

Research

Healthcare spending in high-income and upper-middle-income countries: a cross-country analysis

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Abstract

This research investigates the determinants of government healthcare expenditure in high-income and upper-middle-income countries by exploring economic, demographic, and political influences. By analyzing data from 1990 to 2019 from 28 high-income and 42 upper-middle-income nations, this study employs Bayesian model averaging, the generalized method of moments, and regression discontinuity design. The results reveal that government healthcare spending positively correlates with the previous year's expenditure in both income groups. Additionally, the impact of education on spending differs, while it is positively significant in high-income countries, it is not significant in upper-middle-income countries. The proportion of elderly individuals positively influences healthcare spending in high-income countries but inconsistently influences healthcare spending in upper-middle-income countries. Urbanization significantly impacts spending in upper-middle-income nations. The positive association between industrial employment and spending suggests greater healthcare needs in such areas. Efforts to curb corruption positively affect spending differently for each income group. Out-of-pocket expenses negatively impact spending in both groups, though positively in high-income countries alone. The influence of the young population varies, being negative in high-income countries but positive in upper-middle-income countries. Logistic and probit regression models identify key determinants, including gross domestic product (GDP) per capita, elderly population proportion, out-of-pocket expenses, and corruption control measures in high-income countries. Policymakers can use these findings to tailor strategies, optimize healthcare spending, and ensure equitable access across income levels.

Keywords Healthcare spending · Random intercept · Regression discontinuity design · Bayesian model averaging

1 Introduction

High-quality healthcare is a human right. Good health within a population contributes to increased productivity, fosters development, and stimulates economic growth. Investments in people's well-being can lead to increased life expectancy, enhanced quality of life, decreased infant mortality rates, reduced fertility rates, and ultimately increased gross domestic product (GDP) per capita. Ensuring access to high-quality healthcare is a fundamental human right, and universal health coverage (UHC) is pivotal in achieving this objective. UHC envisions a world where everyone can receive the healthcare they need without facing financial constraints, precisely when and where necessary. In addition to improving health and well-being, UHC contributes to social inclusion, equality, poverty reduction, economic growth, and human dignity. The United Nations 2030 agenda underscores the importance of UHC within Goal 3 of the Sustainable Development Goals (SDGs), with Target 3.8 highlighting its significance [1, 2].

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The role of government expenditures on public health varies between high-income and upper-middle-income countries. In high-income countries, government expenditures on public health tend to be greater, averaging approximately 5.33% of GDP from 1990 to 2019. This higher investment allows for more extensive healthcare coverage, better infrastructure, and advanced medical technologies, improving healthcare outcomes and living standards.

On the other hand, in upper-middle-income countries, government expenditures on public health are typically lower, averaging approximately 2.89% of GDP during the same period. This lower investment may result in limited access to healthcare services, insufficient infrastructure, and challenges in providing adequate healthcare to all population segments. However, as these countries continue to develop economically, there is potential for increased government expenditure on public health to address these challenges and improve overall healthcare outcomes.

Understanding the differences in public health spending between high-income and upper-middle-income countries is crucial for several reasons: (1) Public health spending is intricately linked to economic development. Understanding the relationship between spending levels and economic growth in different income categories can inform sustainable development and poverty reduction strategies. (2) Recognizing how resources are allocated within different income brackets sheds light on where funding is prioritized and how it impacts healthcare delivery. This understanding is essential for policymakers to effectively optimize resource allocation to address specific health challenges. (3) Disparities in public health spending can directly affect population healthcare access. Understanding these differences helps identify potential gaps in access to healthcare services, allowing for targeted interventions to improve equity and inclusivity in healthcare delivery. (4) Public health spending influences health outcomes such as life expectancy, disease incidence, and mortality rates. Comparing spending patterns between high-income and upper-middle-income countries provides insights into which strategies are most effective in improving health outcomes, thus informing evidence-based policy decisions. (5) Recognizing disparities in public health spending fosters international cooperation and collaboration. It encourages resource sharing, knowledge exchange, and joint efforts to address global health challenges, benefiting high-income and upper-middle-income countries. Overall, understanding the differences in public health spending between high-income and upper-middle-income countries enables policymakers, healthcare professionals, and stakeholders to make informed decisions, allocate resources efficiently, and work toward achieving better health outcomes for all.

A study [3] covering 167 countries from 1993 to 2013 revealed that total health expenditure per capita tends to increase over time as incomes rise. One study [4] also examined data from 210 countries from 1990 to 2008 and revealed a notable positive impact of improved health on economic growth, particularly in high- and upper-middle-income countries. These studies, which have typically concentrated on specific countries or small groups of countries, have provided valuable insights into the factors influencing public healthcare spending, the impact of spending levels on healthcare outcomes, and the effectiveness of different healthcare financing models. However, the reliance on older data may limit the applicability of their findings to the current healthcare landscape.

Given the dynamic nature of healthcare systems and the evolving socioeconomic conditions globally, there is a need for more up-to-date research that examines public healthcare spending across a broader range of countries and income categories. By incorporating recent data and conducting comparative analyses across different income groups, researchers can offer more comprehensive and relevant insights into the role of public healthcare spending in promoting health equity, improving healthcare access, and achieving better health outcomes on a global scale.

In this study, we have chosen to examine two distinct groups of countries: high-income countries and upper-middle-income countries. The criteria for classifying high-income and upper-middle-income countries are provided in [Appendix 2](#). We focus on understanding how these two groups differ in allocating resources to public health. Our analysis reveals that upper-middle-income countries allocate less resources to public health than high-income countries. This difference in allocation can have significant implications for healthcare access, service delivery, and health outcomes within these countries. By investigating the disparities in resource allocation between high-income and upper-middle-income countries, we aim to shed light on potential areas for improvement and inform policy decisions to enhance public health systems and outcomes across different income levels.

This research delves into the influence of economic, demographic, and political factors on government spending in the healthcare sector. It aims to pinpoint and examine the essential factors that affect healthcare expenditure. These factors encompass metrics such as GDP per capita and overall government spending, which reflect a country's overall economic prosperity and ability to allocate healthcare resources. Additionally, the study underscores the critical role of corruption control as a determinant of healthcare expenditure, emphasizing its importance in shaping budget allocations, particularly in the healthcare sector.

The primary aim of this study was to discern the determinants of public healthcare spending in 28 high-income and 42 upper-middle-income countries from 1990 to 2019. This study investigated the impact of various economic,

demographic, and political factors on public healthcare spending. Through quantitative analysis, we sought to assess the significance of these diverse factors in driving investment in public health. To achieve this objective, we employed advanced quantitative methods, including Bayesian model averaging (BMA) and the generalized method of moments (GMM). Using BMA was instrumental in addressing the inherent challenge of model uncertainty. GMM was chosen to handle endogeneity in our analysis, ensuring the integrity of the research findings.

Linear mixed models (LMMs) integrate fixed and random coefficients, ensuring the robustness and credibility of our research findings. By employing the random intercept model, a statistical analysis technique, we investigated whether the relationship between public healthcare expenditure and other variables differs among high-income and upper-middle-income countries. Through these statistical methods, researchers can ascertain significant disparities in the effects of public healthcare expenditure across countries based on their income levels.

This research contributes to the literature by thoroughly investigating public healthcare spending determinants in high-income and upper-middle-income countries using the latest comparable data. It sheds light on government strategies for healthcare spending, aiding policymaking for economic growth and development. These insights can also guide emerging economies, helping them avoid stagnation and invest strategically in healthcare for sustainable development. Furthermore, we employed linear mixed models (LMMs) with fixed and random coefficients, bolstering the validity of the results. Logistic and probit regressions were used to analyze public healthcare spending determinants in high-income vs. upper-middle-income countries, aiming for rigorous, reliable findings to inform policy decisions. This study also applied the regression discontinuity design (RDD) technique to assess the impact of corruption control on healthcare spending. RDD is a quasi-experimental method used to measure the causal effects of corruption control on healthcare spending.

This study uses advanced quantitative techniques to understand the determinants of public healthcare spending better. These findings have significant policy implications for sustainable economic development. In summary, this research benefits policymakers in transitioning and emerging economies by guiding healthcare policy and promoting sustainable development and growth.

2 Literature review

A study spanning from 2000 to 2017 [5] revealed income and education as key factors affecting healthcare spending. [6] identified technological progress as a primary driver in 21 Organization for Economic Co-operation and Development (OECD) countries from 1975 to 2004. Research [7] on 19 OECD countries from 1960 to 2004 emphasized wage increases that surpassed productivity growth in escalating healthcare expenditures [8]. GDP growth and Baumol's 'cost disease' theory were found to be significant determinants in 33 OECD countries from 1970 to 2000.

According to a study of 48 U.S. states from 1999 to 2003, healthcare expenditure was primarily influenced by gross state products, the elderly population (aged 65+), urbanization, and hospital bed numbers [9]. Conversely, research on age distribution and income trends in the USA (1980–1998) and Canada (1975–2000) found that while the elderly population drove healthcare spending in a simplified model, technological progress played a larger role in more complex models [10]. Research on 173 countries from 1995–2006 revealed that healthcare was essential. Healthcare spending is least

Table 1 Variable Descriptions.
Source: World Bank (2020),
Valev (2020) and UNESCO
(2020)

No	Variable Definition	Source
DGGHE	Domestic general government health expenditure (% of GDP)	World Bank
DGGHE(-1)	First Lag of DGGHE	World Bank
GEXP	Government Overall Expenditure (% of GDP)	World Bank
GDPC	PPP GDP per capita (2017 constant international USD)	World Bank
EDUI	Average of mean years of education	UNESCO
P014	Population aged 0–14 (% of total population)	World Bank
P65	Population aged 65 and above (% of the total population)	World Bank
OUTPE	Out-of-pocket expenditure (% of current health expenditure)	World Bank
URBP	% of people living in urban areas	World Bank
PDEN	People per sq. km of land area	World Bank
INDU_L	Employment in industry (% of total employment)	World Bank

responsive in low-income countries and most responsive in middle-income countries, with high-income countries in between [11]. The empirical evidence informs optimal government healthcare spending and middle-income growth [12].

In 2011, health status and demographics accounted for 55% of regional healthcare expenditure variation in Germany [13]. In contrast, Australian healthcare spending from 1971 to 2011 emphasized technological change as a key determinant [14]. A study in China from 2010 to 2017 revealed that healthcare spending growth was influenced by income, Baumol's cost disease, and technology [9]. Similarly, another study [15] in China spanning 2002 to 2006 identified factors affecting provincial government healthcare spending per capita, including general budget revenue, central government transfers, population under 15, basic health insurance coverage for urban employees, and urban population size.

A study in Taiwan [16] showed that end-of-life patients at private hospitals have higher inpatient costs than those at public hospitals. Research [17] on the Association of Southeast Asian Nations (ASEAN) data from 2002 to 2011 suggests that industrialization and foreign direct investment affect healthcare spending. Another study [18], based on 2001 data from 44 African countries, highlighted real per capita GDP and per capita foreign aid as key determinants of healthcare expenditure.

The growth of healthcare expenditure in the countries of the European Union is suspected to be aging, economic growth or rising GDP, healthcare resources (hospital beds, staff, high technology), new technology and medical progress, and healthcare systems [19]. Two main factors explaining regional public healthcare expenditure in Spain during 1992–2005 are per capita income and demographic structure [20].

A United States American (USA) county-level health study [21] aimed to identify causal factors behind five outcomes. Correlations between risk factors and outcomes were found, typically limited to a few contemporaneous factors. The study identified five contributors to premature death: adult smoking, obesity, motor vehicle crash death rate, child poverty, and violent crime rate. One study [22] investigated programs designed to promote the well-being and active

Table 2 Summary Statistics for Public Health Spending in High-Income Countries. Source: Authors' calculations

Country	Mean	MIN	MAX	Range	SD
Australia	5.86	5.47	7.10	1.63	0.40
Austria	7.10	6.83	7.62	0.79	0.29
Bahamas	1.98	1.51	3.66	2.15	0.58
Belgium	6.97	5.96	8.34	2.38	0.92
Brunei	2.04	1.64	2.42	0.79	0.21
Canada	6.74	6.01	7.68	1.67	0.60
Cyprus	2.56	2.18	3.93	1.75	0.41
Denmark	7.69	6.74	9.02	2.28	0.74
Finland	6.39	5.37	7.79	2.42	0.87
France	7.55	6.97	8.62	1.65	0.54
Germany	8.06	7.56	9.09	1.54	0.43
Iceland	7.07	6.52	7.91	1.39	0.35
Ireland	5.71	4.58	8.10	3.52	1.11
Israel	4.44	4.17	4.86	0.69	0.15
Italy	6.16	5.50	7.01	1.51	0.48
Japan	6.93	5.66	9.04	3.38	1.42
Kuwait	2.36	1.39	4.78	3.39	0.89
Luxembourg	5.22	4.39	6.36	1.98	0.54
New Zealand	6.38	5.55	7.58	2.03	0.77
Norway	7.28	6.30	9.04	2.74	0.83
Qatar	1.66	1.17	2.63	1.45	0.45
Singapore	1.29	0.88	2.11	1.22	0.38
Spain	5.65	4.87	6.84	1.96	0.75
Sweden	7.33	6.19	9.28	3.09	1.21
Switzerland	3.08	2.60	3.63	1.02	0.32
UAE	1.98	1.32	2.98	1.67	0.46
UK	6.80	5.52	8.18	2.66	1.04
USA	6.91	5.54	8.56	3.02	1.10
All 28 countries	5.33	0.88	9.28	8.39	2.29

lifestyles of elderly individuals in Poland's rural and urban–rural communities from 2012 to 2017. This investigation also identified deficiencies within the healthcare system structure.

Examining public health budget allocation in Southeast Asia, one study [23] revealed that democratic governments increase funding while autocratic governments reduce it. Political liberalization also boosts public health budget allocation. In Nigeria, increased healthcare spending had a limited impact on average health and infrastructure improvement. [24] noted that poverty-stricken individuals experienced worse health and were disproportionately affected by public health spending, leading to significant disparities. A study [25] on Hong Kong's healthcare spending determinants from 1990 to 2017 revealed that income does not affect per capita spending. A greater number of elderly individuals increases public and private spending, while a greater number of children decreases both. Additionally, increased doctor density lowers per capita healthcare spending, suggesting no supplier-induced demand.

3 Research methodology

This study utilizes panel data from 28 high-income and 42 upper-middle-income countries from 1990 to 2019. The data for this study were sourced from the World Development Indicators of the World Bank [26] and Valev [27] and [28]. The dependent variable in this study is public healthcare spending, expressed as a percentage of GDP. This study aimed to understand the economic, demographic, and political factors influencing public health spending. The models developed using Bayesian model averaging, GMM, and generalized linear models are expected to provide insight into the determinants of government spending on healthcare in these economies.

3.1 Bayesian model averaging (BMA)

We can mitigate the uncertainty associated with model selection, stemming from factors such as model assumptions or the model's form, by employing Bayesian model averaging (BMA). Given dataset D , we aim to estimate the government healthcare expenditure denoted as 'g' while considering potential predictors for p . From a pool of 2^p candidate models, including options such as $M_1 \dots M_k$, BMA applies Bayesian principles and probability calculus to address model uncertainty. The posterior distribution of 'g' under BMA can be expressed using the law of total probability as follows:

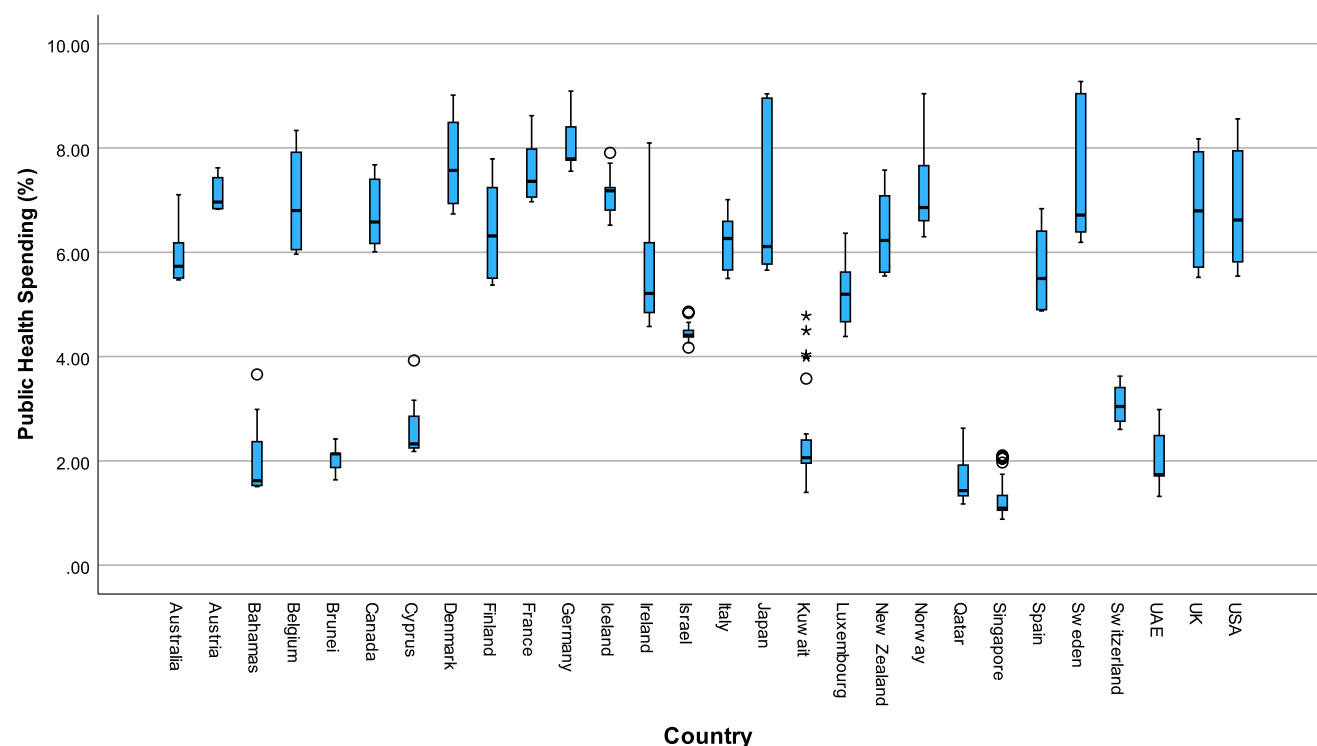


Fig. 1 Public Health Spending as a Percentage of GDP in High-Income Countries

Table 3 Summary Statistics for Public Health Spending in Upper-Middle-Income Countries. Source: Authors' calculations

country	Mean	MIN	MAX	Range	SD
Albania	3.34	2.58	4.47	1.89	0.80
Argentina	5.03	3.74	6.82	3.08	0.90
Armenia	1.36	0.95	1.81	0.86	0.24
Azerbaijan	0.93	0.73	1.30	0.57	0.15
Belarus	4.09	3.09	4.68	1.59	0.39
Belize	2.95	2.09	4.10	2.01	0.73
Bosnia & Herzegovina	5.24	4.09	6.66	2.57	1.00
Botswana	3.54	2.73	4.64	1.91	0.39
Brazil	3.59	3.35	3.96	0.61	0.17
Bulgaria	3.90	3.43	4.49	1.06	0.27
China	1.69	0.97	2.94	1.97	0.79
Colombia	4.62	4.21	5.27	1.06	0.33
Costa Rica	4.86	4.26	5.87	1.61	0.60
Dominican Republic	2.00	1.15	2.82	1.67	0.54
Ecuador	2.35	0.96	4.45	3.49	1.36
Equatorial Guinea	0.35	0.16	0.69	0.53	0.16
Fiji	2.44	2.03	2.86	0.83	0.21
Gabon	1.36	1.05	2.01	0.96	0.28
Georgia	1.56	0.84	3.09	2.25	0.72
Guatemala	2.09	1.95	2.27	0.32	0.07
Guyana	2.21	1.53	3.24	1.71	0.40
Indonesia	0.85	0.55	1.45	0.90	0.26
Iran	2.43	1.79	4.48	2.69	0.93
Iraq	1.78	0.70	2.92	2.22	0.54
Jamaica	2.98	2.29	3.87	1.58	0.40
Jordan	4.49	3.53	6.37	2.84	0.63
Kazakhstan	2.06	1.79	2.66	0.87	0.19
Lebanon	3.40	2.74	4.10	1.36	0.37
Malaysia	1.58	1.20	2.07	0.87	0.29
Maldives	3.85	2.15	7.37	5.22	1.68
Mexico	2.49	2.01	3.13	1.12	0.41
Namibia	4.52	3.46	5.28	1.82	0.51
North Macedonia	4.41	4.02	4.95	0.93	0.30
Paraguay	2.24	1.47	3.17	1.70	0.55
Peru	2.61	2.07	3.18	1.11	0.31
Russia	3.06	2.80	3.51	0.71	0.12
Serbia	5.11	4.26	5.87	1.61	0.51
South Africa	3.27	2.30	4.39	2.09	0.76
Suriname	2.66	1.88	3.89	2.01	0.54
Thailand	2.22	1.66	2.86	1.20	0.46
Tonga	2.56	2.23	3.07	0.84	0.28
Turkey	3.39	2.85	4.45	1.60	0.32
All 42 Countries	2.89	0.16	7.37	7.21	1.37

$$p(g|D) = \sum_{k=1}^K p(g|D, M_k) p(M_k|D),$$

The posterior distribution of 'g' given the model M_k is represented as $\sum_{k=1}^K p(g|D, M_k)$; $p(g|D)$ and $p(g|D, M_k)$ are the probability density and mass functions, respectively, and the posterior probability that M_k is a suitable model, given one

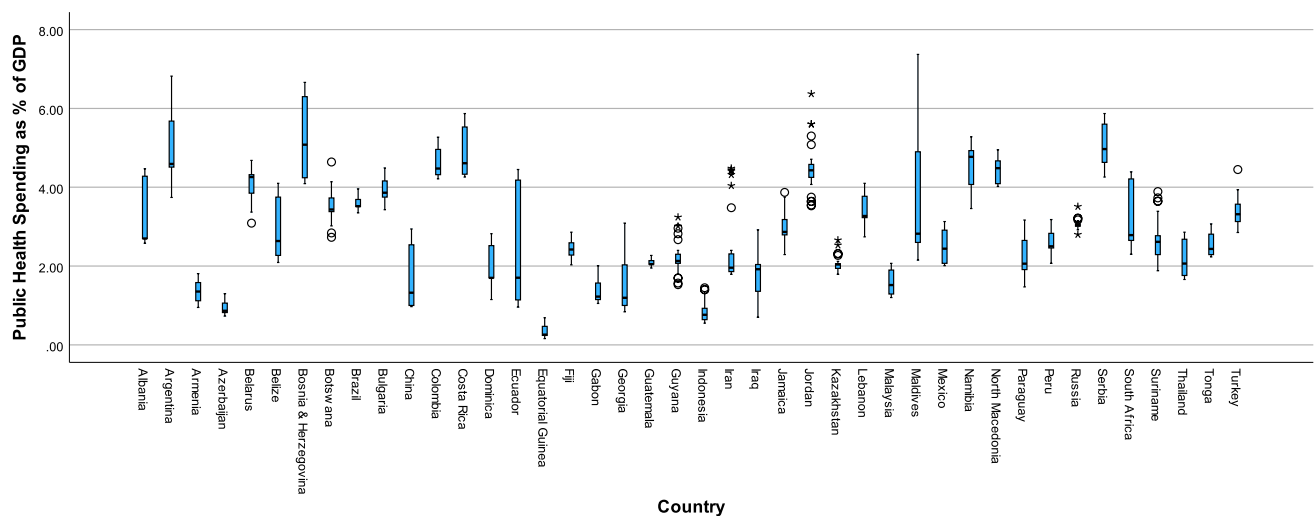


Fig. 2 Public Health Spending as a Percentage of GDP in Upper-Middle-Income Countries

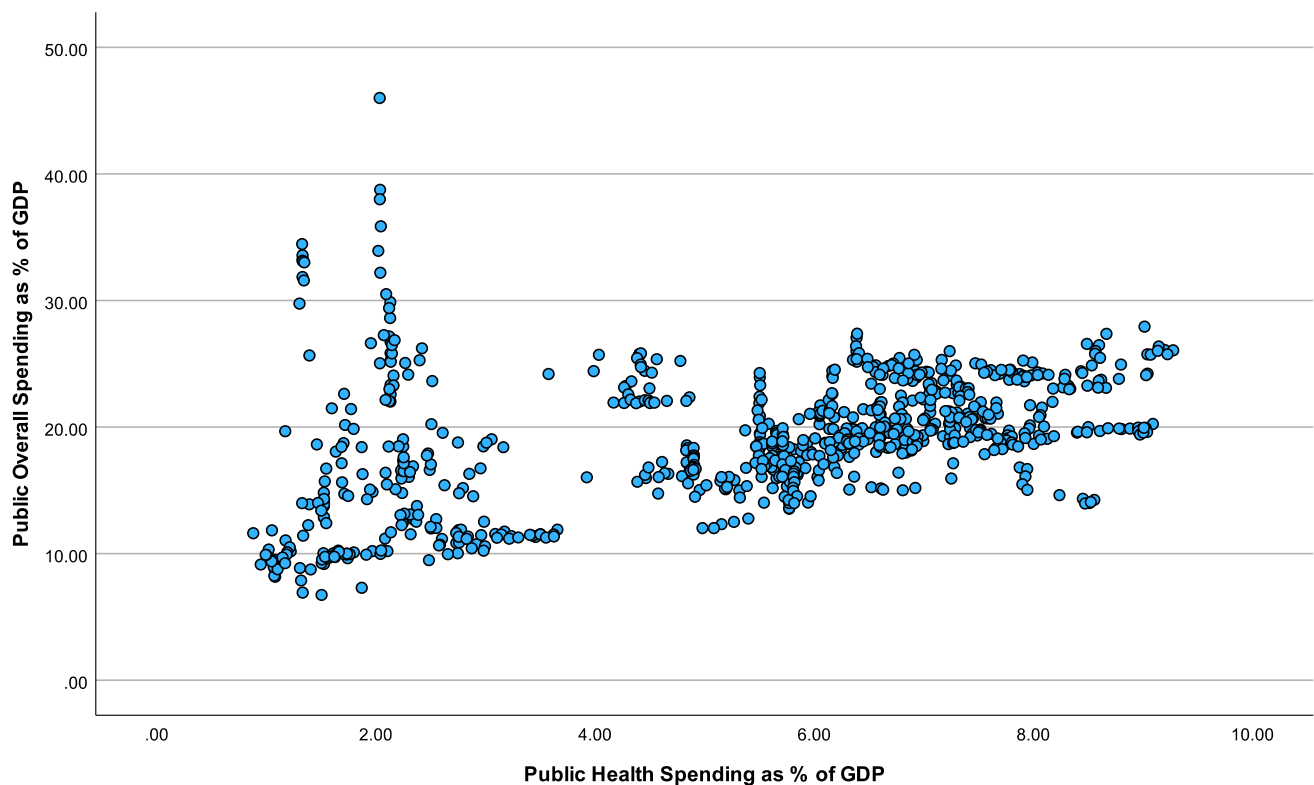


Fig. 3 Scatter Plot for Public Overall and Health Spending in High-Income Countries

correct model out of many considered models, is $p(M_k|D)$. In BMA, the posterior distribution of 'g' is a weighted average of its posterior distribution under each potential model, with weights determined by their respective posterior model probabilities. The posterior model distribution of M_k is as follows:

$$p(D|M_k) = \frac{p(D|M_k)p(M_k)}{\sum_{h=1}^K p(D|M_h)p(M_h)}.$$

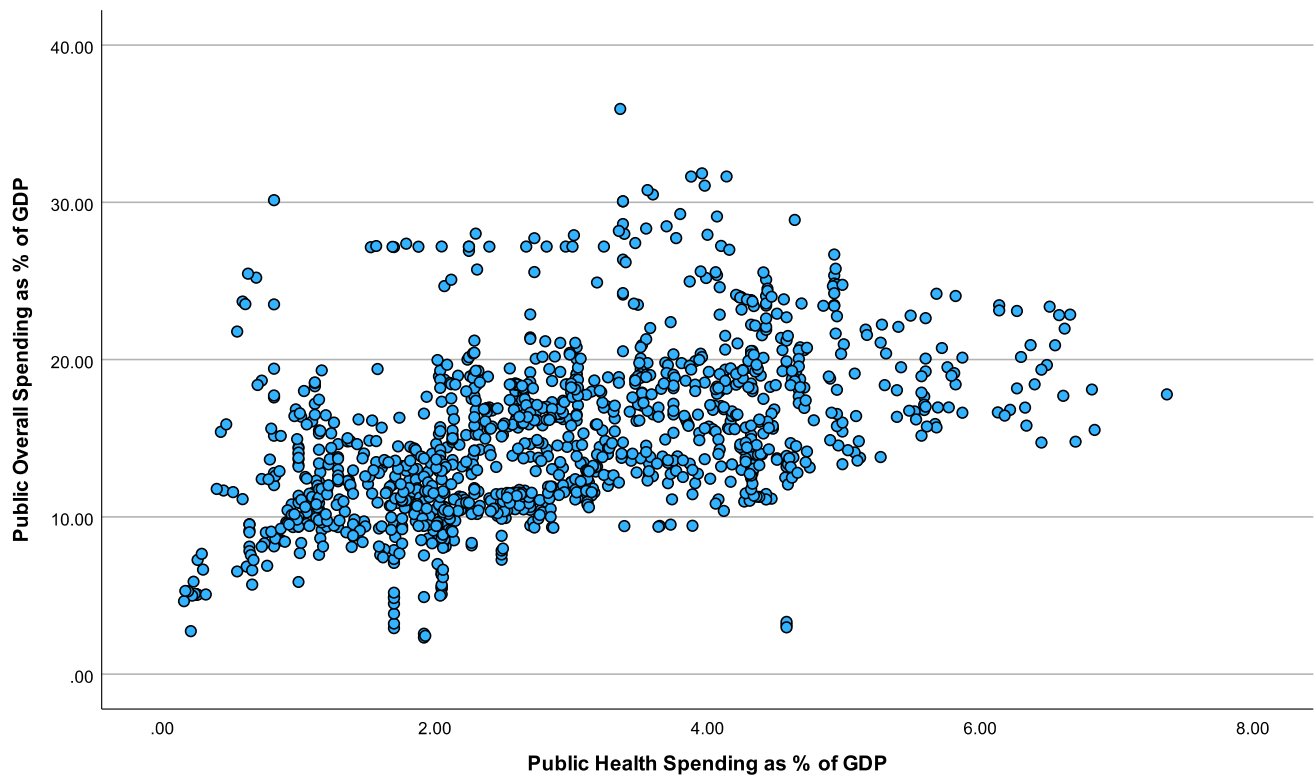


Fig. 4 Scatter Plot for Public Overall and Health Spending in Upper-Middle-Income Countries

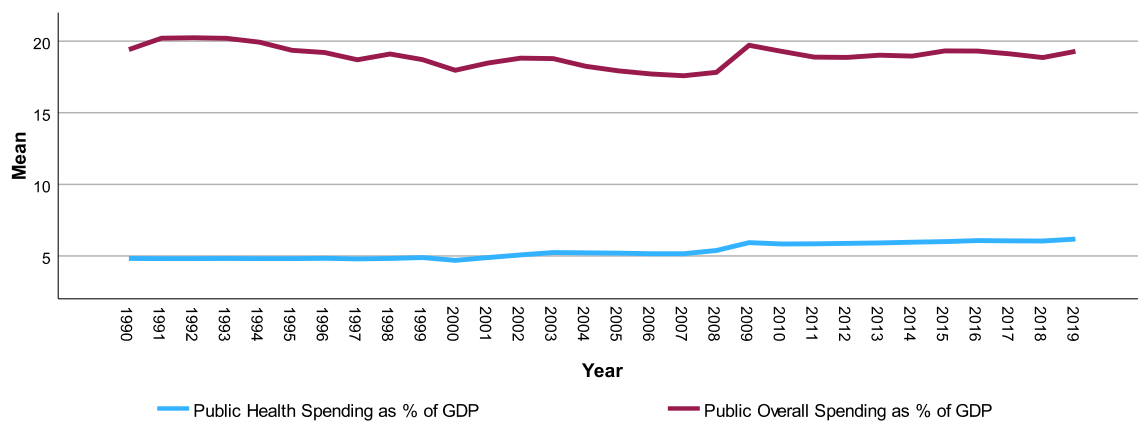


Fig. 5 Public Overall and Health Spending (as a Percentage of GDP) in High-Income Countries

3.2 Generalized method of moments (GMM)

GMM is a method for analyzing short-run dynamics in panel data, as demonstrated by Arellano and Bond [29], Arellano and Bover [30], and Blundell and Bond [31]. In traditional regression analysis, an important assumption is that predictors are uncorrelated with the disturbance term. Violating this assumption biases and makes OLS estimates inconsistent. Endogeneity occurs when predictors correlate with the disturbance term, necessitating the use of instrumental variables for solving simultaneous equations. Below, we present the standard panel data equation:

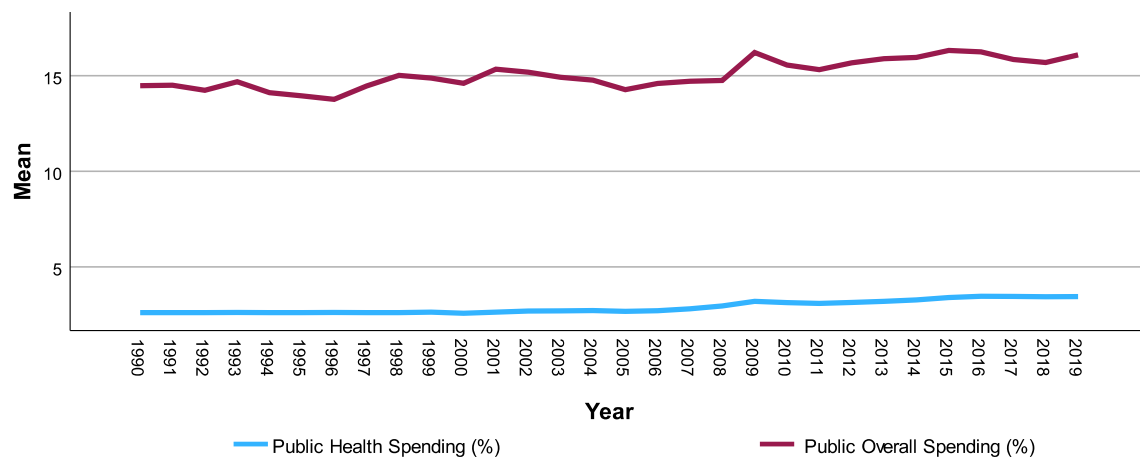


Fig. 6 Public Health and Overall Spending (as a Percentage of GDP) in Upper-Middle-Income Countries

Table 4 BMA Estimates for High-Income and Upper-Middle-Income Countries. Source: Authors' calculations

Variables	High-Income Countries			Upper-Middle-Income Countries		
	Coefficient	Std. Err	Posterior inclusion probability	Coefficient	Std. Err	Posterior inclusion probability
CONSTANT	0.68	0.20	1.00	− 0.69	0.23	1.00
GDPC	− 0.09***	0.02	0.99	0.00	0.00	0.04
GEXP	0.31***	0.03	1.00	0.30***	0.02	1.00
EDUI	1.22***	0.14	1.00	− 0.71***	0.15	1.00
P014	− 0.24***	0.04	1.00	0.17***	0.10	0.83
P65	0.34***	0.02	1.00	0.42***	0.06	1.00
OUTPE	− 0.34***	0.02	1.00	− 0.27***	0.02	1.00
URBP	0.01	0.04	0.15	0.31***	0.02	1.00
PDEN	− 0.04***	0.00	1.00	0.04***	0.01	1.00
INDU_L	0.19***	0.03	1.00	0.20***	0.03	1.00
G_COC	− 0.01	0.02	0.23	0.15***	0.02	1.00

*** $p < 0.01$, ** $p < 0.05$

$$\begin{aligned} \ln DGGHE_{it} = & \alpha + \beta_1 \ln DGGHE_{it-1} + \beta_2 \ln GDPC_{it} + \beta_3 \ln GEXP_{it} \\ & + \beta_4 \ln EDUI_{it} + \beta_5 \ln P014_{it} + \beta_6 \ln P65_{it} + \beta_7 \ln OUTPC_{it} \\ & + \beta_8 \ln URBP_{it} + \beta_9 \ln PDEN_{it} + \beta_{10} \ln INDU_L_{it} \\ & + \beta_{11} \ln G_COC_{it} + \lambda_i + \epsilon_{it} \end{aligned}$$

Table 1 explains the names of the variables. λ denotes the unobserved country-specific effect.

3.3 Mixed model

The linear mixed model (LMM) is versatile in fitting other models framed within mixed linear models [32]. A "random intercept" permits the baseline level of the response variable to differ among groups. This acknowledges that distinct groups (such as countries in the example above) may exhibit varying starting points even before considering the effect of the predictor variable. The random intercept encompasses these discrepancies, enabling each group to possess its baseline level of the response variable. This signifies that although the slope (the impact of the predictor variable) remains constant across groups, the intercept (the baseline level of the response variable when the predictor is zero) can fluctuate. This variance is regarded as a random effect, acknowledging the presence of unseen diversity among the groups that warrant consideration in the model. The random intercept equation format is as follows [33].

Table 5 GMM Estimates for High-Income and Upper-Middle-Income Countries. Source: Authors' calculations

Variables	High-Income Countries			Upper-Middle-Income Countries		
	Coefficient	Std. Err	P value	Coefficient	Std. Err	P value
CONSTANT	0.04	0.21	0.83	− 0.20	0.17	0.25
DGGHE(-1)	0.59***	0.04	0.00	0.81***	0.02	0.00
GDPG	− 0.05	0.05	0.26	0.03	0.01	0.05
GEXP	0.27***	0.04	0.00	0.11***	0.01	0.00
EDUI	0.81**	0.31	0.01	− 0.13**	0.05	0.01
P014	− 0.14***	0.03	0.00	0.01	0.06	0.82
P65	0.09***	0.01	0.00	0.06	0.03	0.09
OUTPE	− 0.10***	0.02	0.00	− 0.02***	0.01	0.00
URBP	0.02	0.08	0.76	0.03***	0.01	0.00
PDEN	− 0.01***	0.00	0.00	0.01***	0.00	0.00
INDU_L	0.09	0.05	0.06	0.01	0.02	0.55
G_COC	0.02**	0.01	0.04	0.05***	0.01	0.00
Prob(J− statistic)			0.908			0.960
Arellano—Bond Serial Correlation Test						
Prob AR(1)			0.008			0.000
Prob AR(2)			0.244			0.821

*** p < 0.01, ** p < 0.05

Table 6 Model Dimension for Mixed Model-Random Intercept Without Group Variation. Source: Author's calculations

	Number of Levels	Covariance Structure	Number of Parameters	Subject Variables
Fixed Effects				
INTERCEPT	1		1	
GDPG	1		1	
GEXP	1		1	
EDUI	1		1	
P014	1		1	
P65	1		1	
OUTPE	1		1	
URBP	1		1	
PDEN	1		1	
INDU_L	1		1	
G_COC	1		1	
Random Effects				
INTERCEPT	1	Variance Components	1	country
Residual			1	
Total	12		13	

Dependent Variable: dgghe

$$\begin{aligned}
 \ln DGGHE_{ij} = & \beta_0 + \beta_1 \ln GDPG_{ij} + \beta_2 \ln GEXP_{ij} + \beta_3 \ln EDUI_{ij} + \beta_4 \ln P014_{ij} \\
 & + \beta_5 \ln P65_{ij} + \beta_6 \ln OUTPE_{ij} + \beta_7 \ln URBP_{ij} + \beta_8 \ln PDEN_{ij} \\
 & + \beta_9 \ln INDU_L_{ij} + \beta_{10} \ln G_COC_{ij} + \alpha_{0i} + \epsilon_{ij}
 \end{aligned} \quad (1)$$

i = 1, 2, ..., 70, j = 1, 2, ..., 0.30.

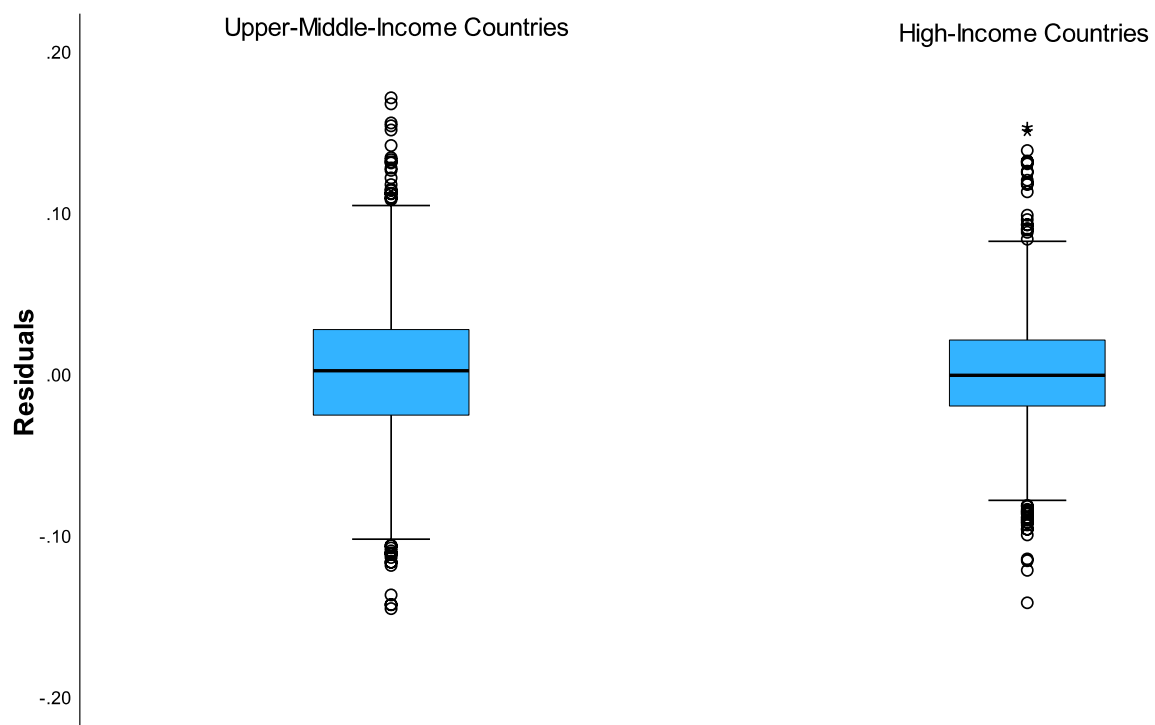
 $\beta_0, \beta_1, \dots, \beta_{10}$, are the fixed intercept and slopes.

Table 7 Fixed Effects of the Random Intercept without Group Variation. Source: Author's calculations

Parameter	Estimate	Std. Error	P value	95% Confidence Interval	
				Lower Bound	Upper Bound
INTERCEPT	0.693	0.107	0.000	0.482	0.903
GDPC	0.007	0.010	0.515	− 0.013	0.027
GEXP	0.114***	0.013	0.000	0.088	0.139
EDUI	0.329***	0.104	0.002	0.126	0.533
P014	− 0.094**	0.036	0.010	− 0.165	− 0.022
P65	0.234***	0.024	0.000	0.188	0.281
OUTPE	− 0.299***	0.013	0.000	− 0.324	− 0.274
URBP	0.055	0.039	0.158	− 0.021	0.131
PDEN	− 0.023	0.014	0.105	− 0.051	0.005
INDU_L	− 0.011	0.019	0.574	− 0.049	0.027
G_COC	0.054***	0.015	0.000	0.024	0.083
R– Squared			0.900		
Akaike's Information Criterion (AIC)			− 6939.59		
Schwarz's Bayesian Criterion (BIC)			− 6928.30		
Random effect Covariance			0.001***		

Dependent Variable: dgghe

***p < 0.01, **p < 0.05

**Fig. 7** Boxplot of the residuals by status

$\alpha_{0i} \sim N(0, \sigma^2 a_0)$ random country effect
 α_{0i} expenditure in year j.
 $\overset{iid}{ij} \sim N(0, \sigma^2)$ random error, independent of α_{0i}
 $DGGHE_{ij}$ – the weight of the i th healthcare

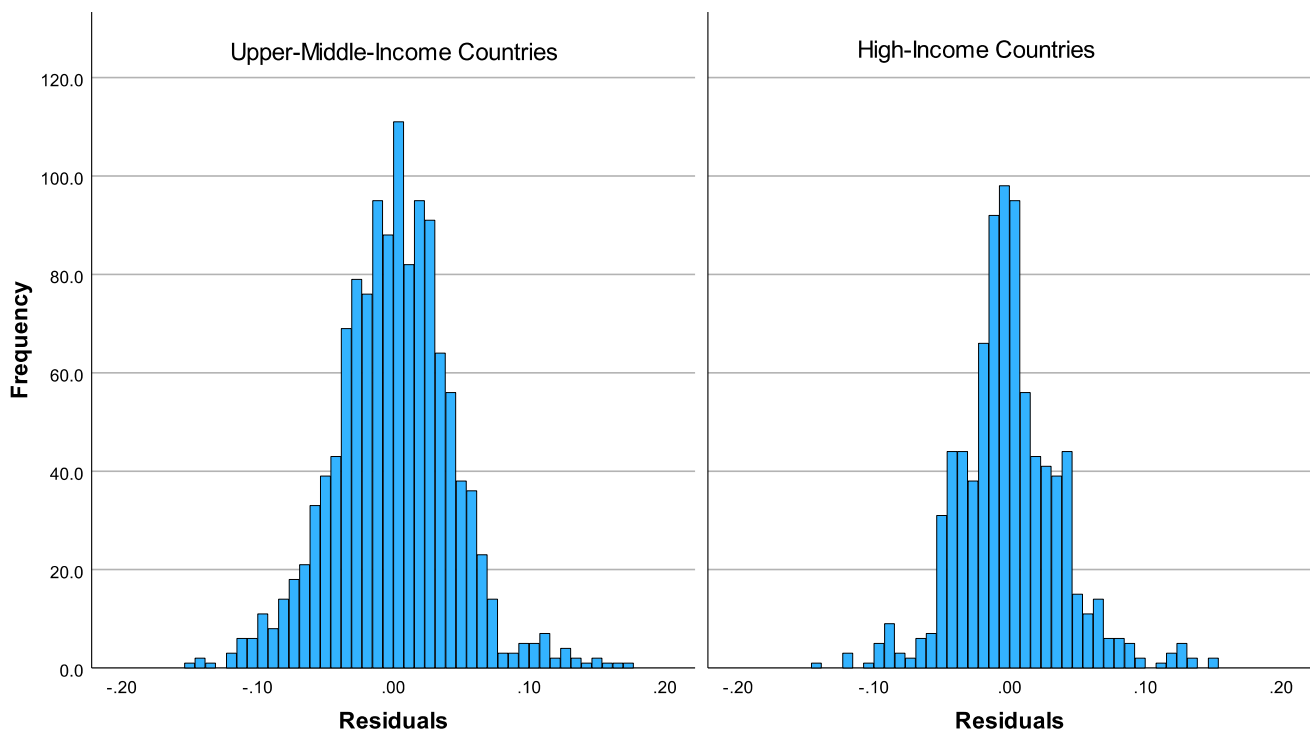


Fig. 8 Simple Histogram of Residuals by Status

3.4 Generalized linear regression

We performed further logistic and probit regression analyses to examine the differences in what drives healthcare spending in high-income and upper-middle-income countries. When working with generalized linear models (GLMs), data from distributions other than the normal distribution can be analyzed, and a constant variance is unnecessary. Therefore, the linear model will be generalized to a GLM. A GLM uses different link functions, such as logit or probit links. The logistic model is based on logit transformation, and the probit model uses an inverse Gaussian link [34].

In binary logistic and probit regressions, there are two response variable categories and more than one predictor variable. In logistic and probit regressions, predictor variables are used to model the probability of the response variable. Our response variable has two categories: 1 = high-income countries and 0 = upper-middle-income countries. Odds ratios are used to interpret the logistic or probit regression coefficients. These ratios are calculated from regression coefficients using an exponential transformation.

3.5 Regression discontinuity design

Regression discontinuity design (RDD) was used to estimate treatment effects in nonexperimental settings [35, 36]. This innovative approach involves determining treatment based on whether an observed "assignment" variable (also known as the "forcing" variable or the "running" variable) surpasses a known cutoff point. The RDD allows for valuable insights when true experimental conditions are not feasible. To conduct a study on causal effects using an RDD (regression discontinuity) design, it is crucial that the score, treatment, and cutoff variables not only be well defined but also exist in the dataset. Furthermore, the relationships among these variables must meet specific conditions that can be objectively and verifiably assessed [37]. We aim to evaluate the influence of corruption control on attaining better healthcare spending by employing a nonexperimental comparison group method known as the regression discontinuity design.

4 Results

Between 1990 and 2019, the average government expenditure on healthcare across 28 countries was approximately 5.33% of their respective gross domestic product (GDP). Several countries, including Germany, Denmark, France, Sweden, Norway, Austria, and Iceland, exceeded this average by allocating more than 7% of their GDP to public health (Table 2).

Meanwhile, Belgium, Japan, the USA, the United Kingdom (UK), Canada, Finland, New Zealand, and Italy also demonstrated a strong commitment to public health, with expenditures surpassing 6% of their GDPs. Australia, Ireland, Spain, and Luxembourg also dedicated a significant portion of their GDPs to health, with health spending exceeding 5% (Table 2).

Israel maintained solid public health investments, with expenditures exceeding 4% of its GDP. On the other hand, countries such as Switzerland, Cyprus, Kuwait, and Brunei spent approximately 3% to 2% of GDP. The Bahamas, the United Arab Emirates (UAE), Qatar, and Singapore showed relatively lower levels of health spending, with their investments falling below the 2% threshold of GDP (Table 2). Figure 1 provides a graphical representation of healthcare spending as a percentage of GDP for high-income countries (Table 2).

Across 42 upper-middle-income countries, the average government expenditure on public health is approximately 2.89%. Bosnia & Herzegovina, Serbia, and Argentina have allocated more than 5% of their GDP to public health. In addition, the GDP spent on public health in Costa Rica, Colombia, Namibia, Jordan, North Macedonia, and Belarus surpassed 4% (Table 3).

Furthermore, Bulgaria, Maldives, Brazil, Botswana, Lebanon, Turkey, Albania, South Africa, and Russia have dedicated more than 3% of their GDP to public health. Another set of 15 countries, including Jamaica, Belize, Suriname, Peru,

Table 8 Model Dimension for Mixed Model-Random Intercept With Group Variation

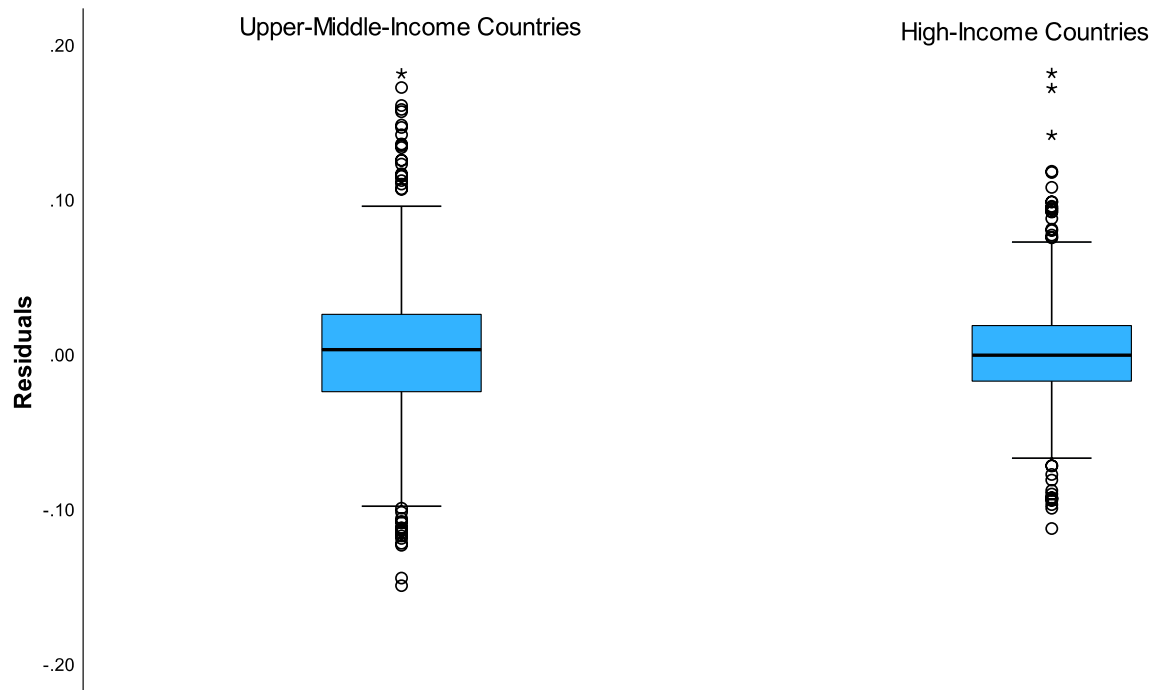
	Number of Levels	Covariance Structure	Number of Parameters	Subject Variables
Fixed Effects				
INTERCEPT	1		1	
GDPC	1		1	
GEXP	1		1	
EDUI	1		1	
P014	1		1	
P65	1		1	
OUTPE	1		1	
URBP	1		1	
PDEN	1		1	
INDU_L	1		1	
G_COC	1		1	
GDPC * STATUS	1		1	
GEXP * STATUS	1		1	
EDUI * STATUS	1		1	
P014 * STATUS	1		1	
P65 * STATUS	1		1	
OUTPE * STATUS	1		1	
URBP * STATUS	1		1	
PDEN * STATUS	1		1	
INDU_L * STATUS	1		1	
G_COC * STATUS	1		1	
Random Effects				
INTERCEPT	1	Variance Components	1	country
Residual			1	
Total	22		23	

Dependent Variable: dgghe

Table 9 Fixed effects of random intercepts with group variation. Source: Author's calculations

Parameter	Estimate	Std. Error	P value	95% Confidence Interval	
				Lower Bound	Upper Bound
INTERCEPT	0.893	0.122	0.000	0.654	1.132
GDP	0.005	0.011	0.642	− 0.017	0.027
GEXP	0.077***	0.015	0.000	0.049	0.106
EDUI	− 0.035	0.134	0.794	− 0.298	0.228
P014	− 0.203***	0.048	0.000	− 0.298	− 0.109
P65	0.162***	0.032	0.000	0.099	0.225
OUTPE	− 0.341***	0.014	0.000	− 0.369	− 0.313
URBP	0.098**	0.042	0.020	0.016	0.180
PDEN	− 0.023	0.020	0.244	− 0.062	0.016
INDU_L	0.092***	0.027	0.001	0.039	0.145
G_COC	0.102***	0.018	0.000	0.067	0.138
GDP * STATUS	− 0.048	0.031	0.117	− 0.109	0.012
GEXP * STATUS	0.218***	0.035	0.000	0.150	0.286
EDUI * STATUS	0.585**	0.226	0.010	0.141	1.029
P014 * STATUS	− 0.052	0.075	0.484	− 0.199	0.094
P65 * STATUS	0.061	0.049	0.218	− 0.036	0.158
OUTPE * STATUS	0.189***	0.030	0.000	0.130	0.247
URBP * STATUS	− 0.160	0.107	0.138	− 0.370	0.051
PDEN * STATUS	0.047	0.031	0.140	− 0.016	0.109
INDU_L * STATUS	− 0.117***	0.042	0.005	− 0.199	− 0.035
G_COC * STATUS	− 0.204***	0.037	0.000	− 0.277	− 0.131
R– Squared			0.957		
Akaike's Information Criterion (AIC)			− 7047.98		
Schwarz's Bayesian Criterion (BIC)			− 7036.69		
Random effect Covariance			0.001***		

*** p < 0.01, ** p < 0.05

**Fig. 9** Boxplot of the residuals by status

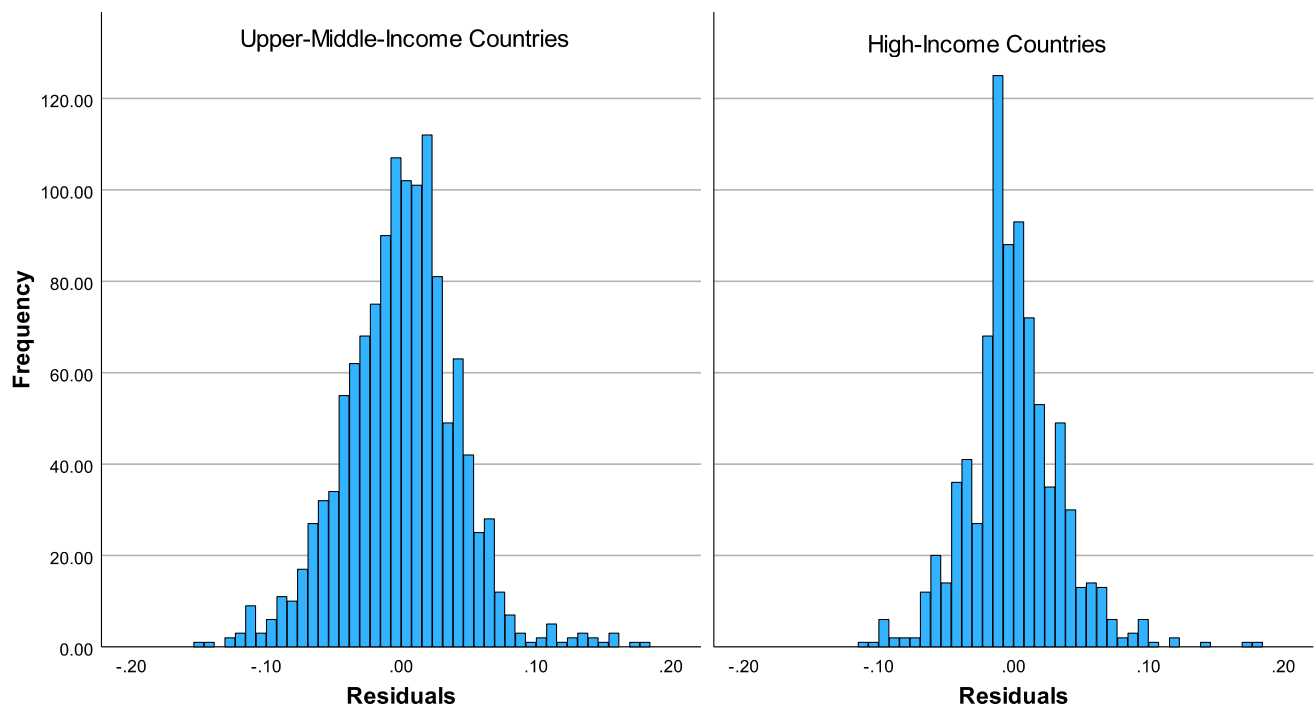


Fig. 10 Simple Histogram of Residuals by Status

Tonga, Mexico, Fiji, Iran, Ecuador, Paraguay, Thailand, Guyana, Guatemala, Kazakhstan, and the Dominican Republic, have invested 2% to 3% of their GDP in public health (Table 3).

Conversely, countries such as Iraq, China, Malaysia, Georgia, Gabon, Armenia, Azerbaijan, Indonesia, and Equatorial Guinea have allocated less than 2% of their GDP to public health (Table 3). Figure 2 visually illustrates the percentage of GDP allocated to public health spending for upper-middle-income countries.

Figure 3 features a scatter plot showing the positive correlation between public health spending and overall government spending across 28 high-income countries from 1990 to 2019. Likewise, in Fig. 4, the scatter plot highlights a positive relationship between public health spending and overall government spending for 42 upper-middle-income countries during the same period, spanning from 1990 to 2019.

Figure 5 illustrates the average government expenditures for overall spending and public health in high-income countries, while Fig. 6 presents the corresponding data for middle-income countries. The average overall government

Table 10 Estimates of the logistic and probit regressions. Source: Author's calculations

Parameter	Logistic Regression			Probit Regression		
	Exp(B)	Std. Error	P value	Exp(B)	Std. Error	P value
INTERCEPT	0.01	1.65	0.00	0.04	1.20	0.01
GDPC	1.00***	0.00	0.00	1.00***	0.00	0.00
GEXP	1.03	0.02	0.16	1.02	0.02	0.23
EDUI	0.12	1.50	0.15	0.14	1.12	0.08
P014	1.00	0.03	0.99	1.00	0.02	0.94
P65	1.10**	0.04	0.01	1.08**	0.03	0.01
OUTPE	1.02**	0.01	0.03	1.01**	0.01	0.03
URBP	1.02	0.01	0.06	1.01	0.01	0.08
PDEN	1.00	0.00	0.19	1.00	0.00	0.28
INDU_L	0.99	0.02	0.55	0.99	0.01	0.45
G_COC	4.89***	0.15	0.00	3.12***	0.11	0.00

*** $p < 0.01$, ** $p < 0.05$

expenditure in high-income nations amounts to 18.96% of GDP, whereas in upper-middle-income countries, it represents 15.07%.

4.1 Bayesian model averaging analysis for healthcare spending

The BMA has an estimated 2048 models. The BMA analysis indicated that in the context of high-income countries, the allocation of health spending is positively influenced by overall government spending, mean years of education, the elderly population, and the industrial workforce. Conversely, healthcare spending in high-income countries is negatively impacted by GDP per capita, the size of the young population, out-of-pocket health expenses, and population density (Table 4).

The results derived from the BMA analysis indicate that in upper-middle-income countries, the allocation of health spending is positively influenced by overall government spending, the young and elderly population, urbanization, population density, the industrial workforce, and corruption control. Conversely, healthcare spending in these countries is negatively impacted by mean years of education and out-of-pocket health expenses (Table 4).

4.2 GMM analysis for healthcare spending

Table 5 shows the GMM results: there is no second correlation in the Arellano–Bond tests, validating the instruments for high- and middle-income countries. Hansen's test confirmed the robustness of the instrument for both groups. According to the GMM, initial health spending, overall public spending, mean years of education, the share of the elderly population, and corruption control positively affected health spending in high-income countries.

In upper-middle-income countries, initial health spending, government spending, urbanization, population density, and corruption control significantly impact health spending. The coefficients for out-of-pocket health expenses and mean years of education were negative and significant (Table 5).

4.3 Random intercept model for healthcare spending

Table 6 reports the covariance structure and number of parameters necessary for the mixed effects model without group variation. The country defines the subjects.

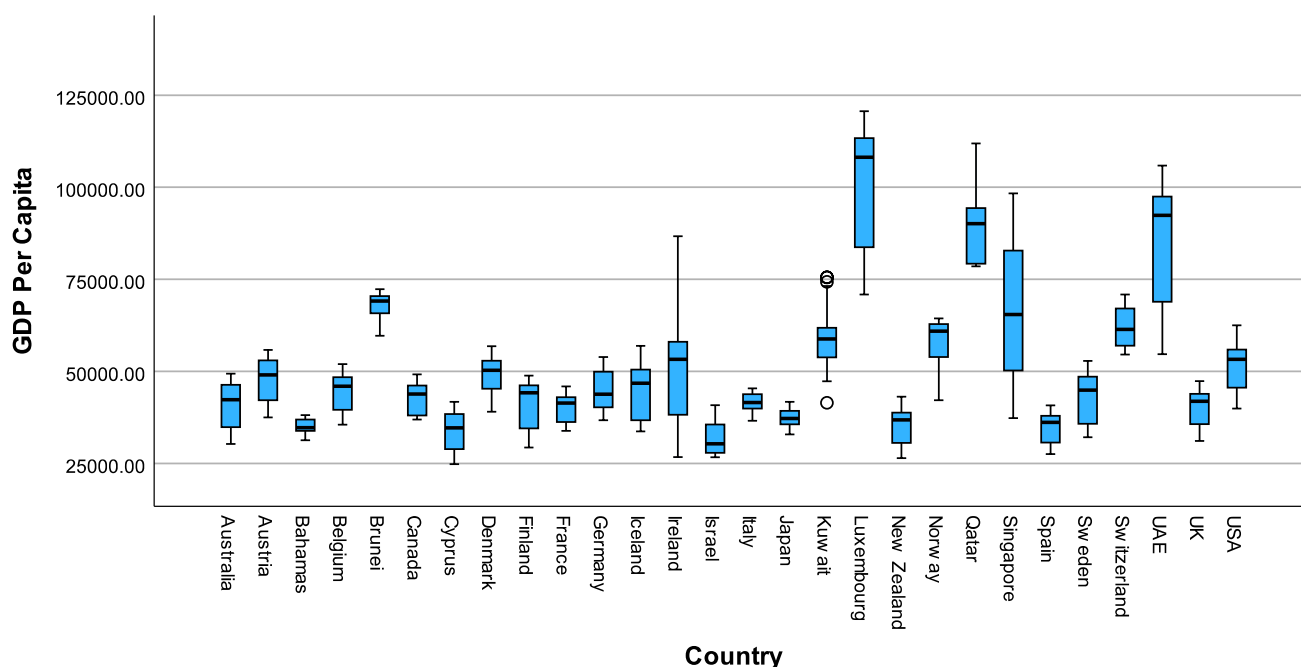


Fig. 11 Scatter Plot for the Health Spending and Corruption Control Index

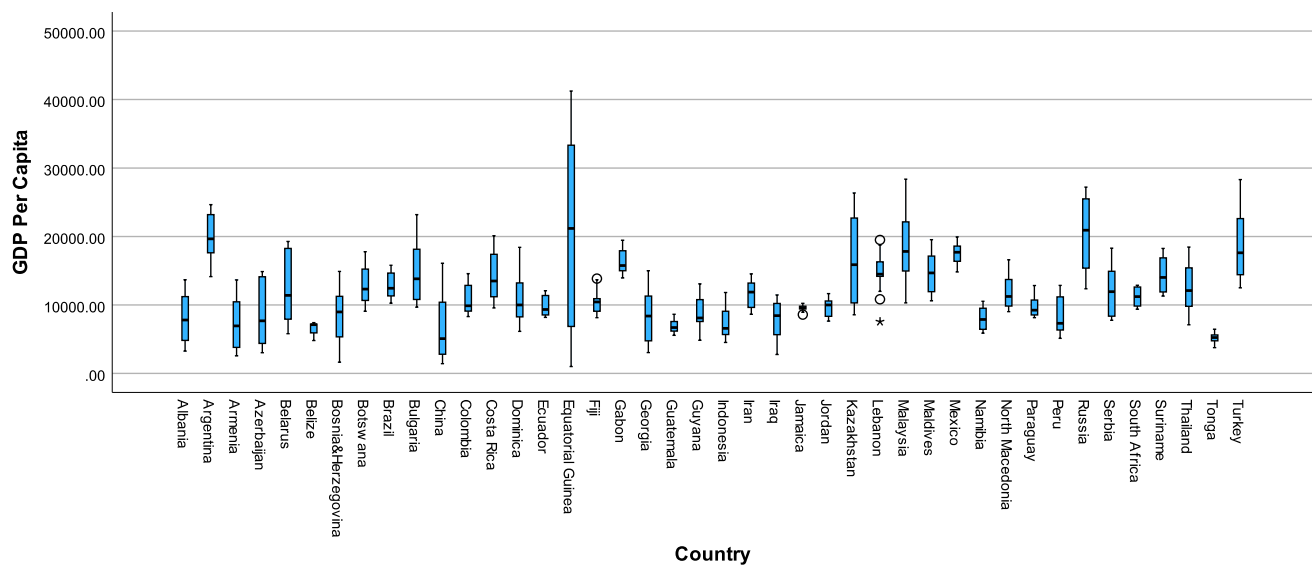


Fig. 12 Regression function fit—Polynomial Order 4

Table 11 RDD Estimates with cut Points for G_COC at 0.90 and 1.90

Cutoff Points	Method	Coef	Std. Err	P Value
0.90	Conventional	1.05***	0.380	0.006
0.90	Bias-corrected	1.22***	0.380	0.001
0.90	Robust	1.22***	0.397	0.002
1.90	Conventional	1.48***	0.337	0.000
1.90	Bias-corrected	1.44***	0.337	0.000
1.90	Robust	1.44***	0.412	0.000

Source: Authors' calculations

*** $p < 0.01$

Table 7 illustrates estimates derived from the random intercept model, which does not incorporate group variation. Notably, key healthcare spending determinants include overall government expenditure, average years of education, elderly population, and effective corruption control measures. Conversely, significant negative coefficients for the young population and out-of-pocket expenses are observed. The model demonstrated strong explanatory power, with an R-squared value of 90.00%. The model residuals exhibit an approximately normal distribution, as depicted in Figs. 7 and 8. The statistical significance of the random effect covariance value for the intercept, which is less than 0.05, suggests appreciable variability across countries for this coefficient.

Table 8 presents the covariance structure and the number of parameters required for the mixed effects model incorporating group variation. The country is the variable that defines subjects.

Table 9 shows the estimations derived from the random intercept model with group variation. Noteworthy common positive determinants of healthcare spending for high-income and upper-middle-income countries include government expenditures, the elderly population, urbanization, industrial employment, and effective corruption control. Conversely, significant negative factors affecting healthcare expenditures include a young population and out-of-pocket expenses.

Based on the random intercept model with group variation, Table 9 emphasizes the most significant interaction variables positively affecting healthcare spending in high-income countries. These include overall government expenditures, mean years of education, and out-of-pocket expenses. Conversely, the coefficients for industrial employment and corruption control are negative for high-income countries. The residual distribution seems normal, as illustrated in Figs. 9 and 10. Additionally, the statistical significance of the random effect covariance value being less than 0.05 suggests noticeable variability across countries for this coefficient.

The superiority of the random intercept model with group variation over the random intercept model without group variation is evident from the lower value of Akaike's information criterion (AIC). Specifically, the random intercept model with group variation exhibited an AIC of -7047.98 , while the random intercept model without group variation had an AIC of -6939.59 . Similarly, Schwarz's Bayesian criterion (BIC) further confirmed this superiority, with the random intercept model with group variation having a BIC of -7036.69 compared to -6928.30 for the random intercept model without group variation, as shown in Tables 7 and 9.

4.4 Logistic and probit regression results for healthcare spending

This study employs binary logistic and probit regression models to explore the underlying factors influencing healthcare expenditure in high-income countries compared to upper-middle-income countries. The logistic and probit models indicate that in high-income nations, greater GDP per capita, a greater share of the elderly population, elevated out-of-pocket healthcare costs, and robust corruption control measures are associated with a greater tendency to allocate resources to healthcare (Table 10). Notably, a significant portion of the variability in public healthcare spending within high-income economies is highlighted by the likelihood ratio statistics, yielding values of 2550.75 ($p < 0.001$) in the logistic regression and 2686.22 ($p < 0.001$) in the probit regression.

The mean GDP per capita in high-income nations was USD (US dollars) 50,652.77 (as depicted in Appendix 1, Fig. 13), whereas for upper-middle-income countries, it was USD 11,827.86 (as illustrated in Appendix 1, Fig. 14). The average proportion of elderly individuals in high-income countries reached 12.70% (as seen in Appendix 1, Fig. 15), surpassing that of upper-middle-income nations, which was 6.84% (as depicted in Appendix 1, Fig. 16). The control of corruption index for high-income countries was 1.55 (as indicated in Appendix 1 Fig. 17), surpassing that of upper-middle-income countries, which was -0.41 (as shown in Appendix 1, Fig. 18).

4.5 Regression discontinuity design

Figure 11 presents a scatter plot for health spending and the corruption control index, showing the presence of nonlinearity for 28 high-income and 42 upper-middle-income countries. The scatterplot displays data from a public health spending–corruption regression–discontinuity design. The vertical axis represents the outcome measure of health spending, while the horizontal axis represents the quantitative assignment variable corruption control index. The vertical line on the plot indicates the cutoff score for healthcare spending.

In Fig. 12, the two regression lines are depicted as sloping lines fitted through the data points in each group. Whether the two regression lines deviate from each other determines the presence of a treatment effect. If the treatment effect is constant for all countries, a vertical displacement in the regression lines will occur at the cutoff point on the corruption control index.

Countries with corruption control index scores above the cutoff are allocated to the experimental group, and their corresponding DGGHE scores are depicted in the right panel of Fig. 12. Conversely, countries with corruption control index scores below the cutoff are placed in the comparison group, and their DGGHE scores are represented in the left panel of Fig. 12.

In Fig. 12, a negative treatment effect is observed for a short time because the regression line in the treatment group is shifted downward compared to the regression line in the comparison group. The downward shift in the treatment effect of the corruption control index on the experimental group could be due to many factors, such as the Great Recession from 2007 to 2009 and other debt, financial, monetary, and economic crises (Table 11).

However, there is evidence of a positive upward shift in the treatment effect for the experimental group on the right panel after corruption control, which exceeds 1.20% (Table 11). Higher corruption control treatment allows countries to achieve more efficient healthcare spending.

In summary, Table 11 presents data from a regression-discontinuity design, and it demonstrates the analysis conducted on the outcome measure (DGGHE) regressed separately onto the corruption control index scores for each treatment condition. The purpose is to compare the two resulting regression lines. Table 11 shows that with a one-unit increase in the corruption control index, health spending experienced a 1.05% increase based on the conventional method. However, employing bias-corrected or robust methodologies for the experimental group yielded an even greater increase of 1.22%.

Overall, the regression-discontinuity design is a powerful tool for generating credible results when conducting a randomized experiment, which is not possible or practical. It provides valuable insights into causal relationships and outperforms nonequivalent group or correlational designs.

RDD estimates show a positive impact of the corruption control index on achieving appropriate public healthcare spending for the experimental group compared to the comparison group after the corruption control index cutoff of 1.20%.

5 Policy implications and conclusion

This research explores the significance of access to quality healthcare as a fundamental human right. It investigates how economic, demographic, and political factors influence government healthcare expenditure. This study scrutinizes government healthcare spending across 28 high-income and 42 upper-middle-income countries from 1990 to 2019. To carry out the analysis, a blend of statistical methodologies, including Bayesian model averaging (BMA), generalized method of moments (GMM), random intercept, and regression discontinuity design (RDD), are utilized. Furthermore, generalized linear models employing logistic and probit regressions are also employed for comprehensive examination.

Healthcare spending in the previous year is a crucial determinant of public healthcare expenditure in high- and upper-middle-income countries. Government funding allocation significantly impacts healthcare expenditure in both groups of nations, a trend consistently revealed across multiple statistical models such as BMA and GMM. This influence is also evident in the random intercept model with group variation, where the coefficient of overall government expenditure proves significant for both high-income and upper-middle-income countries. Particularly in high-income nations, this coefficient demonstrates a positive and substantial association. These findings highlight the pivotal role of government investment in shaping healthcare spending patterns within these countries. They underscore the importance of government policies and budget allocations in determining healthcare provision and accessibility in nations with relatively higher income levels.

The average years of education considerably influence healthcare spending in high-income countries, as evidenced by both BMA and GMM findings. Interestingly, while this influence is notably negative in both analyses, it lacks significance in upper-middle-income countries. This observation is also apparent in the random intercept model with group variation, where the shared coefficient for mean years of education in high-income and upper-middle-income countries fails to achieve statistical significance. However, it is significant for high-income countries individually. This observation suggests that the level of education, as measured by mean years of education, plays a significant role in shaping healthcare spending patterns in high-income countries. However, the precise nature of this influence varies across different statistical models within upper-middle-income countries. Specifically, according to the analysis, higher education levels are associated with lower healthcare spending in upper-middle-income countries, as observed in both BMA and GMM analyses.

This research revealed a significant positive correlation between the proportion of elderly individuals in the population and public healthcare expenditures in high-income countries, which was consistently observed across both BMA and GMM analyses. However, no significant positive correlation was found in upper-middle-income countries using the generalized method of moments (GMM). Although the shared coefficient of the elderly population is significant in the random intercept model with group variation, the coefficient for high-income countries alone lacks significance. This underscores the impact of the proportion of the elderly population on public healthcare spending patterns, which is particularly evident in high-income countries across various statistical models. This implies that as the share of the elderly population increases, so do public healthcare expenditures in high-income countries. Nevertheless, this association is not consistently observed in upper-middle-income countries, as evidenced by the GMM analysis results.

Urbanization stands out as a significant factor impacting healthcare spending in upper-middle-income countries, supported by findings from both BMA and GMM analyses. This influence is also evident for upper-middle-income and high-income countries, as demonstrated by a significant shared coefficient for urbanization in the random intercept model with group variation. However, this significance needs to be considered when considering high-income countries independently. These findings imply that urbanization is crucial in shaping healthcare spending patterns, particularly in upper-middle-income countries. The significant impact of urbanization on healthcare expenditure suggests that as urbanization increases, there is a corresponding need for greater investment in healthcare services to meet the demands of urban populations. This underscores the importance of understanding demographic shifts and urban development trends when effectively formulating healthcare policies and allocating resources. Additionally, when considered independently, the lack of significance in high-income countries suggests that other factors may have a more dominant influence on healthcare spending in these contexts.

Industrial employment emerges as a noteworthy factor affecting healthcare spending in high-income and upper-middle-income countries, according to BMA analysis. This relationship is further supported by the random intercept

model with group variation, where the shared component demonstrates a positive and significant association. However, it is important to note that in high-income countries, the influence of industrial employment on healthcare spending is negative and significant according to the random intercept model with group variation. These findings have significant implications for healthcare policy and resource allocation. Industrial employment impacts healthcare spending patterns in high-income and upper-middle-income countries. The positive association suggests that areas with higher industrial employment tend to necessitate increased healthcare expenditure, likely due to occupational health risks or greater healthcare demands associated with industrial activities. However, observing a negative association within high-income countries suggests a nuanced relationship. This could imply that in high-income settings, industrial employment may be associated with better access to private healthcare services or occupational health programs, leading to lower public healthcare spending. Overall, policymakers need to consider the influence of industrial employment on healthcare spending when designing healthcare policies and resource allocation strategies, particularly in regions where industrial sectors are significant contributors to the economy. Efforts may be needed to address healthcare needs specific to industrial workers while ensuring equitable access to healthcare services for all population segments.

Efforts to curb corruption have a notable and positive influence on healthcare spending in high-income and upper-middle-income countries, as indicated by the generalized method of moments (GMM) analysis. Within the random intercept model, where group variation is accounted for in high-income and upper-middle-income countries, the shared coefficient for corruption control has a positive and significant association. However, it is important to note that this coefficient is negative and significant solely for high-income countries. Notable findings from RDD analysis reveal a positive change in the treatment effect for the experimental group when the corruption control index exceeds 1.20%. This suggests that a stronger corruption control index empowers upper-middle- to high-income countries to improve their healthcare spending.

These findings significantly affect healthcare policy and governance practices in high-income and upper-middle-income countries. The positive association between corruption and healthcare spending suggests that tackling corruption can increase investments in healthcare infrastructure, services, and quality improvement initiatives.

However, the observed negative association, specifically in high-income countries, warrants further examination. This suggests a more complex relationship between corruption control measures and healthcare spending in these contexts. One potential interpretation could be that reduced corruption in high-income countries with stringent anticorruption measures may lead to more efficient resource allocation, resulting in lower healthcare expenditures without compromising the quality of care.

Overall, policymakers need to consider the impact of corruption control efforts on healthcare spending when formulating strategies to improve healthcare systems. Efforts to combat corruption should be prioritized, as they can enhance healthcare provision and improve health outcomes for populations. However, careful monitoring and evaluation are necessary to ensure that reduced healthcare spending in high-income countries does not lead to inadequate access to essential services or compromised quality of care.

Out-of-pocket health expenses consistently negatively influence healthcare spending in high-income and upper-middle-income countries, as observed in both BMA and GMM analyses. The shared coefficient for out-of-pocket health expenses is significantly negative in the random intercept model with group variation applied to high-income and upper-middle-income countries. However, in the same model, there is a significant positive sign for out-of-pocket health expenses, specifically for high-income countries. These findings significantly affect healthcare policy and financial management in high-income and upper-middle-income countries. The consistent negative impact of out-of-pocket health expenses on healthcare spending underscores the importance of reducing reliance on individual payments for healthcare services. Policymakers should consider implementing measures to alleviate the financial burden on individuals, such as expanding insurance coverage or implementing subsidy programs, to mitigate the negative effects of out-of-pocket expenses on healthcare spending.

However, within the random intercept model, the observed positive sign for out-of-pocket health expenses in high-income countries highlights a potential disparity in healthcare financing mechanisms. This suggests that in high-income countries, individuals may have greater capacity to pay for healthcare services out-of-pocket, leading to increased healthcare spending overall. Policymakers should carefully consider the implications of these findings and explore ways to ensure equitable access to healthcare services while minimizing the financial burden on individuals. These findings emphasize the need for comprehensive healthcare-financing reforms to reduce out-of-pocket expenses and promote financial protection for individuals, regardless of income level. By addressing the negative impact of out-of-pocket health expenses on healthcare spending, countries can work toward achieving universal health coverage and improving healthcare access and affordability for all citizens.

The coefficient of the effect of the young population on healthcare spending is negatively significant for high-income countries, according to both BMA and GMM analyses. However, it is positive and significant for upper-middle-income countries in the BMA analysis. Moreover, the effect of the shared coefficient of the young population on healthcare

spending is negatively significant for high-income and upper-middle-income countries. However, the coefficient for high-income countries alone is not significant. These findings have important implications for healthcare policy and resource allocation strategies in high-income and upper-middle-income countries. The negative significance of the coefficient of the effect of the young population on healthcare spending in high-income countries suggests that a greater proportion of young individuals is associated with lower healthcare expenditure. This may indicate lower demand for healthcare services among younger populations or possibly more efficient healthcare delivery systems targeting this demographic.

On the other hand, the positive and significant coefficient observed for upper-middle-income countries in the BMA analysis implies that a greater proportion of young individuals is associated with increased healthcare spending. This could indicate a greater need for healthcare services among younger populations in these countries, potentially due to higher rates of infectious diseases, maternal and child health needs, or other factors. Furthermore, the shared negative significance of the coefficient for high-income and upper-middle-income countries suggests a common trend of reduced healthcare spending associated with a greater proportion of young individuals. However, the nonsignificant coefficient for high-income countries indicates that this relationship may be less pronounced in these nations than in upper-middle-income countries. Policymakers should consider these findings when designing healthcare policies and allocating resources. They highlight the importance of understanding demographic dynamics and healthcare needs across different income levels to ensure effective and equitable healthcare provision. Efforts may be needed to address the specific healthcare needs of younger people in upper-middle-income countries while optimizing resource allocation in high-income countries to meet the healthcare demands of all age groups effectively.

A comparative analysis employing logistic and probit regression methods revealed that crucial determinants impacting healthcare spending in high-income countries include GDP per capita, the proportion of the elderly population, out-of-pocket expenses, and measures for controlling corruption. This finding implies several key factors significantly impact healthcare spending in high-income countries. These factors include the wealth of the nation as measured by GDP per capita, the proportion of elderly individuals in the population, the amount of money people pay out of their own pockets for healthcare, and the effectiveness of measures taken to combat corruption within the healthcare system. This suggests that policymakers in high-income countries should consider these factors when designing healthcare policies to ensure efficient allocation of resources and effective management of healthcare expenditure.

Upper-middle-income countries can work toward increasing GDP per capita to support higher healthcare spending. Policies such as expanding geriatric healthcare services and social support programs should be implemented to address the needs of elderly citizens. Exploring ways to decrease the financial burden on individuals by increasing insurance coverage or implementing subsidies for healthcare services. Measures should be implemented to improve transparency and accountability within the healthcare system to reduce corruption and the misuse of funds.

Preventive measures should be emphasized to reduce the overall burden on the healthcare system and control costs in the long term. Investing in building and upgrading healthcare facilities and training healthcare professionals can improve the quality and efficiency of healthcare services. By taking these steps, upper-middle-income countries can work toward more efficient and sustainable healthcare systems that meet the needs of their populations while managing healthcare spending effectively.

A study referenced in Taiwan [38] suggested that key determinants of Taiwan's per capita health expenditures include prior one-month health expenditures, bed supply per capita, real gross domestic product (GDP) per capita, and standardized mortality ratio (SMR). Our study aligns with [38] on two determinants of health expenditure: prior one-year health expenditures for both country groups and GDP per capita (in probit and logit models) for high-income countries. However, our study diverges from [38] by finding a significant positive impact of the elderly population on health expenditure in high-income countries, contrary to their findings.

A promising avenue for future research in the field involves identifying additional variables that influence government spending on healthcare. This could encompass exploring factors beyond the commonly studied determinants to better understand the dynamics at play. Moreover, there is a need for in-depth investigations specifically focusing on the factors shaping government healthcare expenditure in lower-middle-income and low-income countries. Researchers can uncover insights crucial for effective policymaking and resource allocation by delving into these nations' unique challenges and circumstances.

Furthermore, there is potential for conducting time-series analyses of government health spending for individual countries. This approach allows for tracking expenditure patterns over time, identifying trends, and assessing the impact of various factors on spending dynamics. By examining longitudinal data, researchers can elucidate how government healthcare spending evolves in response to economic conditions, political priorities, healthcare needs, and other pertinent factors.

By exploring additional variables, focusing on specific country income groups, and employing time-series analysis techniques, future research endeavors can contribute significantly to our understanding of government spending on health and inform strategies for enhancing healthcare financing and delivery worldwide. Assessing the impact of health quality expenditure on health quality indicators is likely another effective approach.

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Data availability The data used for this research are available publicly in the following repositories: World Bank (<https://databank.worldbank.org/reports.aspx?source=world-development-indicators>) Global economy (<https://www.theglobaleconomy.com/download-data.php>) data repositories. UNESCO (<http://hdr.undp.org/en/indicators/103706#>, <http://uis.unesco.org/>).

Declarations

Competing interests The author has no relevant financial or nonfinancial interests to disclose. The author has no conflicts of interest to declare relevant to this article's content. The author certifies that he has no affiliations with or involvement in any organization or entity with a financial or nonfinancial interest in the subject matter or materials discussed in this manuscript. The author has no financial or proprietary interests in any material discussed in this article. Research does not involve human participants or animals. This research did not involve any other persons. The author has not received any funds for this research paper. The authors are responsible for the correctness of the statements provided in the manuscript.

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Appendices

Appendix 1

See Fig. [13](#), [14](#), [15](#), [16](#), [17](#) and [18](#)

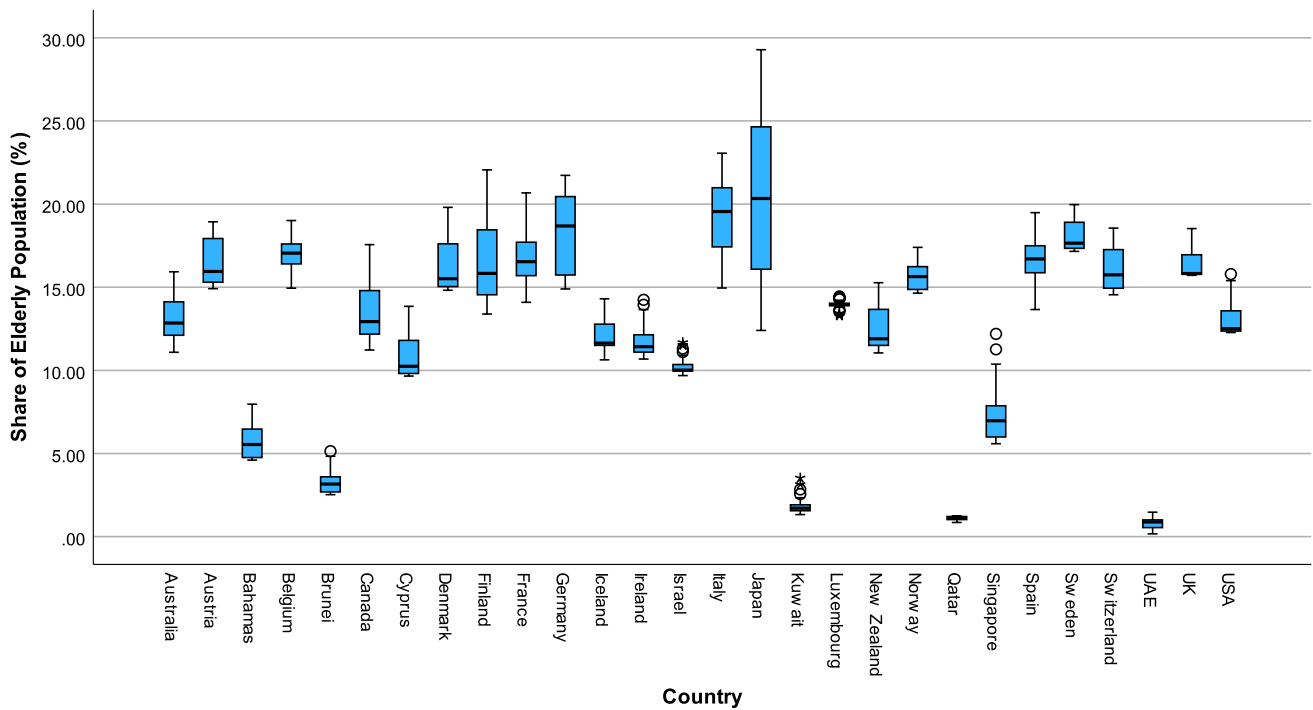


Fig. 13 GDP Per Capita in High-Income Countries

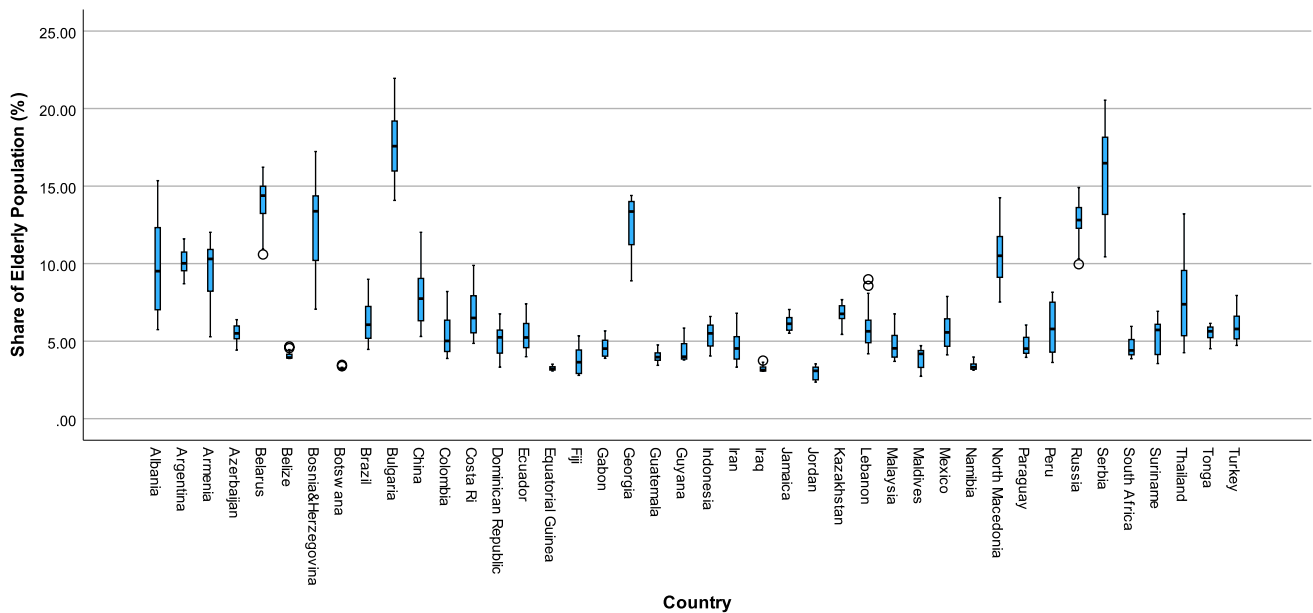


Fig. 14 GDP Per Capita in Middle-Income Countries

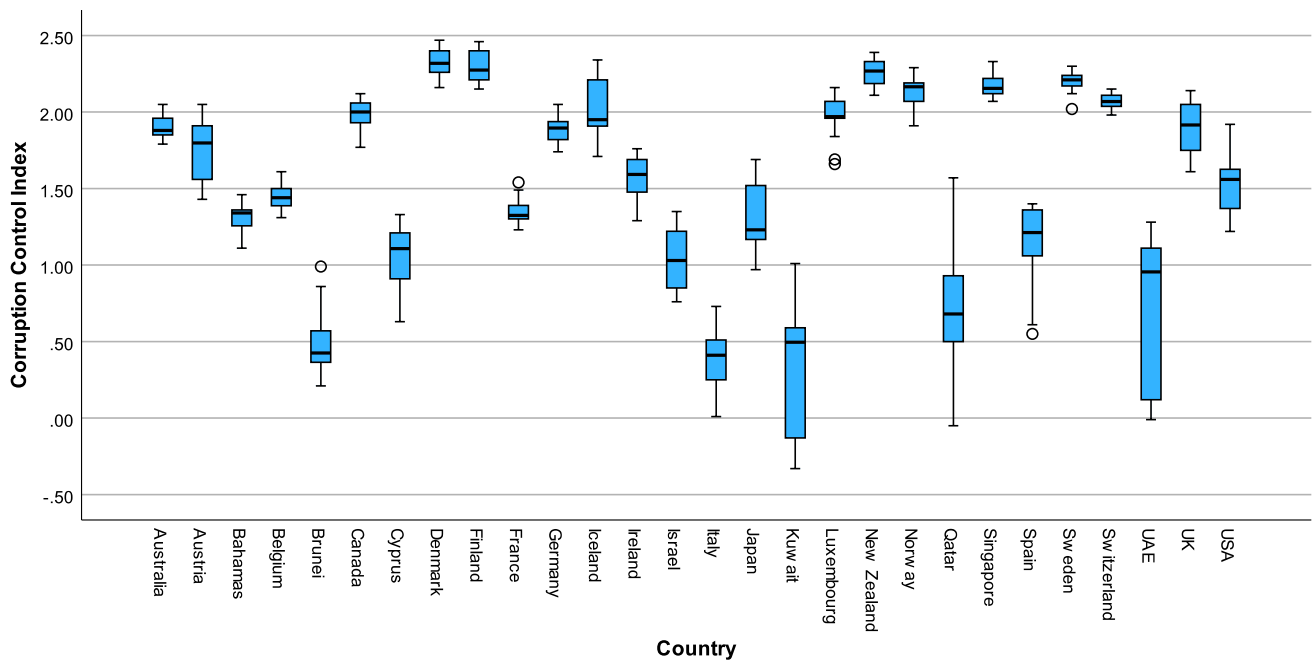


Fig. 15 Share of the elderly population (%) in high-income countries

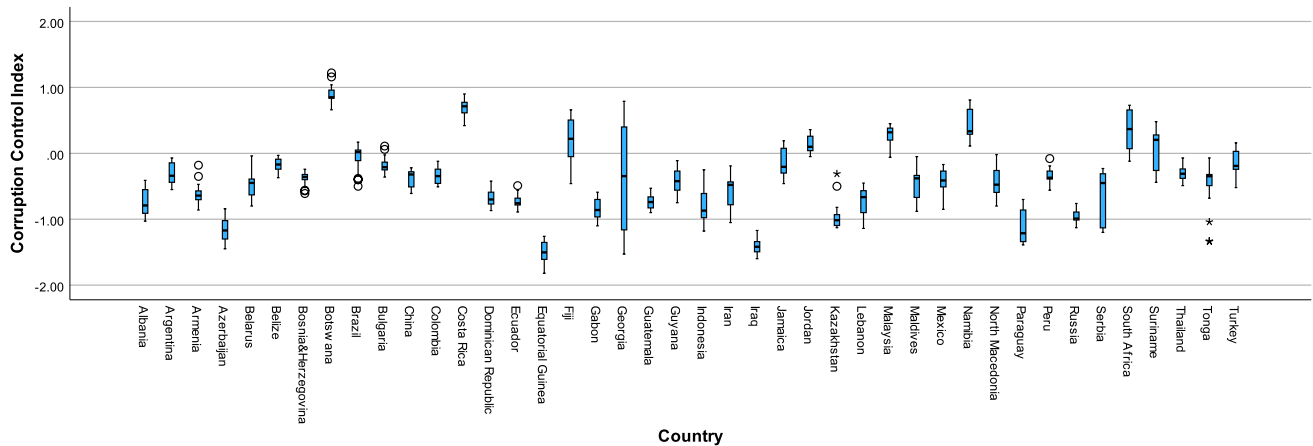


Fig. 16 Share of the Elderly Population (%) in Upper-Middle-Income Countries

Fig. 17 Corruption Control Index in High-Income Countries

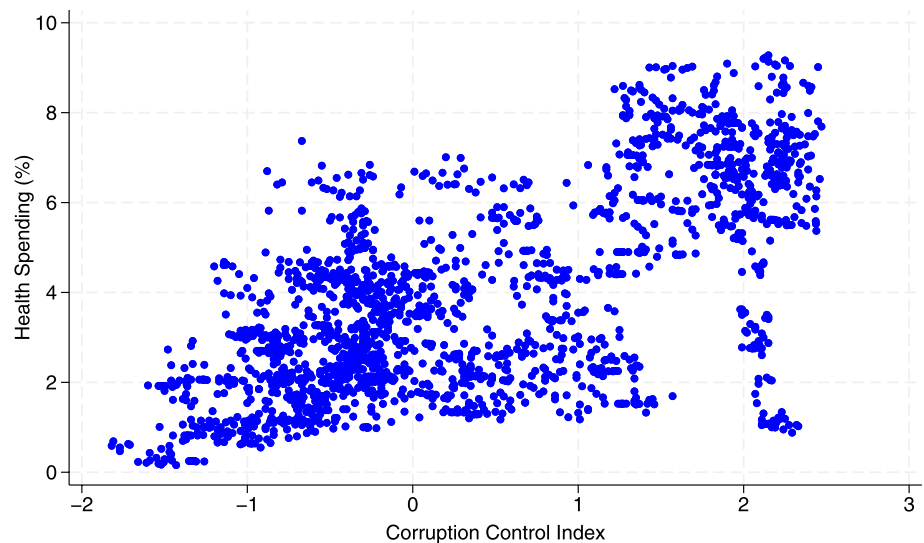
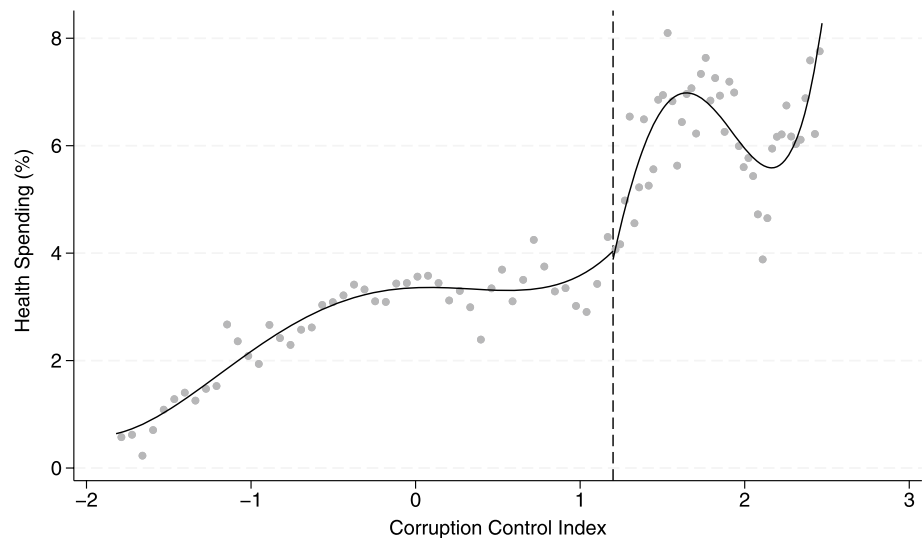


Fig. 18 Corruption Control Index in Upper-Middle-Income Countries



Appendix 2

We analyzed seventy countries, categorizing them into two groups according to the World Bank's classification based on gross national income (GNI) per capita [39]. The income thresholds for this classification are as follows: US\$ 3996 to US\$ 12,375 for upper-middle-income countries and greater than US\$ 12,375 for high-income countries.

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