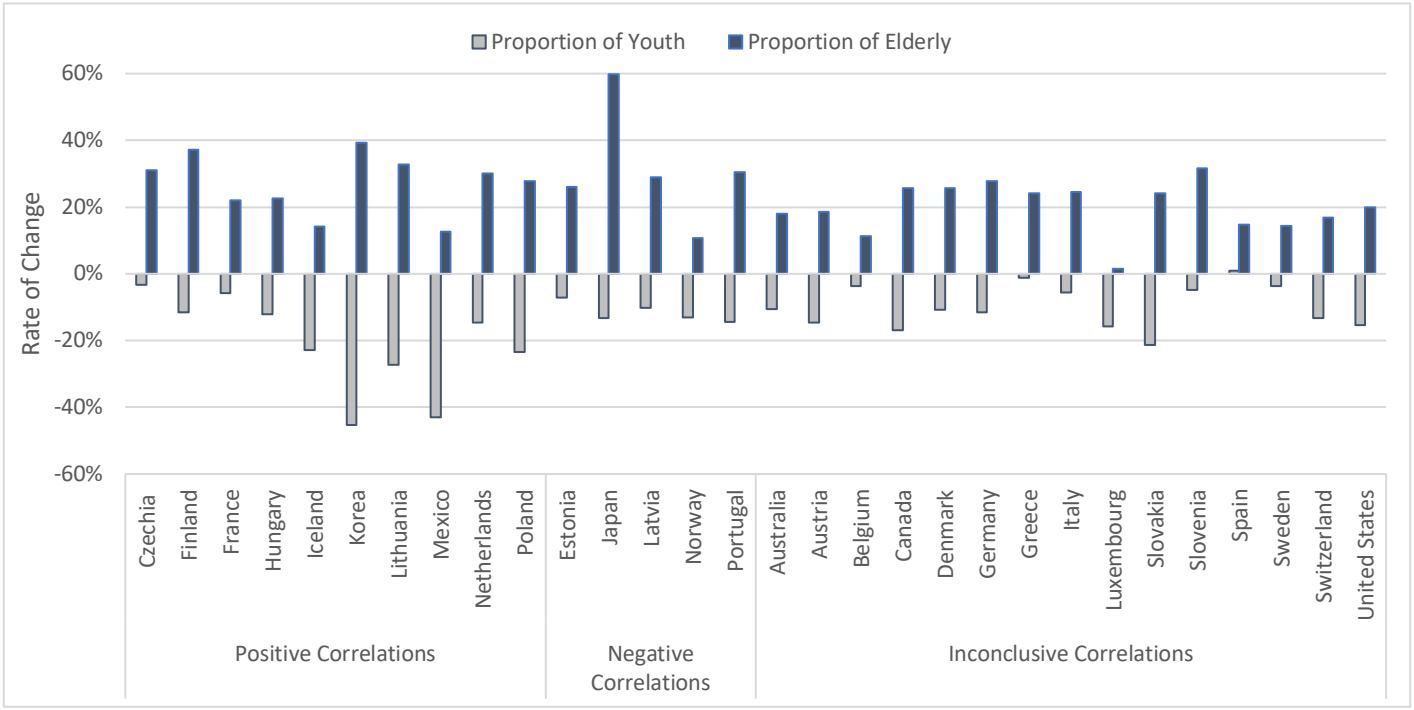
Figure 12. Country Groupings by Health Finance Systems



Country specific population size and structure, defined by population growth rates, and composition, explained by the Human Capital Index (HCI), were examined. The U.S. has the largest population size among the countries in the analysis. It is almost three times larger than the next most populous country of Japan. Population size alone could not predict differences in the relationship between preventive care spending and health outcomes. The average rate of change in the proportion of elderly and youth in the population from 2000 to 2018 were examined. Figure 13 presents the average rate of change in the proportion of youth and elderly arranged by country cross-correlation groups. Trends across all countries show a growing elderly population and declining population of youth from 2000 to 2018. There were no discernible differences between groups based on the growth rates. Korea and Mexico have paced each other in their epidemiological transition and have similar changes in their population structures.[101] The rate of change in the proportion of Korean youth is declining at a rate of -0.45, and the proportion of Korean elderly is increasing at a rate of 0.39. The proportion of Mexican

youth is similar to that of Korea declining at a rate of change of -0.43. However, the proportion of Mexican elderly is steadily increasing at a rate of 0.13. Lastly, the HCI ranged from 0.61 to 0.84, with an average of 0.76. HCI did not vary significantly between countries or between groups. No other noticeable association with HCI was identified between the four paired cross-correlations.

Figure 13. Average Rate of Change in the Proportion of Youth and Elderly, 2000 to 2018



Discussion

Health promotion and disease prevention activities can have large-scale implications in advancing health equity and addressing social determinants of health. However, of the OECD countries analyzed, the reported spending using public funds were between 2% to 3% of total health funds on preventive care, based on the results of Figures 7 and 8. These amounts are consistent with previous OECD-based analyses on the proportion of funds dedicated to prevention.[1,11] It appears counterintuitive to spend a relatively small portion on prevention given the potential population-level benefits.[102,103] Perhaps the lack of empirical research on preventive care spending patterns could be the result of unreliable or unavailable health expenditure data. This may contribute to the challenges in advocating and sustaining continued investments in public health.[16] This dissertation explored the available expenditure data related to public health and concludes the need for better quality public health spending data. This could support and encourage further research on public funding for prevention and its relationship to health outcomes. The following provides a discussion on the descriptive and cross-correlation analyses accompanied by possible explanations. This is proceeded by a review of data quality based on the System of Health Accounts (SHA), recommendations, limitations, and conclusions.

Descriptive Analyses

Preventive care is comprised of a combination of population-level and individual clinical preventive services. Based on the proportion of expenditures in health promotion and disease prevention activities, in Figure 7, more funds were spent on individual-level clinical preventive services than population-level programs in 2019. This is contrary to the evidence which suggests that population-level programs have a greater impact and require less individual effort.[1,102] Individual-level services include health condition monitoring (33%), immunization (13%), and early disease detection (12%). Within clinical preventive services, 33% is spent on programs like annual wellness check-ups, dental exams, and antenatal visits which constitute health condition monitoring. This is a significant amount considering that these programs do not have extensive cost-effective evidence compared to immunization and early disease detection programs.[1]

The scale of funding within population-based programs are equivalent to the 2015 OECD descriptive analysis on preventive care spending.[1] Population-based programs include information, education, and counselling (23%), epidemiological surveillance (18%), and emergency preparedness and response (0.22%). This may indicate that countries are not altering their pattern of spending on prevention or countries are not reporting their spending on prevention. It perpetuates a cycle of panic and neglect within public health systems. This cycle was penned by the World Bank in 2015 about the reactionary response leaders have in attending to the public health systems during an emergency and disregards it when the urgency fades.[104] Though this was stated in the context of emergency preparedness and response, a resilient

public health system is necessary to continually safeguard the public. Ending this cycle requires additional evidence that aligns the benefits, both human and economic, with the investments made by the public. The literature provides some limited evidence showing the economic returns from investing in public health.[32,58] Even less is published on the impact on health outcomes or quality of life as a result of changes in the level of spending for preventive care.[105] This work adds to the evidence base by presenting results of a cross-correlation function of four paired relationships between health outcomes and preventive care spending. These results incorporate descriptive analyses to provide an explanation and possible implications.

A third of countries in the analysis had positive cross-correlations across the four relationships after a lag of approximately two to three years. A positive cross-correlation suggests that spending on prevention and health outcomes move in the same direction after a period of time. Policy makers may find these results useful when faced with budget reductions as a result of an economic crisis or a human or natural emergency. It is important to note that the strength of the correlation may vary between the four paired relationships even though they have the same direction. The variation in strength within countries may denote a spurious conclusion in examining a lag between zero and four as a result of 20 time periods for a time series analysis. It would be important to test if changes in the timescale match these results.

Five out of 10 countries in the positive group had a single-payer financing system model. Though the sample size is small, previous research suggests that health systems based on this model experience lower administrative costs, spend a smaller share of the GDP on health, and cover a

larger portion of the population.[98] Compared to countries with a multiple insurance scheme and national health systems, countries with a single-payer model have also been found to have greater perceived health status.[84] Because of these benefits, advocates of a single-payer model have campaigned for it to be part of healthcare reform in the U.S.[97] More research can be done within the context of health systems to determine the effect size between preventive care expenditures and health outcomes.[17] A Granger causality model can test whether there are lagged and repeated patterns between preventive care expenditures and health outcomes over time within the context of a single-payer systems.[106] This may provide evidence of a predictive relationship of preventive care spending with future health outcomes. Differences in preventive care expenditures between countries in the context of their finance systems can be meaningful. A fixed effects model could be used to explain the variation in spending as a function of the financing system, controlling for the utilization rates for clinical preventive services.[42] It can highlight variation in the cost to provide clinical preventive services and differences in screening and vaccination rates. Results could drive future studies examining the context in which a financing system reduces financial barriers and lowers costs for preventive care services.

The countries with four negative cross-correlation coefficients describe the extent that health outcomes and preventive care expenditures move in opposite directions. A ceiling effect could play a role in these results. Spending on prevention alone may not be sufficient to improve health outcomes. The systems, policies, and practices in place may have a reciprocal effect in reducing financial barriers, strengthening equitable allocation of resources, and improving access to preventive care services. From Figure 7 in 2019, compared to other OECD countries, Canada

and the U.S. spent the largest amount per capita of approximately $300. Both Canada and the U.S. were in the inconclusive group. Further research is needed on efficiencies in spending to improve performance in adhering to policies and practices and service delivery.[107] Funding allocation practices, like performance-based strategies or optimization- and formula-based models, may have implications in the equitable distribution of funds by targeting hard-to-reach and vulnerable populations.[107] The differences between countries may also call for a closer investigation on the type of approaches used for preventive service delivery. Though clinical preventive services is more prohibitive because it has higher individual effort, population-based approaches to deliver these services can have a large impact.[102] These approaches are strategies to reach and manage patients regardless of the distribution of risk for a disease or condition.[102] For example, using a population-based approach to screen for high blood pressure, which is usually asymptomatic, can improve quality of life and reduce the likelihood of experiencing a cardiovascular event.[102] Alternatively, opportunistic-based approaches leave the initiation of clinical preventive services to the individual.[1] Evidence of screening rates from high-income countries suggest that those with population-based screening programs are more effective in reaching those with lower socioeconomic status.[1] The nuances of the policies and practices to distribute funds and the strategies in which funds are used can provide more insight on the efficiencies of funds allocated to preventive care.

Countries with negative cross-correlations were contrary to the expected hypothesis of this study. These results could be the result of insufficient time periods in examining lags of more than four periods. It could also point to the lack of consistent reporting by countries in conveying

their true spending in prevention. Alternatively, it may suggest that governments are ill-informed of public health impact. Reinvestment rarely happens as a result of a successful public health action. This is known as the "wrong pocket" problem.[105] It occurs when a public health program is successful, but it does not gain the savings that accompany improvements in health, and the benefits are likely enjoyed by another sector. For example, an infectious disease outbreak investigation prevents exposure to an infected individual, or a tobacco cessation campaign helps individuals stop smoking. These public health actions avert thousands of dollars in medical or hospitalization bills, typically paid by the individual and/or healthcare payer/insurer. Though public funds may finance the prevention activity, the costs averted may benefit another entity, i.e., the accrued savings goes into the "wrong pocket."[105] Without knowing the true population-level benefits, including savings, of prevention spending, decision makers are not fully informed about the value of public health. The lack of information on the value of prevention spending is likely to result in chronic underfunding based on systemic undervaluing of public health impact.[73]

Half of the countries in this analysis had inconclusive cross-correlations and did not support this dissertation's hypothesis of four positive cross-correlation coefficients. Similar to the countries with four negative cross-correlations, these results could be due to limited timeseries or variability and inaccurate reporting in preventive care funding levels. As shown in Figure 5, the growth rate of preventive care fluctuated in the early part of the study period, and it did not recover after the Great Recession. This signals that the inability to sustain predictable funding levels overtime may have contributed to the inconclusive results. Given that on average 3% of total health spending is allocated to prevention among OECD countries, it is also possible that a

larger proportion of funds is needed to have an effect on health outcomes. Currently, there are no formal recommendations for an optimal funding level. Without robust investigations on spending patterns in preventive care, it is difficult to know the optimal or minimum funding level at which public health can thrive. As a result, it presents challenges to advocate for predictable funding levels and, therefore, difficult to maintain a resilient public health system. The inconclusive cross-correlations could be related to the allocation of funds to programs like health condition monitoring in which cost-effective evidence is absent.[1] Health condition monitoring accounts for a large proportion (33%) of an already small fraction of total health spending. The opportunity cost in programs like these make it hard to justify continued investment in public health. Allocating resources to programs that lack sufficient evidence on their effectiveness can potentially overburden the health system, and impose the possibility for duplicative tests, over-diagnosis, and waste.[108]

The extensive connection between health outcomes and socioeconomic factors, or social determinants of health[3], could reflect the study's findings of either a negative or inconclusive cross-correlation. The System of Health Accounts (SHA) defines preventive care as health promotion or early disease detection activities where the primary purpose of those activities is health.[7] The prevailing definition of prevention addresses social determinants of health which inherently partners across sectors, like education, planning, housing, and labor sectors.[3] Defining it through the traditional sense does not account for multisectoral collaboration that could contribute to improvements in overall health outcomes. Failing to account for expenditures that support social factors underestimates the depth of public health research and practice.

Examining funds allocated to preventive care in conjunction with funding associated with programs that address social determinants of health may be the critical force that drives improvements in health. However, extracting funding levels or determining sources of funds can be overly complicated and difficult to collect from multiple stakeholders. Additionally, the SHA's definition of prevention underestimates the amount spent and its impact by not accounting for public health regulatory and fiscal activities. It does not include the cost of certain regulatory activities, like road safety or the costs to implement a sin tax - a tax on unhealthy products. This constrained perspective of preventive care could be another reason why research in this area is so limited. Measuring the full extent of public health prevention expenditures and their impact could help justify the need for sustained and predictable funding.

Review of the System of Health Accounts

The SHA was first developed in 2000 but was updated in 2011. The revisions included reclassification of preventive care and the provision of supplemental guidance on the definitions and boundaries to account for preventive care expenditures.[109] Table 3 presents the SHA classification of preventive care services and programs. Though the supplementary guidance addressed ambiguities that were present in the updated 2011 revisions, uncertainties remain in accurately reporting preventive care expenditures. The guidance does not provide examples of activities on what constitutes preparing for disasters and emergency response (HC.6.6). Since 2011, on average, eight of 38 countries consistently reported expenditures in this category. The credibility of those that report disaster preparedness and emergency response is questioned

given that guidance is lacking. Without a clear distinction, expenditures for the category remain unreported or lack credibility. This public health activity is particularly relevant in assessing the funding levels countries appropriated and their ability to effectively respond to SARS-COV-2 and its variants. In theory, providing guidance on what constitutes emergency preparedness may help sustain financing at the country level and support the global community to prepare for the next natural or human emergency.

Table 3. Classification of preventive care expenditures[1]

Health Care Classification	Preventive Care Program
HC.6.1	Information, education, and counselling programs
HC.6.2	Immunization programs
HC.6.3	Early disease detection programs
HC.6.4	Healthy condition monitoring programs
HC.6.5	Epidemiological surveillance and risk and disease control programs
HC.6.6	Preparing for disaster and emergency response

The category epidemiological surveillance and risk and disease control programs (HC.6.5) acts as a catch-all for any type of system or data collecting mechanism that analyzes disease risk and trends. It can include the planning, monitoring, and evaluation of interventions; public health surveillance systems; health service management systems; monitoring samples of drinking water and food; or epidemiological assessment studies.[109] Aggregating the expenditures of these systems, studies, and programs into a single category clouds the level of funding that was invested. Investments in epidemiological surveillance is of particular relevance given that health systems globally were ineffective in responding to COVID-19.[110] Systems were neither integrated nor interoperable with other data systems, and the workforce was not sufficiently trained to

manage and use health data.[110] Without knowing the level of expenditures, it veils the gap in funding to strengthen public health information systems. Aligning the SHA's definition of epidemiological surveillance with the World Health Organization's (WHO) SCORE technical package can guide the boundary for this category.[111] The technical package is a comprehensive set of strategies and interventions for country health information systems. It can be a path to disaggregate epidemiological surveillance and risk and disease control programs and determine their cost boundaries.

Though OECD countries report expenditure data, their reliability and credibility are subject to scrutiny. Out of 38 OECD countries, only 23 countries consistently reported preventive care expenditures from 2000 to 2019. In 2019, 21 countries reported the amount spent on health promotion and disease prevention activities and the number of countries that report by activity vary over time. Countries may not be able to report total spending on prevention or by activity because their health systems or funding streams may be too complex to report according to the SHA framework. The public health care sector and public health services are indistinguishable in countries that are financed through a national health system.[11] Alternatively, countries may define public health differently from the SHA framework. This may result in large discrepancies between national and internationally reported data.[11] Inconsistency in reporting expenditure data obscures the interpretation of public health spending measures, either as a share of GDP or per capita, and obscures cross-country comparisons. Irregular reporting complicates the ability to measure sustainability of public health and could perpetuate a culture of panic and neglect of the public health system.[104]

Recommendations

Results from this analysis drive the need for improvements in the quality of public health expenditure data. A recommendation is to establish a basic standard for public health for the purposes of securing sustained and predictable funding. This has been a recommendation from many public health leaders but have received little traction for implementation.[112,113] These programs can be extended to include population-based programs as well as clinical preventive services for both noncommunicable and infectious diseases. It can act as a benchmark to ensure a basic standard for public health is met and consistently measured to reliably delineate differences between health systems and public health services. It could offer details and examples on what constitutes public health activities. Similar to the U.S. Preventive Services Task Force (USPSTF), an independent voluntary panel of experts could be convened to recommend core programs and services inclusive of social determinants of health.[114] An independent panel of global public health experts could achieve consensus on consistent guidance on core and/or minimum level of public health programs for every country. WHO and its regional affiliates are the likely agencies to convene global experts to establish a standard for public health given their role as arbiters in norm and best practices.[115] WHO does not have the authority to enforce uptake and implementation, but the regional affiliates and other global partners could provide the political and technical support for implementation.[116] Any global standard should exercise progressive elaboration which uses results from on-the-ground implementation and empirical research to improve guidelines and standards in an iterative process. This could usher in more

cost-effectiveness studies from diverse countries and establish an evidence base to inform decision making for public health funding. But for this to occur, researchers would need to rely on credible and reliable spending data. Otherwise, future research results on preventive care puts will be of questionable validity. These data quality problems will likely contribute to extending and exacerbating the likelihood of prolonged chronic underfunding in public health.[71,117,118]

The economic and demographic variables used to assess differences between countries and groups did not prove to have any discernible patterns with the correlations between health outcomes and preventive care spending. This could be the result of poor-quality data or because the sample of countries in the analysis were demographically and economically similar. OECD countries are mostly high-income with similar population structure, like increasing rates of elderly and declining rates of youth, and composition, including education and socioeconomic status. These countries are also comparable in their capacity as strong fiscal stewards.[11] This alludes to the importance of reporting and monitoring expenditure data from countries that are less homogeneous. Expenditure data from OECD countries are typically used in studies because it is open, easily accessible, and regularly updated. Currently, health expenditure data for low- and middle-income countries are not comparable between countries or easily retrievable, and are inaccessible, or outdated. Given that prioritizing public health cultivates workforce productivity and economic growth, reliable and available health expenditure data from low- and middle-income countries can advance economic development.[31] It could be used to improve efficiencies for the limited resources allocated to public health to improve the precision in

decision-making to target vulnerable populations and to achieve greater value. A recommendation from these results is for organizations, like WHO or the OECD, to provide technical assistance to build global capacity to report and monitor public health spending data. These organizations can facilitate technical assistance and have the capacity and infrastructure to host digital data. Countries could establish policies that strengthen infrastructure and workforce capacities to ensure that systems are interoperable.[110] Establishing a data governance framework is a mechanism to collect, manage, and disseminate consistent and complete data from different data providers in a centralized and coordinated way.[110] There have been calls for this mechanism to facilitate national and global data comparisons for epidemiological data but can be easily translated to expenditure data.[110]

Creating a culture of making expenditure data available, reliable, and credible in low-and middle-income countries can lead to meaningful policies and strategies in transitioning away from development assistance in health (DAH). DAH are financial and in-kind contributions from donor organizations to low- and middle-income countries.[119] From 2000 to 2019 DAH ballooned over 30% from $12.4 billion to $40.6 billion.[119] Countries depend on these funds to improve health systems, prevent and control specific diseases, and contribute in funding the gap in transnational global functions.[120] As low- and middle-income countries experience economic growth, they are eligible to transition away from DAH and depend on domestic sources of funds.[119] Self-dependency allows low- and middle-income countries to set health priorities and allocate funds based on their specific needs and context. However, without strong financing systems in place and aligning expenditures with health outcomes, population-level inequities and inequalities can

be exacerbated. Individuals are forced to pay out-of-pocket for health services, which may be of poor quality, and this can lead to catastrophic household health spending and eventually affect economic progress.[119] Health expenditure data that is easily available and accessible can be used to reveal spending patterns and inform policymakers how best to allocate scarce resources for greater public health impact. This can contribute to making countries' health systems more robust and lead to greater self-sufficiency, ideally contributing to improved health coverage for all.

Limitations

There are limitations to recognize as part of this analysis. The sample size of the time series is a key limitation. It may also have resulted in spurious findings and possibly a reason for inconclusive results from the cross-correlation function. The time series was 20 years of data, which may not be sufficient for governments to make changes in the level of preventive care spending and for those changes to impact health outcomes. Because of the limited time series, the cross-correlation was not estimated beyond four lags to avoid poor approximations of the correlation coefficients. The decision to study four lags was a result of the small sample size to avoid the risk of minimizing the time series further. Longer lags, beyond four resulted in, at times, greater absolute results or a change in direction. For example, Italy had inconclusive results with two negative correlations and two positive correlations. If eight lags were used, all four correlations would have been positive. A lag of eight means that changes in health outcomes occur eight years after a change in preventive care expenditures. However, this

further reduces the values across the time series and forces the correlation on a smaller set of values.

The sample of countries that report expenditure data is another limitation. There are 38 member countries in the OECD, but only 30 countries reported total preventive care expenditures from 2000 to 2019. Of those countries, 10 had missing values during the study period, which truncated the time series and the available data for analysis. The number of countries that reported by prevention activities was much less than those that reported total prevention expenditures. In 2019, 21 of 38 countries reported the amount spent on health promotion and disease prevention activities. The countries that do not report activity level data may introduce bias as illustrated by a difference from 3% to 2% in the average preventive care expenditure, shown in Figure 6 and 7. This indicates that the countries that did not report by activity (Figure 6) are significant enough to reduce the average by 1%. Also, the lack of a clear definition of what constitutes preventive care subcategories resulted in a limited number of countries to report expenditures for emergency preparedness and response. This may have allowed for systemic bias which could distort cross-country comparisons for the descriptive analysis. Any missing value may indicate that definitional issues for preventive care exist, it does not necessarily mean that funds were not spent in a preventive care activity. A missing value could mean that funds were spent but not reported. This could suggest a possible overall underestimate in country-specific and average amount allocated to preventive care. Because of these limitations, the data are too noisy for aggregate and category empirical analysis which further adds to the need to improve the quality of expenditure data reported by OECD countries.

Another possible limitation occurred in the selection of ARIMA models during the data cleaning phase before running the cross-correlation function. ARIMA models were selected based on a commonly used diagnostic approach of p-values of corresponding statistics and visual inspection of graphs like the QQ plot and histogram. Diagnostic results were not always definitive and called for a combination of using a commonly used diagnostic approaches and knowledge of the data to make the best judgement. The selection of another ARIMA model may have changed the strength of the correlation but may not have changed the direction of the coefficient. Thereby estimating the parameters of a variable as an ARIMA (0,1,1) instead of as an ARIMA (1,1,0), it may have marginally altered the strength to be closer or farther to 1 or -1, but the direction would have stayed consistent.

Conclusion

This dissertation provided the opportunity to explore the relationship between preventive care expenditures and health outcomes to assess the extent to which public funds improve health outcomes. However, as a result of conducting the analysis, this dissertation could not make a definitive relationship due to expenditure data lacking reliability, credibility, availability, and accessibility. Improving the quality of expenditure data can be measured against health outcomes to ensure the sustainability of a health system. It can be used to assess the extent to which the population has access to high-quality and low-cost health care without having to pay catastrophic out-of-pocket expenses. Governments have the opportunity to harness the social

and economic deficits exposed by the current pandemic to invest in and improve population health and strengthen fiscal accountability.

Results of the cross-correlation and possible explanation presented through the descriptive analysis can be used as the underpinning to further explore the association between expenditures in disease prevention and health promotion with health outcomes. Without sustained and predictable funding, it will be challenging to study the relationship between preventive care spending and health outcomes. It is also important to understand the nuances of policies and practices to ensure an equitable distribution and fiscal stewardship of public funds. Variation between financing systems could offer financial protection, which may lower barriers in accessing clinical preventive services. Having expenditure data from economic and geographically diverse countries can support cross-country analysis.

Two recommendations are products of this analysis. First, establish a global expert group to gain consensus on a basic standard for public health programs. Inconsistent funding levels have led to a fragmented public health infrastructure and the current funding mechanisms.[112] Without a minimum or basic standard, it is the budget that dictates the services or programs offered to the public.[112] By establishing a comparable benchmark, countries could determine funding gaps wherever deficits exist. The second recommendation is for multi-lateral institutions like the OECD or WHO to provide technical assistance to low- and middle-income countries to regularly report public health spending. These institutions also have the infrastructure and the capacity to publicly host the data. These results and recommendations can initiate improvements in the

reliability, credibility, availability, and accessibility of public health expenditure data. This could lead to further analysis which may provide economic justification for sustained and predictable funding for public health. Additional research showing support for economic development and growth outcomes associated with prevention spending may serve to support policy makers in making better informed allocation decisions and spending targets consistent with improving health outcomes.

Relative to the growth rate of GDP and total health spending, the consistent low growth rate in prevention since 2010 demonstrates chronic underfunding of public health. The volatility in the preventive care spending per capita illustrates the cycle of panic and neglect in public health.[104] In the face of a public health emergency, governments take a reactionary response by allocating a significant amount of resources until a new headline takes interest.[104] New calls for a sustained level and positive growth rate for public health funding have resonated across the U.S. and globally as the COVID-19 pandemic highlighted the alarming inadequacies of public health systems.[69] DeSalvo and colleagues (2019) estimated that $4.5 billion per year is required to adequately carry out public health activities in the U.S.[18] Perhaps the economic and personal toll of the COVID-19 pandemic, especially in high-income countries, will break the cycle of panic and neglect. Beyond having a dedicated funding stream, it is critical to develop policies that will allocate funds to programs equitably, improve systems, and strengthen the workforce for a more sustainable public health system.

Appendix

Appendix A. Country Codes

Code	Country
AUS	Australia
AUT	Austria
CAN	Canada
CRI	Costa Rica
CZE	Czechia
DNK	Denmark
EST	Estonia
FIN	Finland
FRA	France
DEU	Germany
GRC	Greece
HUN	Hungary
ISL	Iceland
IRL	Ireland
ITA	Italy
JPN	Japan
KOR	Korea
LVA	Latvia
LTU	Lithuania
LUX	Luxembourg
MEX	Mexico
NLD	Netherlands
NOR	Norway
POL	Poland
PRT	Portugal
SVK	Slovakia
SVN	Slovenia
ESP	Spain
SWE	Sweden
CHE	Switzerland
GBR	United Kingdom
USA	United States

Appendix B. Durbin-Watson test statistic and p-value

Country	PGDP	Conclusion	PCAP	Conclusion	HALE	Conclusion	LE	Conclusion
Australia	0.445, <.0001	autocorrelation	0.184, <.0001	autocorrelation	0.040, <.0001	autocorrelation	0.044, <.0001	autocorrelation
Austria	0.283, <.0001	autocorrelation	0.134, <.0001	autocorrelation	0.033, <.0001	autocorrelation	0.070, <.0001	autocorrelation
Belgium	1.122, 0.0257	autocorrelation	0.981, 0.0105	autocorrelation	0.049, <.0001	autocorrelation	0.120, <.0001	autocorrelation
Canada	0.495, <.0001	autocorrelation	0.123, <.0001	autocorrelation	0.042, <.0001	autocorrelation	0.030, <.0001	autocorrelation
Czechia	0.398, <.0001	autocorrelation	0.215, <.0001	autocorrelation	0.038, <.0001	autocorrelation	0.043, <.0001	autocorrelation
Denmark	0.518, <.0001	autocorrelation	0.288, <.0001	autocorrelation	0.028, <.0001	autocorrelation	0.041, <.0001	autocorrelation
Estonia	0.336, <.0001	autocorrelation	0.163, <.0001	autocorrelation	0.040, <.0001	autocorrelation	0.036, <.0001	autocorrelation
Finland	0.176, <.0001	autocorrelation	0.162, <.0001	autocorrelation	0.029, <.0001	autocorrelation	0.043, <.0001	autocorrelation
France	1.849, 0.3653	autocorrelation	1.508, 0.1279	autocorrelation	0.035, <.0001	autocorrelation	0.074, <.0001	autocorrelation
Germany	0.252, <.0001	autocorrelation	0.073, <.0001	autocorrelation	0.046, <.0001	autocorrelation	0.091, <.0001	autocorrelation
Greece	0.836, 0.0033	autocorrelation	0.786, 0.0021	autocorrelation	0.067, <.0001	autocorrelation	0.156, <.0001	autocorrelation
Hungary	0.242, <.0001	autocorrelation	0.357, <.0001	autocorrelation	0.040, <.0001	autocorrelation	0.053, <.0001	autocorrelation
Iceland	0.49, <.0001	autocorrelation	0.361, <.0001	autocorrelation	0.032, <.0001	autocorrelation	0.274, <.0001	autocorrelation
Italy	0.126, <.0001	autocorrelation	0.126, <.0001	autocorrelation	0.035, <.0001	autocorrelation	0.105, <.0001	autocorrelation
Japan	0.102, <.0001	autocorrelation	0.068, <.0001	autocorrelation	0.046, <.0001	autocorrelation	0.069, <.0001	autocorrelation

Korea	0.077, <.0001	autocorrelation	0.057, <.0001	autocorrelation	0.030, <.0001	autocorrelation	0.032, <.0001	autocorrelation
Latvia	1.407, 0.1074	autocorrelation	1.006, 0.0146	autocorrelation	0.067, <.0001	autocorrelation	0.070, <.0001	autocorrelation
Lithuania	0.433, <.0001	autocorrelation	0.248, <.0001	autocorrelation	0.101, <.0001	autocorrelation	0.099, <.0001	autocorrelation
Luxembourg	0.770, 0.0008	autocorrelation	0.700, 0.0004	autocorrelation	0.031, <.0001	autocorrelation	0.082, <.0001	autocorrelation
Mexico	0.440, <.0001	autocorrelation	0.348, <.0001	autocorrelation	0.350, <.0001	autocorrelation	0.642, 0.0002	autocorrelation
Netherlands	0.344, <.0001	autocorrelation	0.347, <.0001	autocorrelation	0.036, <.0001	autocorrelation	0.042, <.0001	autocorrelation
Norway	0.282, <.0001	autocorrelation	0.133, <.0001	autocorrelation	0.050, <.0001	autocorrelation	0.057, <.0001	autocorrelation
Poland	0.743, <0.0010	autocorrelation	0.902, 0.0047	autocorrelation	0.040, <.0001	autocorrelation	0.059, <.0001	autocorrelation
Portugal	0.157, <.0001	autocorrelation	0.199, <.001	autocorrelation	0.030, <.0001	autocorrelation	0.057., <.0001	autocorrelation
Slovakia	0.603, 0.0001	autocorrelation	0.557, <.0001	autocorrelation	0.040, <.0001	autocorrelation	0.045, <.0001	autocorrelation
Slovenia	0.756, 0.0012	autocorrelation	0.954, 0.0072	autocorrelation	0.048, <.0001	autocorrelation	0.072, <.0001	autocorrelation
Spain	0.325, <.001	autocorrelation	0.297, <.0001	autocorrelation	0.032, <.0001	autocorrelation	0.072, <.0001	autocorrelation
Sweden	0.273, <.0001	autocorrelation	0.118, <.0001	autocorrelation	0.035, <.0001	autocorrelation	0.066, <.0001	autocorrelation
Switzerland	0.816, 0.0014	autocorrelation	0.851, 0.0020	autocorrelation	0.035, <.0001	autocorrelation	0.066, <.0001	autocorrelation
United States	0.588, <.0001	autocorrelation	0.143, <.0001	autocorrelation	0.099, <.0001	autocorrelation	0.070, <.0001	autocorrelation

Note: PGDP is the preventive care expenditure as a proportion of GDP, PCAP is the preventive care expenditure per capita, HALE is the health adjusted life expectancy, and LE is life expectancy.

Appendix C. Augmented Dickey-Fuller results (τ, p-value)

Country	PCEGDP	Conclusion	PCECAP	Conclusion	HALE	Conclusion	LE	Conclusion
Australia	-1.20, 0.6516	non-stationarity	-0.53, 0.8627	non-stationarity	-4.35, 0.0034	non-stationarity	-5.14, 0.0007	non-stationarity
Austria	-2.92, 0.0619	non-stationarity	-2.65, 0.1004	non-stationarity	-2.30, 0.1813	non-stationarity	-1.53, 0.4950	non-stationarity
Belgium	-2.38, 0.1619	non-stationarity	2.25, 0.1992	non-stationarity	-1.20, 0.6508	non-stationarity	-0.80, 07960	non-stationarity
Canada	-2.84, 0.0708	non-stationarity	-1.85, 0.3458	non-stationarity	-3.86, 0.0095	non-stationarity	-3.24, 0.0333	non-stationarity
Czechia	-1.55, 0.4874	non-stationarity	-1.02, 0.7240	non-stationarity	-1.15, 0.6747	non-stationarity	-0.95, 0.7491	non-stationarity
Denmark	-1.73, 0.4014	non-stationarity	-0.70, 0.8229	non-stationarity	-2.03, 0.2730	non-stationarity	-0.47, 0.8779	non-stationarity
Estonia	-0.15, 0.9296	non-stationarity	0.60, 0.9856	non-stationarity	-1.28, 0.6151	non-stationarity	-0.51, 0.8696	non-stationarity
Finland	-1.21, 0.6476	non-stationarity	-1.07, 0.7068	non-stationarity	-2.18, 0.2195	non-stationarity	-1.48, 0.5198	non-stationarity
France	-3.81, 0.0104	non-stationarity*	-3.41, 0.0235	non-stationarity*	-2.35, 0.1681	non-stationarity	-1.31, 0.6048	non-stationarity
Germany	-1.26, 0.6244	non-stationarity	0.3, 0.9715	non-stationarity	-3.30, 0.0297	non-stationarity	-1.46, 0.5333	non-stationarity
Greece	-2.14, 0.2322	non-stationarity	-1.94, 0.3073	non-stationarity	-2.11, 0.2444	non-stationarity	-1.38, 0.5706	non-stationarity
Hungary	-0.82, 0.7904	non-stationarity	-1.45, 0.5354	non-stationarity	-1.64, 0.4466	non-stationarity	-1.17, 0.6665	non-stationarity
Iceland	-2.76, 0.0822	non-stationarity	-2.59, 0.1118	non-stationarity	-2.11, 0.2440	non-stationarity	-2.11, 0.2410	non-stationarity
Italy	-0.36, 0.8982	non-stationarity	-0.04, 0.9430	non-stationarity	-3.41, 0.0238	non-stationarity	-0.87, 0.7748	non-stationarity
Japan	0.04, 0.9504	non-stationarity	0.83, 0.9915	non-stationarity	-1.33, 0.5942	non-stationarity	-0.84, 0.7844	non-stationarity

Korea	-0.34, 0.9017	non-stationarity	0.45, 0.9797	non-stationarity	-6.59, <.0001	non-stationarity	-1.78, 0.3795	non-stationarity
Latvia	-2.90, 0.0688	non-stationarity	-2.32, 0.1796	non-stationarity	-0.15, 09295	non-stationarity	-0.50, 0.8696	non-stationarity
Lithuania	-0.01, 0.9427	non-stationarity	1.26, 0.9967	non-stationarity	0.51, 0.9825	non-stationarity	0.88, 0.9927	non-stationarity
Luxembourg	-2.38, 0.1610	non-stationarity	-2.43, 0.1465	non-stationarity	-3.24, 0.0330	non-stationarity	-0.83, 0.7887	non-stationarity
Mexico	-3.13, 0.0414	non-stationarity	-2.96, 0.0572	non-stationarity	-2.90, 0.0639	non-stationarity	-2.21, 0.2096	non-stationarity
Netherlands	-0.66, 0.8349	non-stationarity	-1.23, 0.6387	non-stationarity	-4.12, 0.0055	non-stationarity	-1.53, 0.4957	non-stationarity
Norway	-1.07, 0.7029	non-stationarity	-1.17, 0.6610	non-stationarity	-2.22, 0.2077	non-stationarity	-1.13, 0.6808	non-stationarity
Poland	-3.49, 0.0217	non-stationarity	-2.39, 0.1593	non-stationarity	-1.90, 0.3247	non-stationarity	-1.34, 0.5882	non-stationarity
Portugal	-0.73, 0.8171	non-stationarity	-1.02, 0.7252	non-stationarity	-3.58, 0.0170	non-stationarity	-1.24, 0.6333	non-stationarity
Slovakia	-2.24, 0.1990	non-stationarity	-2.22, 0.2050	non-stationarity	-0.56, 0.8584	non-stationarity	0.06, 0.9532	non-stationarity
Slovenia	-1.97, 0.2966	non-stationarity	-2.17, 0.2248	non-stationarity	-1.22, 0.6445	non-stationarity	-1.03, 0.7200	non-stationarity
Spain	-2.50, 0.1316	non-stationarity	-2.44, 0.1448	non-stationarity	-3.01, 0.0520	non-stationarity	-0.98, 0.7394	non-stationarity
Sweden	-0.98, 0.7378	non-stationarity	-0.48, 0.8742	non-stationarity	-3.92, 0.0084	non-stationarity	-0.24, 0.9175	non-stationarity
Switzerland	-1.74, 0.3985	non-stationarity	-2.73, 0.0868	non-stationarity	-3.84, 0.0099	non-stationarity	-1.52, 0.5013	non-stationarity
United States	-2.50, 0.1300	non-stationarity	-2.20, 0.2132	non-stationarity	-1.77, 0.3828	non-stationarity	-2.19, 0.2152	non-stationarity

Note: PGDP is the preventive care expenditure as a proportion of GDP, PCAP is the preventive care expenditure per capita, HALE is the health adjusted life expectancy, and LE is life expectancy. * Denotes that the p-value is significant and suggests stationarity but will treat variables as non-stationarity to be consistent with other variables in the analysis

Appendix D. Diagnostics results from differencing (p-value of X^2)

Country	PCEGDP	Conclusion	PCECAP	Conclusion	HALE	Conclusion	LE	Conclusion
Australia	0.1652	Stationarity	0.1493	stationarity	0.034*	non-stationarity	0.031*	non-stationarity
Austria	0.9408	stationarity	0.6034*	non-stationarity	0.9035	stationarity	0.4418	stationarity
Belgium	0.6162	stationarity	0.5423	stationarity	0.6613	stationarity	0.0473*	non-stationarity
Canada	0.0141*	non-stationarity	0.013*	non-stationarity	0.001*	non-stationarity	0.0375*	non-stationarity
Czechia	0.291	stationarity	0.174	stationarity	0.8702	stationarity	0.5161	stationarity
Denmark	0.8267	stationarity	0.9445	stationarity	0.0223*	non-stationarity	0.2083	stationarity
Estonia	0.7691	stationarity	0.3326	stationarity	0.7938	stationarity	0.8576	stationarity
Finland	0.5661	stationarity	0.3413	stationarity	0.1134	stationarity	0.1962	stationarity
France	0.1753	stationarity	0.1492	stationarity	0.8943	stationarity	0.658	stationarity
Germany	0.3093	stationarity	0.0763*	stationarity	0.4318	stationarity	0.3554*	non-stationarity
Greece	0.4811	stationarity	0.5471	stationarity	0.5814	stationarity	0.0339*	non-stationarity
Hungary	0.9927	stationarity	0.8439	stationarity	0.805	stationarity	0.11	stationarity
Iceland	0.9972	stationarity	0.9926	stationarity	0.837	stationarity	0.2712	stationarity
Italy	0.8808	stationarity	0.5651	stationarity	0.3326	stationarity	0.1093*	non-stationarity
Japan	0.3959	stationarity	0.4872	stationarity	0.6522	stationarity	0.4498	stationarity
Korea	0.3427	stationarity	0.274	stationarity	0.0015*	non-stationarity	0.8326	stationarity
Latvia	0.3184	stationarity	0.4214	stationarity	0.3359	stationarity	0.4927	stationarity
Lithuania	0.33	stationarity	0.9093	stationarity	0.8025	stationarity	0.7167	stationarity
Luxembourg	0.4279	stationarity	0.5202	stationarity	0.5234	stationarity	0.4899	stationarity
Mexico	0.9533	stationarity	0.9425	stationarity	0.8543	stationarity	0.6762	stationarity
Netherlands	0.8938	stationarity	0.9623	stationarity	<.0001*	non-stationarity	0.7275	stationarity
Norway	0.4961	stationarity	0.9321	stationarity	0.0809	stationarity	0.6129	stationarity
Poland	0.9821	stationarity	0.9562	stationarity	0.359	stationarity	0.845	stationarity
Portugal	0.2703	stationarity	0.2992	stationarity	0.0344*	non-stationarity	0.1663	stationarity
Slovakia	0.8251*	non-stationarity	0.8066*	non-stationarity	0.0701*	non-stationarity	0.0754*	non-stationarity
Slovenia	0.3712*	non-stationarity	0.3912	stationarity	0.8629	stationarity	0.0024*	non-stationarity

Spain	0.7626	stationarity	0.9148*	non-stationarity	0.0331	non-stationarity	0.3631	stationarity
Sweden	0.3435	stationarity	0.1766*	non-stationarity	0.0655*	non-stationarity	0.2147	stationarity
Switzerland	0.3512	stationarity	0.2709	stationarity	0.1001	stationarity	0.1366	stationarity
United States	0.0121*	non-stationarity	0.0166*	non-stationarity	0.0036*	non-stationarity	0.1348	stationarity

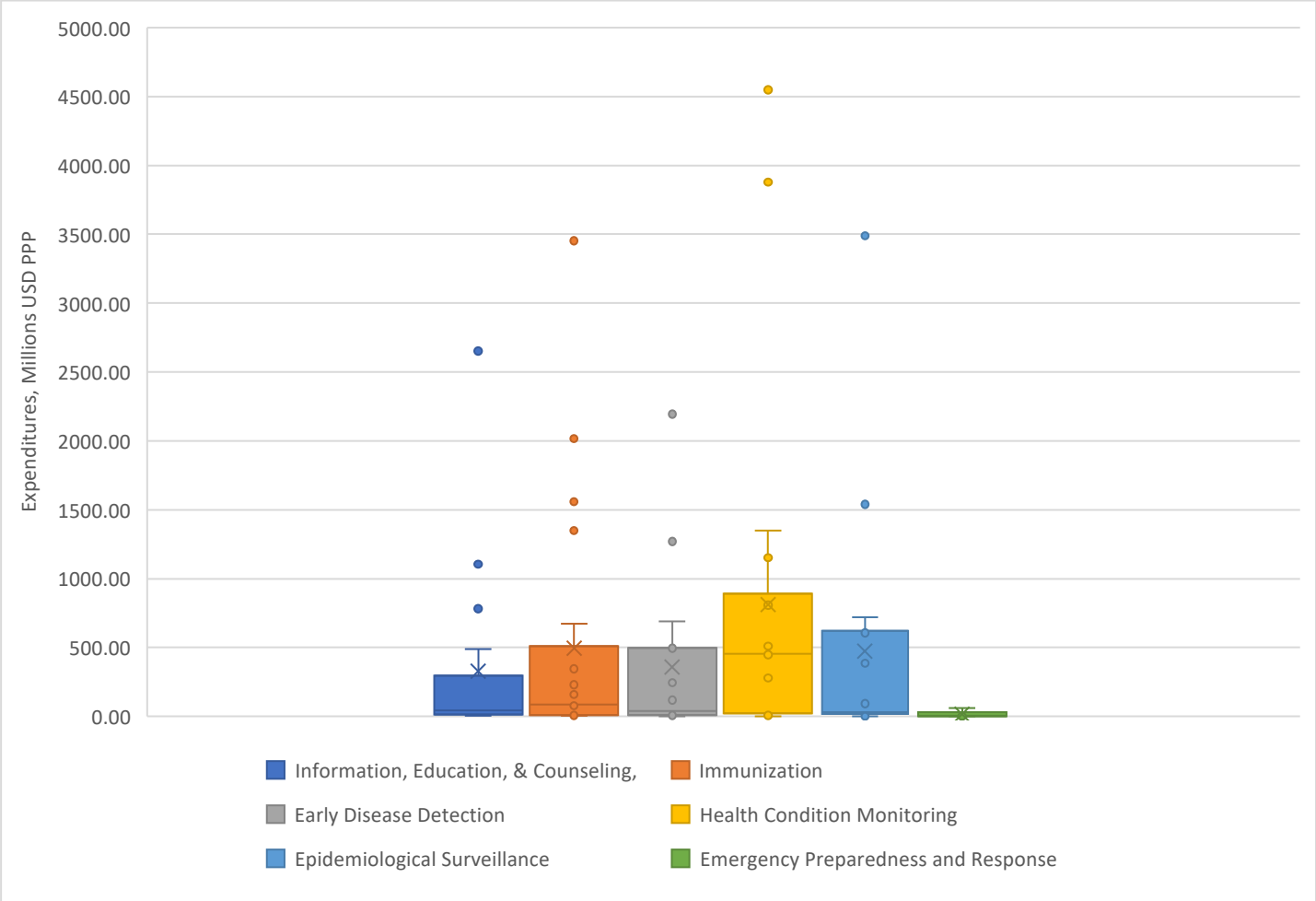
Note: PGDP is the preventive care expenditure as a proportion of GDP, PCAP is the preventive care expenditure per capita, HALE is the health adjusted life expectancy, and LE is life expectancy. *Denotes further modeling was necessary as a result of visual inspection of ACF and PACF.

Appendix E. Summary of variable parameters by country

Country	PCEGDP	PCECAP	HALE	LE
Australia	Difference	Difference	ARRIMA (1,1,0)	ARIMA (1,1,0)
Austria	Difference	ARIMA (1,1,0)	Difference	ARIMA (0,1,1)
Belgium	Difference	Difference	Difference	ARIMA (0,1,1)
Canada	ARIMA (1,1,1)	ARIMA (1,1,1)	ARIMA (1,1,0)	ARIMA (1,1,0)
Czechia	Difference	Difference	Difference	Difference
Denmark	Difference	Difference	MA (1,1)	Difference
Estonia	Difference	Difference	Difference	Difference
Finland	Difference	Difference	Difference	Difference
France	Difference	Difference	Difference	Difference
Germany	Difference	ARIMA (0,1,1)	Difference	ARIMA (1,1,0)
Greece	Difference	Difference	Difference	ARIMA (0,1,1)
Hungary	Difference	Difference	Difference	Difference
Iceland	Difference	Difference	Difference	Difference
Italy	Difference	Difference	Difference	ARIMA (1,1,0)
Japan	Difference	Difference	Difference	Difference
Korea	Difference	Difference	ARIMA (0,1,2)	Difference
Latvia	Difference	Difference	Difference	Difference
Lithuania	Difference	Difference	Difference	Difference
Luxembourg	Difference	Difference	Difference	Difference
Mexico	Difference	Difference	Difference	Difference
Netherlands	Difference	Difference	ARMA (0,1,1)	Difference
Norway	Difference	Difference	Difference	Difference
Poland	Difference	Difference	Difference	Difference
Portugal	Difference	Difference	ARIMA (1,1,0)	Difference
Slovakia	ARIMA (0,1,1)	ARIMA (0,1,1)	ARIMA (0,1,2)	ARIMA (0,1,2)
Slovenia	ARIMA (1,1,0)	Difference	Difference	ARIMA (1,1,0)
Spain	Difference	Difference	ARIMA (0,1,1)	ARIMA (0,1,1)
Sweden	Difference	ARIMA (0,1,1)	ARIMA (1,1,0)	Difference
Switzerland	Difference	Difference	Difference	Difference
United States	ARIMA (1,1,0)	ARIMA (0,1,1)	ARIMA (1,1,0)	Difference

Note: PGDP is the preventive care expenditure as a proportion of GDP, PCAP is the preventive care expenditure per capita, HALE is the health adjusted life expectancy, and LE is life expectancy

Appendix F. Distribution of Preventive Care Funds by Category of 21 OECD Countries, 2019

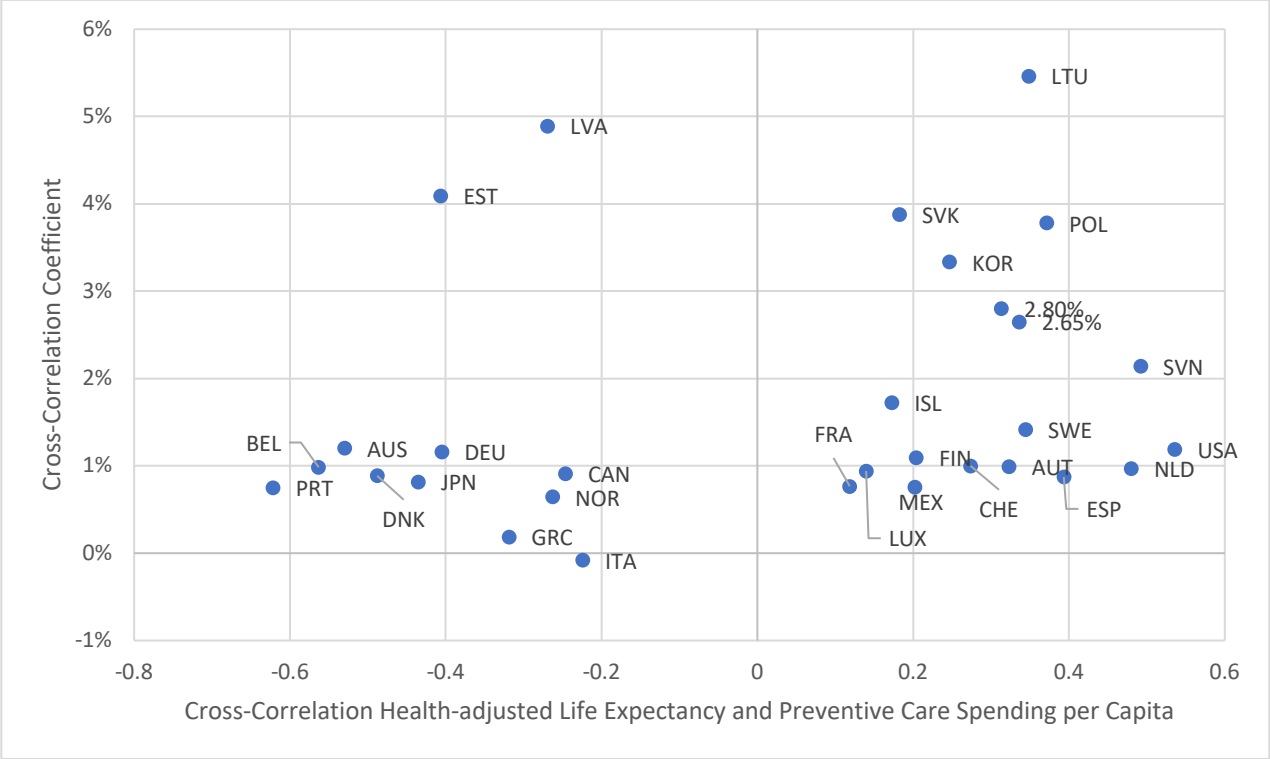


Appendix G. Summary of cross-correlation measures by country

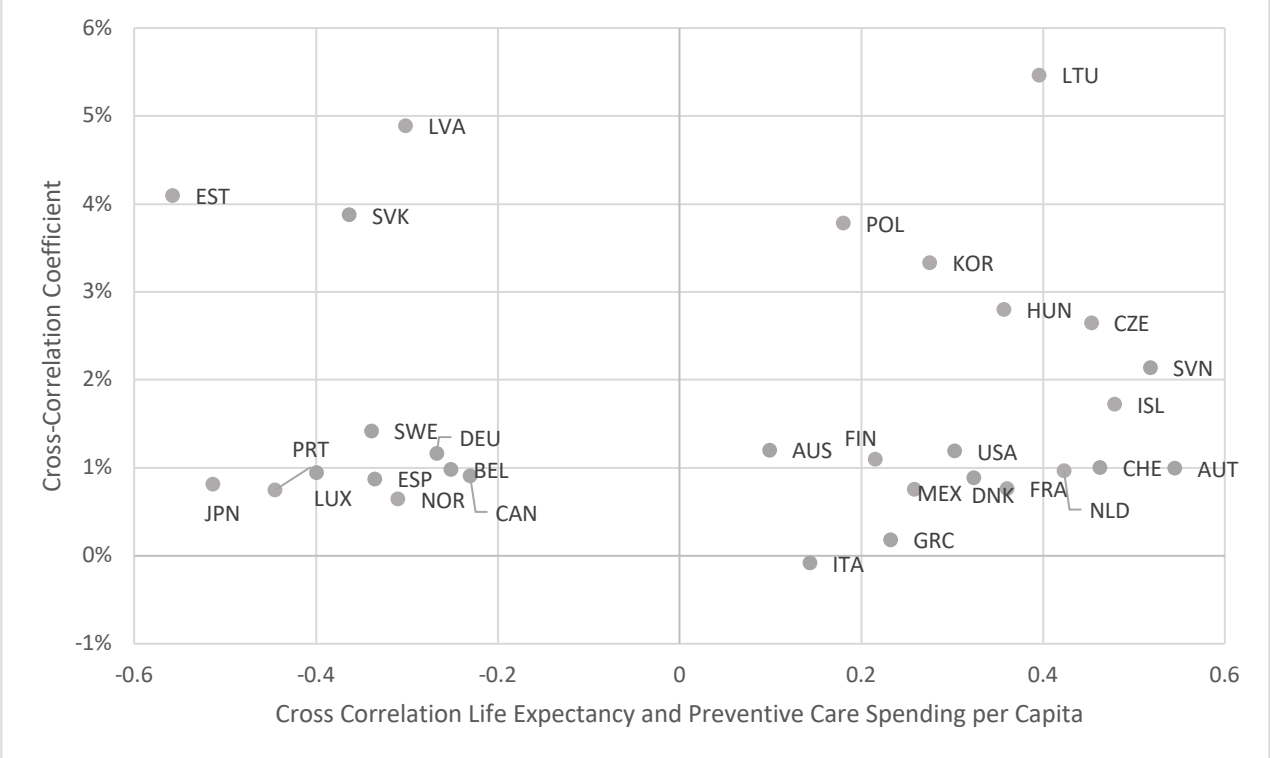
Country	HALE_PCAP	Lag	HALE_PGDP	Lag	LE_PCAP	Lag	LE_PGDP	Lag
Australia	-0.5300	0	-0.5589	0	0.0989	-4	0.2115	-4
Austria	0.3232	-3	0.3921	-3	0.5451	-3	-0.4436	-2
Belgium	-0.5630	-2	0.5328	-2	-0.2514	-2	-0.2025	-2
Canada	-0.2465	0	-0.2040	0	-0.2303	0	0.3013	-3
Czechia	0.3360	-2	0.3625	-2	0.4530	-2	0.4720	-2
Denmark	-0.4879	0	-0.4174	0	0.3241	-2	0.2320	-4
Estonia	-0.4064	0	-0.5453	-3	-0.5575	0	-0.4687	-3
Finland	0.2042	-1	0.3163	-1	0.2151	-1	0.3073	-1
France	0.1186	-3	0.0953	-3	0.3601	-3	0.3447	-3
Germany	-0.4051	-4	0.2485	-2	-0.2671	-4	-0.2444	-3
Greece	-0.3189	-2	-0.2780	-2	0.2323	-4	-0.5138	-2
Hungary	0.3134	-2	0.3325	-2	0.3568	-2	0.3871	-2
Iceland	0.1725	0	0.2048	0	0.4786	-2	0.5073	-2
Italy	-0.2244	-1	-0.1366	-1	0.1433	-2	0.1483	-2
Japan	-0.4348	-3	-0.4360	-3	-0.5132	-4	-0.4810	-4
Korea	0.2466	-3	0.2706	-4	0.2753	0	0.3538	0
Latvia	-0.269	-4	-0.3248	-4	-0.3015	-4	-0.3418	-4
Lithuania	0.3482	-3	0.3191	-3	0.3958	-3	0.3826	-3
Luxembourg	0.1395	-1	0.1559	-1	-0.3993	-4	-0.3803	-2
Mexico	0.2019	-4	0.1590	-4	0.2582	-4	0.2053	-4
Netherlands	0.4802	-3	0.3696	-3	0.4230	-2	0.4046	-3
Norway	-0.2628	-2	-0.2239	-2	-0.3096	-3	-0.3179	-2
Poland	0.3710	0	0.3188	0	0.1800	-3	0.1548	-3
Portugal	-0.6214	-2	-0.6124	-2	-0.4449	-2	-0.4053	-2
Slovakia	0.1824	-4	0.1713	-4	-0.3631	-2	-0.3109	-2
Slovenia	0.4919	0	-0.3052	-1	0.5182	0	-0.3231	-1
Spain	0.3932	-1	0.2532	-3	-0.3352	-4	0.3311	-3
Sweden	0.3440	-4	0.4824	-4	-0.3389	0	-0.4275	0
Switzerland	0.2737	-3	-0.2029	0	0.4628	-3	0.4160	-3
United States	0.5358	0	-0.3319	-1	0.3025	-3	-0.1370	-4

Note: PGDP is the preventive care expenditure as a proportion of GDP, PCAP is the preventive care expenditure per capita, HALE is the health adjusted life expectancy, and LE is life expectancy

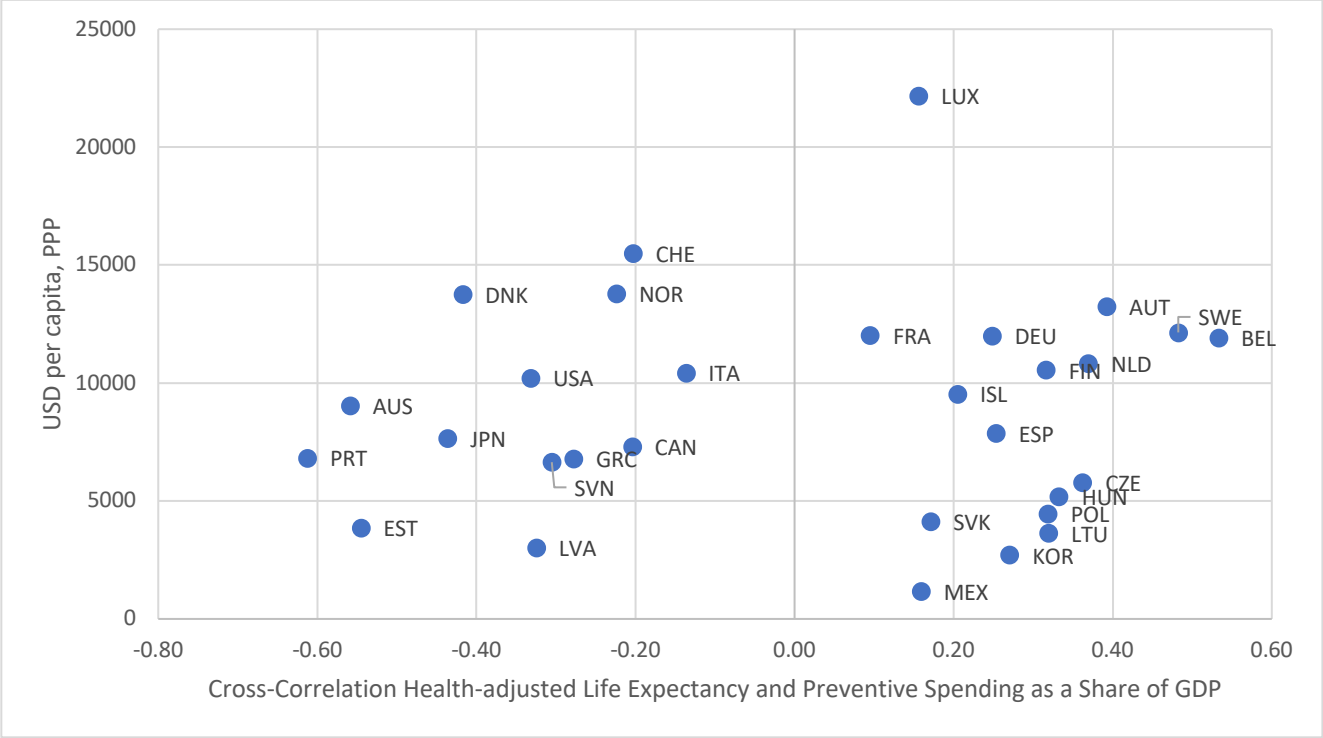
Appendix H1. Average annual GDP growth rate per capita by the cross-correlation of HALE and preventive care spending per capita



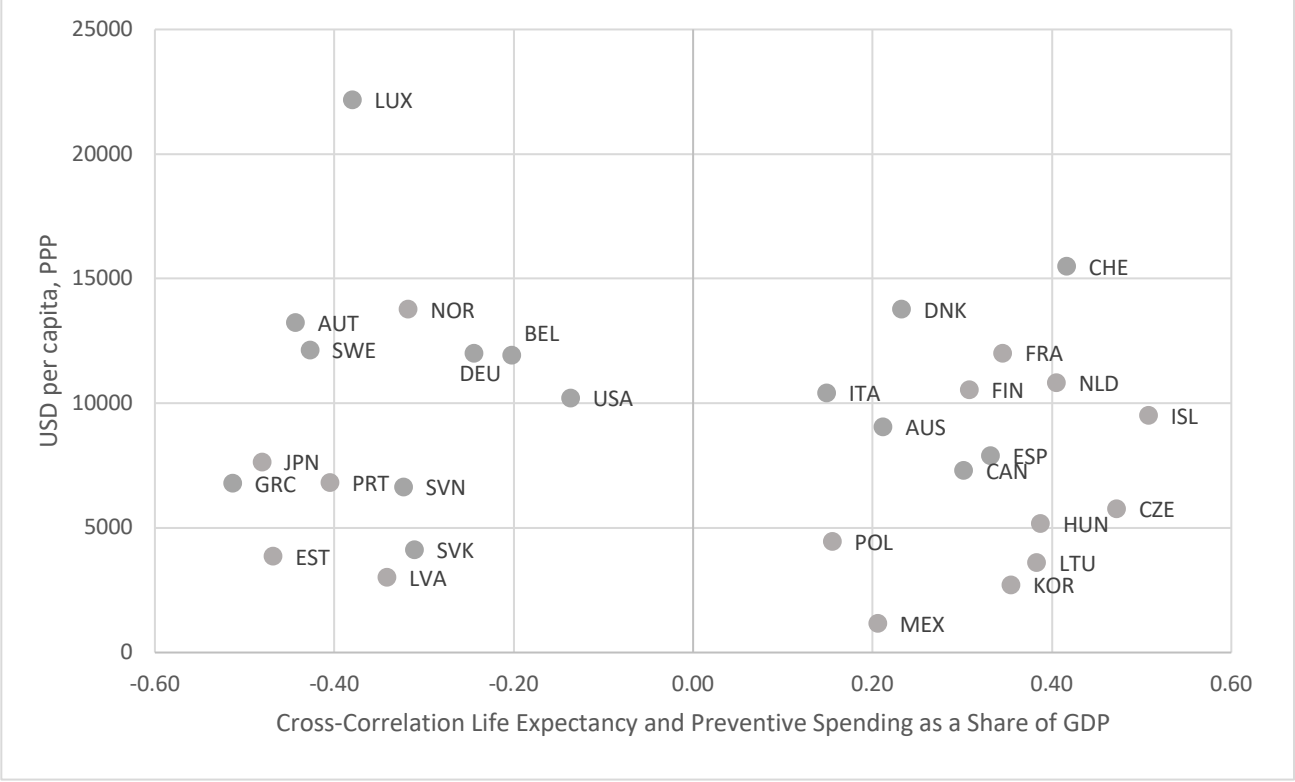
Appendix H2. Average annual GDP growth rate per capita by the cross-correlation of LE and preventive care spending per capita



Appendix I1. Average social protection expenditure per capita by the cross-correlation of HALE and preventive care spending as a share of GDP



Appendix I2. Average social protection expenditure per capita by the cross-correlation of LE and preventive care spending as a share of GDP



References

1. Gmeinder M, Morgan D, Mueller M. How much do OECD countries spend on prevention? Published online December 11, 2017.

2. Frieden TR. The Future of Public Health. *N Engl J Med*. 2015;373(18):1748-1754. doi:10.1056/NEJMsa1511248

3. Braveman P, Gottlieb L. The Social Determinants of Health: It's Time to Consider the Causes of the Causes. *Public Health Rep*. 2014;129(Suppl 2):19-31.

4. Masters R, Anwar E, Collins B, Cookson R, Capewell S. Return on investment of public health interventions: a systematic review. *J Epidemiol Community Health*. 2017;71(8):827-834. doi:10.1136/jech-2016-208141

5. Honoré PA, Zometa C, Thomas C, Edmiston A. The Public Health Uniform National Data System (PHUND$): A Platform for Monitoring Fiscal Health and Sustainability of the Public Health System. *J Public Health Manag Pract*. 2019;25(4):366-372. doi:10.1097/PHH.0000000000000838

6. Honoré PA, Scott W. *Priority Areas for Improvement of Quality in Public Health*. Department of Health and Human Services; 2010.

7. OECD, Eurostat, WHO. A System of Health Accounts. *OECD Publ*. Published online 2011. doi:10.1787/9789264116016-en

8. Kenton W. Organisation for Economic Co-operation and Development (OECD). Investopedia. Accessed February 8, 2021. https://www.investopedia.com/terms/o/oecd.asp

9. OECD. Our global reach. Accessed February 6, 2021. https://www.oecd.org/about/members-and-partners/

10. Mueller M, Morgan D. New insights into health financing: First results of the international data collection under the System of Health Accounts 2011 framework. *Health Policy*. 2017;121(7):764-769. doi:10.1016/j.healthpol.2017.04.008

11. Rechel B. Funding for public health in Europe in decline? *Health Policy*. 2019;123(1):21-26. doi:10.1016/j.healthpol.2018.11.014

12. Amadeo K, Boyle MJ. The OECD and Member Countries. The Balance. Published January 16, 2021. Accessed February 8, 2021. https://www.thebalance.com/organization-economic-cooperation-development-3305871

13. Savedoff WD. What Should A Country Spend On Health Care. *Health Aff (Millwood)*. 2007;26(4):962-970. doi:10.1377/hlthaff.26.4.962

14. Mcintyre D, Meheus F, Røttingen J-A. What level of domestic government health expenditure should we aspire to for universal health coverage? *Health Econ Policy Law*. 2017;12(2):125-137. doi:10.1017/S1744133116000414

15. Satcher D. The Prevention Challenge And Opportunity. *Health Aff (Millwood)*. 2006;25(4):1009-1011. doi:10.1377/hlthaff.25.4.1009

16. Mays GP, Smith SA. Evidence links increases in public health spending to declines in preventable deaths. *Health Aff Proj Hope*. 2011;30(8):1585-1593. doi:10.1377/hlthaff.2011.0196

17. Wang F. The roles of preventive and curative health care in economic development. *PLOS ONE*. 2018;13(11):e0206808. doi:10.1371/journal.pone.0206808

18. DeSalvo KB. Public Health 3.0: A Call to Action for Public Health to Meet the Challenges of the 21st Century. *Prev Chronic Dis*. 2017;14. doi:10.5888/pcd14.170017

19. Kreuter MW, Thompson T, McQueen A, Garg R. Addressing Social Needs in Health Care Settings: Evidence, Challenges, and Opportunities for Public Health. *Annu Rev Public Health*. 2021;42(1):329-344. doi:10.1146/annurev-publhealth-090419-102204

20. Hahn RA, Truman BI, Williams DR. Civil rights as determinants of public health and racial and ethnic health equity: Health care, education, employment, and housing in the United States. *SSM - Popul Health*. 2017;4:17-24. doi:10.1016/j.ssmph.2017.10.006

21. Hoffman SJ, Creatore MI, Klassen A, Lay AM, Fafard P. Building the political case for investing in public health and public health research. *Can J Public Health*. Published online May 6, 2019.

22. Himmelstein DU, Woolhandler S. Public Health's Falling Share of US Health Spending. *Am J Public Health*. 2016;106(1):56-57. doi:10.2105/AJPH.2015.302908

23. Maani N, Galea S. COVID-19 and Underinvestment in the Public Health Infrastructure of the United States. *Milbank Q*. 2020;98(2). doi:10.1111/1468-0009.12463

24. Benjamin GC. Ensuring health equity during the COVID-19 pandemic: the role of public health infrastructure. *Rev Panam Salud Pública*. 2020;44:e70. doi:10.26633/rpsp.2020.70

25. Devi S. US public health budget cuts in the face of COVID-19. *Lancet Infect Dis*. 2020;20(4):415. doi:10.1016/S1473-3099(20)30182-1

26. Kostova D, Husain MJ, Sugerman D, et al. Synergies between Communicable and Noncommunicable Disease Programs to Enhance Global Health Security. *Emerg Infect Dis*. 2017;23(Suppl 1):S40-S46. doi:10.3201/eid2313.170581

27. Cutler DM, Summers LH. The COVID-19 Pandemic and the $16 Trillion Virus. *JAMA*. 2020;324(15):1495-1496. doi:10.1001/jama.2020.19759

28. Teixeira da Silva JA, Tsigaris P. Estimating worldwide costs of premature mortalities caused by COVID-19. *J Health Res*. 2021;ahead-of-print(ahead-of-print). doi:10.1108/JHR-09-2020-0406

29. Raghupathi V, Raghupathi W. Healthcare Expenditure and Economic Performance: Insights From the United States Data. *Front Public Health*. 2020;8. doi:10.3389/fpubh.2020.00156

30. Grossman M. On the concept of health capital and the demand for health. *J Polit Econ*. 1972;80(2):223-255.

31. Bloom DE, Canning D, Kotschy R, Prettner K, Schünemann JJ. *Health and Economic Growth: Reconciling the Micro and Macro Evidence*. National Bureau of Economic Research; 2019.

32. Bloom DE, Canning D, Sevilla J. The Effect of Health on Economic Growth: A Production Function Approach. *World Dev*. 2004;32(1):1-13. doi:10.1016/j.worlddev.2003.07.002

33. Papanicolas I, Woskie LR, Jha AK. Health Care Spending in the United States and Other High-Income Countries. *JAMA*. 2018;319(10):1024-1039. doi:10.1001/jama.2018.1150

34. Hermosilla SC, Kujawski SA, Richards CA, Muennig PA, Galea S, El-Sayed AM. An Ounce of Prevention: Deaths Averted From Primary Prevention Interventions. *Am J Prev Med*. 2017;52(6):778-787. doi:10.1016/j.amepre.2017.01.002

35. The Commonwealth Fund. U.S. Health Care from a Global Perspective, 2019: Higher Spending, Worse Outcomes? Accessed March 11, 2021. https://www.commonwealthfund.org/publications/issue-briefs/2020/jan/us-health-care-global-perspective-2019

36. Turner B. Putting Ireland's health spending into perspective. *The Lancet*. 2018;391(10123):833-834. doi:10.1016/S0140-6736(18)30461-6

37. Turner B. The new system of health accounts in Ireland: what does it all mean? *Ir J Med Sci*. 2017;186(3):533-540. doi:10.1007/s11845-016-1519-2

38. OECD. *Health at a Glance 2019: OECD Indicators*. OECD Publishing; 2019.

39. Karanikolos M, Mladovsky P, Cylus J, et al. Financial crisis, austerity, and health in Europe. *Lancet Lond Engl*. 2013;381(9874):1323-1331. doi:10.1016/S0140-6736(13)60102-6

40. Wang K-M. Health care expenditure and economic growth: Quantile panel-type analysis. *Econ Model*. 2011;28(4):1536-1549. doi:10.1016/j.econmod.2011.02.008

41. IMF World Economic Outlook (WEO) - Coping with High Debt and Sluggish Growth, October 2012 -- Table of Contents. IMF. Accessed September 27, 2021. https://www.imf.org/en/Publications/WEO/Issues/2016/12/31/Coping-with-High-Debt-and-Sluggish-Growth

42. Jaba E, Balan CB, Robu I-B. The Relationship between Life Expectancy at Birth and Health Expenditures Estimated by a Cross-country and Time-series Analysis. *Procedia Econ Finance*. 2014;15:108-114. doi:10.1016/S2212-5671(14)00454-7

43. Healthy Life Expectancy (HALE). Accessed March 23, 2021. https://portal.who.int/triplebillions/Home/FAQDetails?faqPage=_FAQHALE

44. Kyu HH, Abate D, Abate KH, et al. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 2018;392(10159):1859-1922. doi:10.1016/S0140-6736(18)32335-3

45. WHO. The Triple Billion targets: Methods to deliver impact. Accessed July 23, 2020. https://www.who.int/data/stories/the-triple-billion-targets-a-visual-summary-of-methods-to-deliver-impact

46. Poullier J-P, Hernandex P, Kawabata K, Savedoff WD. Patterns of Global Health Expenditures: Results for 191 Countries. In: *Health System Performance Assessment Debates, Methods, and Empiricism*. WHO; 2003:195-203.

47. Ariste R, Di Matteo L. Value for money: an evaluation of health spending in Canada. *Int J Health Econ Manag*. 2017;17(3):289-310. doi:10.1007/s10754-016-9204-6

48. Deshpande N, Kumar A, Ramaswami R. *The Effect of National Healthcare Expenditure on Life Expectancy*. World Bank; 2014. Accessed May 21, 2021. https://smartech.gatech.edu/handle/1853/51648

49. Obrizan M, Wehby GL. Health Expenditures and Global Inequalities in Longevity. *World Dev*. 2018;101:28-36. doi:10.1016/j.worlddev.2017.08.003

50. Cutler DM, Rosen AB, Vijan S. The Value of Medical Spending in the United States, 1960–2000. *N Engl J Med*. 2006;355(9):920-927. doi:10.1056/NEJMsa054744

51. Nixon J, Ulmann P. The relationship between health care expenditure and health outcomes. Evidence and caveats for a causal link. *Eur J Health Econ HEPAC Health Econ Prev Care*. 2006;7(1):7-18. doi:10.1007/s10198-005-0336-8

52. Aísa R, Clemente J, Pueyo F. The influence of (public) health expenditure on longevity. *Int J Public Health*. 2014;59(5):867-875. doi:10.1007/s00038-014-0574-6

53. van den Heuvel WJA, Olaroiu M. How Important Are Health Care Expenditures for Life Expectancy? A Comparative, European Analysis. *J Am Med Dir Assoc*. 2017;18(3):276.e9-276.e12. doi:10.1016/j.jamda.2016.11.027

54. Baltagi BH, Moscone F, Tosetti E. Medical technology and the production of health care. *Empir Econ*. 2012;42(2):395-411. doi:10.1007/s00181-011-0472-1

55. van Baal P, Obulqasim P, Brouwer W, Nusselder W, Mackenbach J. The influence of health care spending on life expectancy. Published online January 1, 2013. Accessed May 21, 2021. https://repub.eur.nl/pub/40722/

56. Fonseca R, Michaud P-C, Galama T, Kapteyn A. Accounting for the Rise of Health Spending and Longevity. *J Eur Econ Assoc*. 2021;19(1):536-579. doi:10.1093/jeea/jvaa003

57. Russell LB. Preventing chronic disease: an important investment, but don't count on cost savings. *Health Aff Proj Hope*. 2009;28(1):42-45. doi:10.1377/hlthaff.28.1.42

58. Wang F, Wang J-D, Huang Y-X. Health expenditures spent for prevention, economic performance, and social welfare. *Health Econ Rev*. 2016;6(1):45. doi:10.1186/s13561-016-0119-1

59. Ethgen O, Rémy V, Wargo K. Vaccination budget in Europe: an update. *Hum Vaccines Immunother*. 2018;14(12):2911-2915. doi:10.1080/21645515.2018.1504528

60. Singh SR. Public Health Spending and Population Health: A Systematic Review. *Am J Prev Med*. 2014;47(5):634-640. doi:10.1016/j.amepre.2014.05.017

61. Ransom J, Schaff K, Kan L. Is there an association between local health department organizational and administrative factors and childhood immunization coverage rates? *J Health Hum Serv Adm*. 2012;34(4):418-455.

62. Cohen RM. How the Labor Movement Is Thinking Ahead to a Post-Trump World. The Intercept. Published January 21, 2018. Accessed April 20, 2020. https://theintercept.com/2018/01/21/labor-movement-us-unions/

63. Wilson JF. Can Disease Prevention Save Health Reform? *Ann Intern Med*. 2009;151(2):145-148. doi:10.7326/0003-4819-151-2-200907210-00021

64. Neilan AM, Bulteel AJB, Hosek SG, et al. Cost-effectiveness of Frequent HIV Screening Among High-risk Young Men Who Have Sex With Men in the United States. *Clin Infect Dis*. 2020;(ciaa1061). doi:10.1093/cid/ciaa1061

65. Woolf SH. The Power of Prevention and What It Requires. *JAMA*. 2008;299(20):2437. doi:10.1001/jama.299.20.2437

66. McGinnis JM, Williams-Russo P, Knickman JR. The Case For More Active Policy Attention To Health Promotion. *Health Aff (Millwood)*. 2002;21(2):78-93. doi:10.1377/hlthaff.21.2.78

67. Maciosek MV, Coffield AB, Flottemesch TJ, Edwards NM, Solberg LI. Greater Use Of Preventive Services In U.S. Health Care Could Save Lives At Little Or No Cost. *Health Aff (Millwood)*. 2010;29(9):1656-1660. doi:10.1377/hlthaff.2008.0701

68. Huang J, Gwarnicki C, Binns S, Bachler M, Chaloupka FJ. *State Tobacco Control and Prevention Expenditures: FY2008-2011*. Health Policy Center; 2015.

69. Eager W, Herman D, House M, Robinson L, Williams C. *Confronting a Legacy of Scarcity: A Plan for America's Re-Investment in Public Health*. Yale University; 2021. https://law.yale.edu/sites/default/files/area/center/ghjp/documents/publichealthfunding_final_6.7.21.pdf

70. Diamond D. The Health 202: Feds supercharged public health. Now the challenge is wisely spending it. *Washington Post*. https://www.washingtonpost.com/politics/2021/05/25/health-202-feds-supercharged-public-health-now-challenge-is-wisely-spending-it/. Published May 25, 2021. Accessed September 27, 2021.

71. Eger W, Herman D, House M, Robinson L, Williams C. *Confronting a Legacy of Scarcity: A Plan for America's Re-Investment in Public Health*. Yale University; 2021.

72. Confronting a legacy of scarcity in U.S. funding for public health. STAT. Published June 28, 2021. Accessed September 27, 2021. https://www.statnews.com/2021/06/28/confronting-a-legacy-of-scarcity-a-plan-for-reinvesting-in-u-s-public-health/

73. Galea S, Maani N. The cost of preventable disease in the USA. *Lancet Public Health*. 2020;5(10):e513-e514. doi:10.1016/S2468-2667(20)30204-8

74. Derrick TR, Thomas JM. Time Series Analysis: the Cross-Correlation Function. In: *Innovative Analyses of Human Movement*. Kinesiology Publications; 2004:189-205.

75. Dean RT, Dunsmuir WTM. Dangers and uses of cross-correlation in analyzing time series in perception, performance, movement, and neuroscience: The importance of constructing transfer function autoregressive models. *Behav Res Methods*. 2016;48(2):783-802. doi:10.3758/s13428-015-0611-2

76. Cryer JD, Chan K-S. Chapter 11: Time series regression model. In: *Time Series Analysis with Applications in R.* 2nd ed. Springer-Verlag; 2008:249-273.

77. Probst WN, Stelzenmuler V, Fock HO. Using cross-correlations to assess the relationship between time-lagged pressure and state indicators: an exemplary analysis of North Sea fish population indicators. *ICES J Mar Sci*. 2012;69(4):670-681. doi:https://doi.org/10.1093/icesjms/fss015

78. van Aart C, Boshuizen H, Dekkers A, Korthals Altes H. Time lag between immigration and tuberculosis rates in immigrants in the Netherlands: a time-series analysis. *Int J Tuberc Lung Dis Off J Int Union Tuberc Lung Dis*. 2017;21(5):486-492. doi:10.5588/ijtld.16.0548

79. Chhugani R. An Overview of Autocorrelation, Seasonality and Stationarity in Time Series Data. Analytics India Magazine. Published October 19, 2020. Accessed June 15, 2021. https://analyticsindiamag.com/an-overview-of-autocorrelation-seasonality-and-stationarity-in-time-series-data/

80. SAS Institute Inc. SAS/ETS 13.2 User's Guide. In: *The ARIMA Procedure*. SAS Institute Inc; 2014.

81. Pal A, Prakash P. *Practical Time-Series Analysis: Master Time Series Data Processing, Visualization, and Modeling Using Python*. Pakt Publishing; 2017.

82. UCLA Statistical Consulting. Durbin-Watson statistic. Accessed July 11, 2021. https://stats.idre.ucla.edu/sas/faq/how-can-i-compute-durbin-watson-statistic-and-1st-order-autocorrelation-in-time-series-data/

83. Sharma R. Health and economic growth: Evidence from dynamic panel data of 143 years. *PLOS ONE*. 2018;13(10):e0204940. doi:10.1371/journal.pone.0204940

84. Ivankova V. Health care financing systems and thier effectiveness: an empirical study of OECD countries.

85. Chen H, Chen G, Zheng X, Guo Y. Contribution of specific diseases and injuries to changes in health adjusted life expectancy in 187 countries from 1990 to 2013: retrospective observational study. *BMJ*. 2019;364:l969. doi:10.1136/bmj.l969

86. OECD. *Expenditure on Prevention Activities Under SAH 2011: Supplementary Guidance*. OECD; 2017. www.oecd.org/health

87. OECD. *OECD Compendium of Productivity Indicators 2019*. OECD; 2019. https://www.oecd-ilibrary.org/industry-and-services/oecd-compendium-of-productivity-indicators-2019_b2774f97-en

88. OECD. Purchasing Power Parities. Accessed August 20, 2021. https://www.oecd.org/sdd/prices-ppp/purchasingpowerparities-frequentlyaskedquestionsfaqs.htm#FAQ2

89. Reynolds MM, Avendano M. Social Policy Expenditures and Life Expectancy in High-Income Countries. *Am J Prev Med*. 2018;54(1):72-79. doi:10.1016/j.amepre.2017.09.001

90. Carrieri V, Bilger M. Preventive care: underused even when free. Is there something else at work? *Appl Econ*. 2013;45(2):239-253. doi:10.1080/00036846.2011.597729

91. Fletcher JM, Frisvold DE. Higher Education and Health Investments: Does More Schooling Affect Preventive Health Care Use? *J Hum Cap*. 2009;3(2):144-176. doi:10.1086/645090

92. World Bank. *The Human Capital Index 2020 Update: Human Capital in the Time of COVID-19*. World Bank; 2021.

93. Murray CJL, Barber RM, Foreman KJ, et al. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013: quantifying the epidemiological transition. *The Lancet*. 2015;386(10009):2145-2191. doi:10.1016/S0140-6736(15)61340-X

94. Ye L, Zhang X. Nonlinear Granger Causality between Health Care Expenditure and Economic Growth in the OECD and Major Developing Countries. *Int J Environ Res Public Health*. 2018;15(9). doi:10.3390/ijerph15091953

95. Pradhan RP. The Long Run Relation between Health Spending and Economic Growth in 11 OECD Countries: Evidence from Panel Cointegration. *Int J Econ Perspect*. 2010;4(2):427-438.

96. OECD. Gross domestic product (GDP) (indicator). Published 2021. Accessed August 5, 2021. https://data.oecd.org/gdp/gross-domestic-product-gdp.htm

97. Donnelly PD, Erwin PC, Fox DM, Grogan C. Single-Payer, Multiple-Payer, and State-Based Financing of Health Care: Introduction to the Special Section. *Am J Public Health*. 2019;109(11):1482-1483. doi:10.2105/AJPH.2019.305353

98. Glied S. Single Payer as a Financing Mechanism. *J Health Polit Policy Law*. 2009;3(4). doi:10.1215/03616878-2009-017

99. Lorenzoni L, Koechlin F. *International Comparisons of Health Prices and Volumes: New Findings*. OECD; 2017.

100. OECD. Population (indicator). Published 2021. Accessed August 5, 2021. https://data.oecd.org/pop/population.htm

101. Santosa A, Wall S, Fottrell E, Högberg U, Byass P. The development and experience of epidemiological transition theory over four decades: a systematic review. *Glob Health Action*. 2014;7:10.3402/gha.v7.23574. doi:10.3402/gha.v7.23574

102. Frieden TR. A Framework for Public Health Action: The Health Impact Pyramid. *Am J Public Health*. 2010;100(4):590-595. doi:10.2105/AJPH.2009.185652

103. Marcotte LM, Dugdale DC. Prevention as a Population Health Strategy. *Prim Care*. 2019;46(4):493-503. doi:10.1016/j.pop.2019.07.004

104. International Working Group on Financing Preparedness. *From Panic and Neglect to Investing in Health Security: Financing Pandemic Preparedness at a National Level*. World Bank; 2017.

105. McCullough JM. Declines in Spending Despite Positive Returns on Investment: Understanding Public Health's Wrong Pocket Problem. *Front Public Health*. 2019;7:159. doi:10.3389/fpubh.2019.00159

106. Devlin N, Hansen P. Health care spending and economic output: Granger causality. *Appl Econ Lett*. 2001;8(8):561-564. doi:10.1080/13504850010017357

107. Joseph KT, Rice K, Li C. Integrating Equity in a Public Health Funding Strategy. *J Public Health Manag Pract JPHMP*. 2016;22(Suppl 1):S68-S76. doi:10.1097/PHH.0000000000000346

108. OECD. *OECD Reviews of Public Health: Japan: A Healthier Tomorrow*. OECD; 2019. doi:10.1787/9789264311602-en

109. OECD. *Expenditures on Prevention Activities under SHA 2011: Supplementary Guidance*. OECD; 2017.

110. Azzopardi-Muscat N, Kluge HHP, Asma S, Novillo-Ortiz D. A call to strengthen data in response to COVID-19 and beyond. *J Am Med Inform Assoc*. 2021;28(3):638-639. doi:10.1093/jamia/ocaa308

111. World Health Organization. *Score for Health Data Technical Packge: Global Report on Health Data Systems and Capacity, 2020*.; 2021.

112. Browning P, von Cube A, Leibrand H. Minimum Public Health Standards as a Basis for Secure Public Health Funding. *J Public Health Manag Pract*. 2004;10(1):19-22.

113. DeSalvo K, Parekh A, Hoagland GW, et al. Developing a Financing System to Support Public Health Infrastructure. *Am J Public Health*. 2019;109(10):1358-1361. doi:10.2105/AJPH.2019.305214

114. About the USPSTF | United States Preventive Services Taskforce. Accessed April 6, 2021. https://www.uspreventiveservicestaskforce.org/uspstf/about-uspstf

115. What Does the World Health Organization Do? Council on Foreign Relations. Accessed October 3, 2021. https://www.cfr.org/backgrounder/what-does-world-health-organization-do

116. Burwell M, Townsend FF. *Improving Pandemic Preparedness: Lessons from COVID-19*. The Council on Foreign Relations; 2020. Accessed October 3, 2021. https://www.cfr.org/report/pandemic-preparedness-lessons-COVID-19/

117. The Impact of Chronic Underfunding on America's Public Health System: Trends, Risks, and Recommendations, 2021. tfah. Accessed September 28, 2021. https://www.tfah.org/report-details/pandemic-proved-underinvesting-in-public-health-lives-livelihoods-risk/

118. A Funding Crisis for Public Health and Safety. tfah. Accessed September 28, 2021. https://www.tfah.org/report-details/a-funding-crisis-for-public-health-and-safety-state-by-state-and-federal-public-health-funding-facts-and-recommendations/

119. Institute of Health Metrics and Evaluation (IHME). *Financing Global Health 2019: Tracking Health Spending in a Time of Crisis*. IHME; 2020.

120. Yamey G, Jamison D, Hanssen O, Soucat A. Financing Global Common Goods for Health: When the World is a Country. *Health Syst Reform*. 2019;5(4):334-349. doi:10.1080/23288604.2019.1663118