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Research Article

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ASSESSING THE ECONOMIC CONSEQUENCES OF ANTIMICROBIAL RESISTANCE IN DEVELOPING ECONOMIES LIKE INDIA

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ABSTRACT

This paper aims to address Antimicrobial Resistance in India from the economic perspective of two indicators: the relationship between mortality rates (male adult mortality per 1,000 male adults) and the GDP per employee, constant in PPP dollars for the year 2021, and the relationship between antibiotic resistance percentage and out-of-pocket expenditure, % of current health expenditure. Utilizing 32 years of available data for the first analysis and 22 years in the second analysis of the research, this work uses statistical analysis to identify patterns and insights from the data collected. It goes further in exploring the connection between health and economic development. Data have shown that higher mortality rates portray lower GDP per person employed and it is indicative of negative productivity effects. The study finds a bidirectional relationship between GDP per capita and adult mortality rates where lagged GDP affects mortality and lagged mortality affects GDP. Antibiotic resistance and healthcare expenditure also exhibit a strong influence on past values and indicate self-reinforcing trends rather than direct causal effects between the two. Such findings highlight the need for strategic policy interventions to mitigate the economic impact of AMR and to understand improvement in health outcomes in India, an agenda that could help increase the efficiency of health funds and antibiotic usage. To estimate both short- and long-term impacts, Vector Auto regression is used as a tool for modelling; this paper will delve deeper into the complex relationship between health and economic development.

Keywords: AMR, Economic Effects, Healthcare, out of pocket expenditure, Dynamic Relationships.

INTRODUCTION

According to the World Health Organisation (WHO), Antimicrobial Resistance poses a threat to the effective prevention and treatment of an increasingly wide range of infections caused by bacteria, parasites, viruses, and fungi. AMR occurs when these bacteria, viruses, fungi, and parasites evolve and progressively become resistant to drugs that may make it more challenging to treat infections and which increase the risk of a contagious disease transfer, exacerbation, and death. This makes the drugs useless, hence infection persistence in the body and increased risk of transmission to others. Antimicrobials are drugs that include antibiotics, antivirals, antifungals, and antiparasitic, which are primarily used in preventing and treating infections in humans, animals, and plants (WHO, 2019).

Antimicrobial resistance has become a critical public health problem in developing countries like India, threatening the health system and the country's economy. In 2019, India recorded an estimated 297,000 deaths directly attributable to AMR and over 1 million deaths associated with this factor, thus highlighting the severity of the situation. AMR-related mortality in India remains higher than that from conditions like neoplasms, respiratory infections, and diabetes all combined, thus making it a leading cause of concern. The most common causative pathogens are Escherichia coli, Klebsiella pneumoniae, and Staphylococcus aureus, while major infections like tuberculosis, respiratory tract infection, and urinary tract infection are ascribed to these. A National AMR Action Plan was adopted but its financing and subsequent implementation are only partial. The load of AMR threatens the health infrastructure of India, which is in urgent need of addressing to make the health system work more sustainably (Institute for Health Metrics and Evaluation, 2023).

Besides the debilitating health effects, AMR creates massive economic expenses, particularly for developing nations such as India. According to the World Bank's estimate, AMR is estimated to incur additional healthcare costs amounting to US$ 1 trillion by 2050, with losses to global GDP ranging from US$ 1 trillion to US$ 3.4 trillion annually by 2030 (WHO, 2023). For countries like India, with developing economies, the financial ramifications are profound. This is besides the fact that increased health expenditure, with several treatments being more expensive and requiring longer hospitalization, puts a high burden on health systems that are already stretched to their limit. Apart from that, AMR threatens labour productivity in the sense that the effectiveness of the work would be further heightened by increased sickness and disability, immediately impacting workforce participation and, accordingly, national output. In the production sectors, agriculture, and livestock, which are heavy users of antibiotics, AMR could lead to reduced production and increased costs of producing foodstuffs, translating into inflation and food insecurity. For a country like India, which has one of the highest burdens related to AMR-attributable deaths and infections, it could mean an economic ripple effect that deepens inequality, slows poverty alleviation, and strains public health resources to make AMR a serious threat to long-run economic growth, not just a public health crisis.

The motivation for this research centres on the economic impact of antimicrobial resistance (AMR), particularly its effects on mortality, GDP per person employed, and out-of-pocket expenditure in developing countries like India. Such high mortality figures related to AMR call for systemic interventions in the healthcare system as well as a need for policy changes. Based on this background, analysing the effects of AMR on workforce productivity and national economic performance is core to this study. Finally, it explores the financial burden that AMR imposes on households in terms of out-of-pocket expenditures and practices exacerbating inequity in access to health

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care. This research is essential to the understanding of the multifaceted implications brought by the rise of AMR, to inform policy decisions and indeed stakeholders, about the need for sustainable solutions. Ultimately, the hope is to contribute toward a more holistic approach that combines the health and economic dimensions of resilience in health systems.

This study seeks to explore two key research questions that address significant issues in public health and economic development:

1. What is the relationship between adult male mortality rates and GDP per employee?

This question would explore whether there is a statistical relationship between economic productivity, whereby the output per employee has been evaluated through GDP, and the deaths of adult males. Analysis of such a relationship can elucidate how economic factors determine the determinants of health, especially among male adults who experience different socio-economic conditions.

2. How does the rise of antibiotic resistance contribute to the proportion of health expenditure out-of-pocket?

This question delves into the economic impact of antibiotic resistance in terms of individual health expenditure. The study explains the relationship between the escalating antibiotic resistance and patient costs, hence exploring broader determinants of the public health cost and personal finances implications of antibiotic resistance. This is important in the aim of managing the challenge of antibiotic resistance in healthcare systems by policymakers.

This study aims to attain the following objectives:

1. Evaluate the Economic Burden of AMR:

Conduct a comprehensive statistical analysis in order to examine the relationship between adult male mortality rates, GDP per employee, and out-of-pocket health expenditures on account of antibiotic resistance. This would allow quantification of the economic impact of AMR on public health systems and the economy of individual finances.

2. Identification of Potential Policy Interventions:

The following policy interventions are recommended in mitigating the economic burden from AMR. This research will, therefore, focus on the identification of policy interventions that might be suggested based on the findings that shall emerge from the statistical analyses. Targeted policy interventions will seek to improve health outcomes and reduce healthcare expenditure, thus being of relevance in the achievement of effective management of antibiotic resistance and associated challenges.

This study contributes to the existing literature by looking at the dual relationships between health outcomes, represented by mortality and antibiotic resistance, and economic metrics in terms of GDP and health expenditure within India. Most of the research on these issues nowadays is either done on a global scale or oriented to developed countries, leaving quite a gap in such studies on these relationships in developing countries. This analysis brings localization into the paper through its findings and thus may be used for better policy decisions adapted to the obstacles of developing economies in their unique way. The variables of health outcomes and economic conditions in India, a country where most of its population falls within the brackets of middle and lower income, are so different from those of other wealthy nations. This study focuses on out-of-pocket expenditure as a percentage of healthcare costs, reflecting the financial burdens associated with households trying to access health care-a dimension often overlooked in global studies.

LITERATURE REVIEW

1. AMR and Global Economic Effects

Antimicrobial resistance is generally acknowledged as one of the huge global health threats, which has extensive economic implications. Based on estimates from the 2014 Review on Antimicrobial Resistance, Jim O'Neill expected that, without action, AMR would cause 10 million additional deaths each year and an astonishing cost of $100 trillion by 2050 (O'Neill, 2014). The report of the World Bank (2017) has particularly stated that AMR is likely to drive 24 million people into extreme poverty, affecting low- and middle-income countries disproportionately, and exposing those regions to higher economic burdens (World Bank, 2017).

Economic theories-the health capital model also explains how health relates to productivity. This model suggests that improved health means higher productivity in labour since healthier workers take fewer days off to nurse an illness, therefore positively impacting output in the economy (Grossman, 1972). Empirical evidences show that the countries that invest in health experience economic growth at a higher rate; hence another explanation for why something should be done about AMR to avoid losing productivity and having unwanted economic downturns (Bloom & Canning, 2003).

2. Mortality and Economic Growth

It has been pointed out that there is a well-established relationship between mortality rates and economic performance. Studies show that high mortality rates of infectious diseases may slow down economic growth due to the shrinking labour force and inefficient development of human capital. Bloom and Canning (2003) conclude that an increase of 10% in life expectancy results in a 0.3% increase in GDP per capita.

Studies based on India report that healthcare challenges posed by AMR take a huge blow in terms of the economic impact. The Indian Council of Medical Research (2020) study showed that over 1 percent of India's GDP per year may be lost to early deaths and productivity losses due to resistance to drugs caused by AMR (ICMR, 2020). This is the double burden of poor health outcomes and economic stagnation, thus underpinning the issue of investments in healthcare infrastructure to fight AMR appropriately.

3. Antibiotic Resistance and Healthcare Costs

The economic burden of AMR extends to healthcare costs, particularly out-of-pocket expenditures for patients. Research indicates that individuals facing antibiotic-resistant infections incur significantly higher treatment costs, leading to financial strain. A World Health Organization report (2019) revealed that these costs can result in catastrophic health expenditures, particularly in low-income settings where health insurance coverage is limited (WHO, 2019).

There is thus still a need for a much larger body of literature, particularly on the socioeconomic impacts of AMR in developing countries. More comprehensive assessments that include direct costs in healthcare should then include broader economic consequences brought about by the loss of productivity as well as a reduction in workforce participation. Filling these gaps is crucial for framing targeted policies that might mitigate the impact of AMR while ensuring economic resilience for vulnerable groups.

Data

1. Mortality Rates

Variable: Male adult mortality per 1000 male adults

Data Source: The World Bank provides a brief overview of mortality statistics from its Global Health Observatory, typically drawn out from national health interviews, vital registration, and demographic health surveys.

Time Period: The range of the study is three decades and two years, from 1990-2022. More so an extended period would allow for a robust analysis of trends and their relationship with economic variables.

2. GDP per Person Employed

Variable: GDP per person, employed (cost 2021 PPP$).

Data Source: GDP estimates are obtained from the World Bank database where data regarding GDP adjusted by purchasing power parity (PPP) is constant and comparable.

This would mean comparability between countries and years as well.

Period: As in the case of the mortality rates, the period of the GDP data is also thirty-two years, covering the period between 1992 to 2022, to enable the vast changes in economic growth to be viewed against health changes over the years.

3. Antibiotic Resistance Percentages

Variable: Percentage of antibiotic resistance amongst the major pathogen, Fluoroquinolones.

Source of Data: Antibiotic resistance data comes from research by Sardar *et al.,* (2023), titled 'Harnessing the Power of Bio Adsorbents: A Review on Sustainable Approach to Eliminate Antibiotic Residues in Wastewater for Better Public Health'

Year of Analysis: The years 2000-2022 are examined over 22 years. The timeline covers antibiotic resistance and public health implications.

4. Out-of-pocket health expenditures

Indicator: Out-of-pocket share of total health expenditures.

Source of Data: The World Bank collects data on health financing and expenditure. The above three channels-public, private, and out-of-pocket provisions-how much health care costs are divided into them are better explained through national health accounts.

Period: Similar to antibiotic resistance, this study period also spans 22 years, from 2000-2022. In this period, it could give insight into how rising healthcare costs affect the same increases in average personal spending.

METHODOLOGY

The approach used in this research is multivariate and among its main objectives is to make quantification of relationships between the above variables. The study calculates correlation coefficients to learn about relationships among mortality rates, GDP per person employed, percentage of antibiotic resistance, and out-of-pocket health expenditures. Time trends would also be illustrated visually using time series and scatter plots to facilitate pattern recognition and relationships among variables. Analysis of these sources and methods aims at providing balanced perspectives and recommendations for policy application and intervention in the economic and health areas of AMR.

Dependent and Independent Variables

1. GDP per Person Employed and Mortality Rates Dependent Variable:

GDP per Person Employed: An economic measure of productivity, reflecting economic performance in health outcomes measures.

Independent Variable:

Mortality Rates: Male adult mortality rates per 1,000 males. As it reflects health outcomes that can impact economic productivity.

2. Antibiotic Resistance and Healthcare Costs Dependent Variable:

Out-of-Pocket Health Expenditures: The extent of payments from individuals spending on health care has much to do with the factor of rising antibiotic resistance.

Independent Variable:

Antibiotic Percentages of Resistance: The variable measures the amount of resistance in pathogens against the given antibiotics and thus can be expected to play a critical role in treatment costs and health outcomes.

Econometric Model

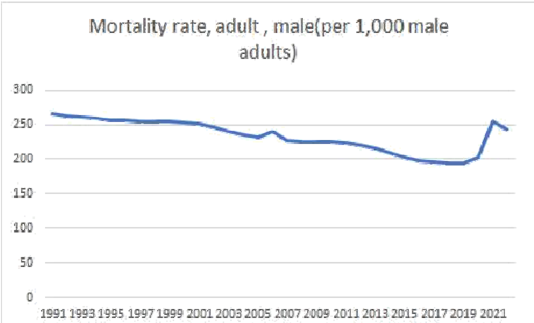
Vector Auto regression (VAR) is used to capture the linear interdependencies among multiple time series data. This is a study where mortality rates associated with GDP, antibiotic resistance, and healthcare costs are analysed over a given period. The model VAR will enable the estimation of the impacts of these four variables. Well-defined models are apt for this type of study because health and economic variables form complex interrelationships among many things. The VAR model captures loops among mortality rates and GDP very effectively and sharply, where the pattern changes from one to another. This model enables the discussion on immediate response among such variables as mortality influencing GDP for the short run, while other variables can sustain this relationship for many periods.

Econometric Test

Augmented Dickey-Fuller (ADF) Test was used to determine whether a time series is stationary or has a unit root, indicating non-stationarity. In this study, the ADF test will be applied to both the mortality rates and GDP data to ensure that they are stationary before further analysis. On the preliminary analysis, both the sets were stationary at the first difference, so the entire model is run on the first difference data point.

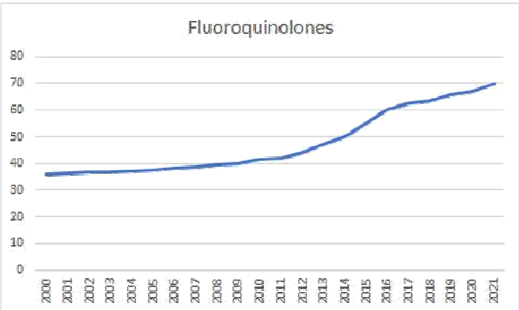
RESULTS

Mortality rate, adult , male(per 1,000 male adults)

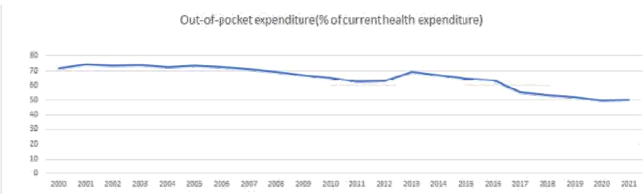


GDP per capita (constant 2021 PPP$)

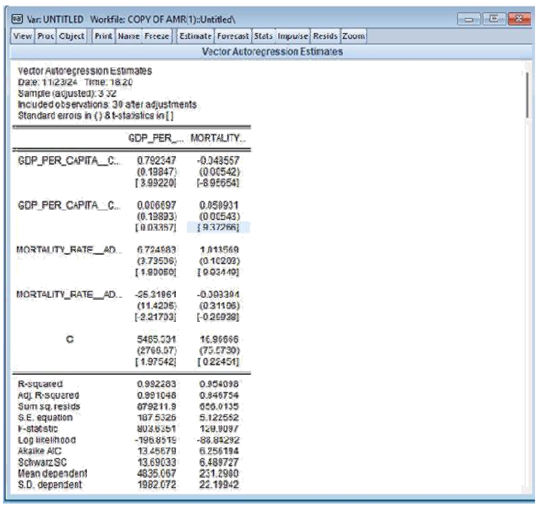
Antibiotic resistance percentage (Fluoroquinolones)



Out-of-pocket expenditure (% of current health expenditure)



Model Estimation Results:



Var: UNTITLED Workfile: COPY OF AMR(1)::Untitled\

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Impulse | Resids | Zoom

Vector Autoregression Estimates

Vector Autoregression Estimates
Date: 11/23/24 Time: 18:20
Sample (adjusted): 3 32
Included observations: 30 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	GDP_PER_...	MORTALITY...
GDP_PER_CAPITA__C...	0.792347	-0.048557
	(0.19847)	(0.00542)
	[3.99220]	[-8.95654]
GDP_PER_CAPITA__C...	0.006697	0.050931
	(0.19893)	(0.00543)
	[0.03367]	[9.37266]
MORTALITY_RATE__AD...	6.724983	1.013569
	(3.73506)	(0.10203)
	[1.80050]	[9.93449]
MORTALITY_RATE__AD...	-25.31961	-0.093394
	(11.4205)	(0.31196)
	[-2.21703]	[-0.29938]
C	5465.331	16.96666
	(2766.07)	(75.5730)
	[1.97542]	[0.22451]
R-squared	0.992283	0.954098
Adj. R-squared	0.991048	0.946754
Sum sq. resids	879211.9	656.0135
S.E. equation	187.5326	5.122552
F-statistic	803.6351	129.9097
Log likelihood	-196.8519	-88.84292
Akaike AIC	13.45679	6.256194
Schwarz SC	13.69033	6.489727
Mean dependent	4835.067	231.2980
S.D. dependent	1982.072	22.19942

VAR for the GDP per capita and Mortality Rate

Equation 1: GDP_PER_CAPITA__CONSTANT

Dependent variable:

GDP_PER_CAPITA__CONSTANTGDP_PER_CAPITA__CONSTANTGDP_PER_CAPI TA__CONSTANT

- GDP_PER_CAPITA_CONSTANT (-1): Coefficient = 0.792347, t-statistic = 3.99220 (significant).
  - o A 1-unit increase in GDP per capita at lag 1 increases GDP per capita at time ttt by 0.79 units.
- GDP_PER_CAPITA_CONSTANT (-2): Coefficient = 0.006697, t-statistic = 0.03367 (not significant).
  - o The second lag of GDP per capita has no meaningful effect on current GDP per capita.
- MORTALITY_RATE__ADULT__−1-1−1: Coefficient = 6.724983, t-statistic = 1.80050 (weakly significant).
  - o An increase in adult mortality rate at lag 1 has a weak positive effect on current GDP per capita.
- MORTALITY_RATE__ADULT__−2-2−2: Coefficient = -25.31961, t-statistic = - 2.21703 (significant).
  - o A 1-unit increase in adult mortality rate at lag 2 reduces GDP per capita by 25.32 units.
- Constant term: Coefficient = 5465.331, t-statistic = 1.97542 (weakly significant).
  - o Indicates that GDP per capita is around 5465 when other variables are at zero. Equation 2: MORTALITY_RATE__ADULT__

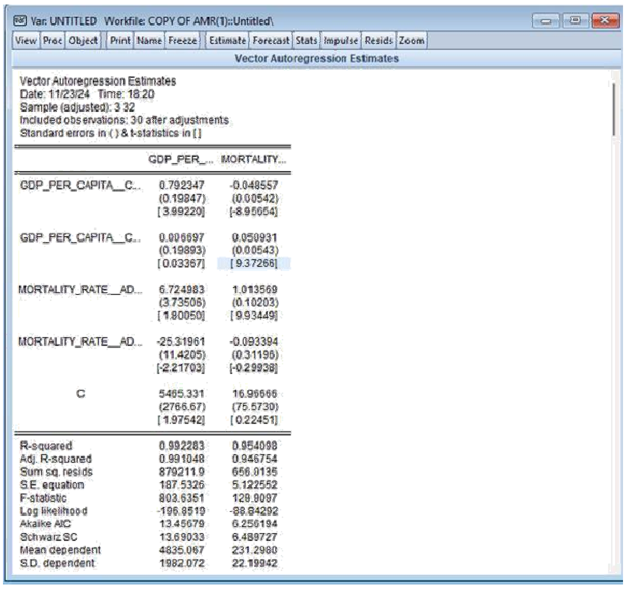
Dependent variable:

MORTALITY_RATE__ADULT__MORTALITY_RATE__ADULT__MORTALITY_RA TE__ADULT__

- GDP_PER_CAPITA__CONSTANT (-1): Coefficient = -0.048557, t-statistic = - 8.95654 (highly significant).
  - o A 1-unit increase in GDP per capita at lag 1 reduces the adult mortality rate by 0.0485 units.
- GDP_PER_CAPITA__CONSTANT (-2): Coefficient = 0.050931, t-statistic = 9.37266 (highly significant).
  - o A 1-unit increase in GDP per capita at lag 2 increases the adult mortality rate by 0.0509 units.
- MORTALITY_RATE__ADULT__−1-1−1: Coefficient = 1.013569, t-statistic = 9.93449 (highly significant).
  - o A 1-unit increase in the adult mortality rate at lag 1 increases the current mortality rate by 1.01 units.
- MORTALITY_RATE__ADULT__−2-2−2: Coefficient = -0.093394, t-statistic = - 0.29938 (not significant).
  - o The second lag of the adult mortality rate has no significant effect.
- Constant term: Coefficient = 16.96666, t-statistic = 0.22451 (not significant).
  - o Indicates no significant baseline adult mortality rate when other variables are zero.
- GDP and Adult Mortality Rate Interaction:
  - • Past values of GDP per capita significantly influence adult mortality rates (negative lag-1 and positive lag-2 effects).
  - • Past values of adult mortality rates (lag-1 and lag-2) also influence GDP per capita, with opposing effects (positive lag-1, negative lag-2).

- Dynamic Relationships:

  There appears to be a bidirectional relationship between GDP per capita and adult mortality rates. Lagged GDP affects mortality, and lagged mortality affects GDP.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View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Impulse | Resids | Zoom
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S.D. dependent	1982.072	22.19942

VAR for out-of-pocket expenditure and antibiotic resistance Equation 1: ANTIBIOTIC_RESISTANCE_PE Dependent variable: ANTIBIOTIC_RESISTANCE_PE

- ANTIBIOTIC_RESISTANCE_PE (-1): Coefficient = 1.068688, t-statistic = 3.97336 (highly significant).
  - o Antibiotic resistance at lag 1 has a strong positive impact on current antibiotic resistance, with a 1-unit increase at lag 1 leading to a 1.07-unit increase now. This indicates persistence in antibiotic resistance over time.
- ANTIBIOTIC_RESISTANCE_PE (-2): Coefficient = 0.103769, t-statistic = 0.35680 (not significant).
  - o The second lag has no meaningful effect.
- OUT_OF_POCKET_EXPENDITUR (-1): Coefficient = −0.022598-0.022598−0.022598, t-statistic = −0.11813-0.11813−0.11813 (not significant).
  - o Out-of-pocket expenditure at lag 1 has no significant effect on current antibiotic resistance.
- OUT_OF_POCKET_EXPENDITUR (-2): Coefficient = 0.271407, t-statistic = 1.55595 (weakly significant).
  - o There is a weak positive effect, suggesting that higher past out-of-pocket healthcare spending could slightly increase antibiotic resistance, possibly due to overuse of antibiotics without regulation.

Equation 2: OUT_OF_POCKET_EXPENDITUR

Dependent variable: OUT_OF_POCKET_EXPENDITUR

- ANTIBIOTIC_RESISTANCE_PE (-1): Coefficient = −0.380410-0.380410−0.380410, t-statistic = −1.03543-1.03543−1.03543 (not significant).
  - o Past antibiotic resistance does not significantly affect current healthcare spending out of pocket.
- ANTIBIOTIC_RESISTANCE_PE(-2): Coefficient = −0.064784-0.064784−0.064784, t-statistic = −0.16308-0.16308−0.16308 (not significant).
  - o The second lag also has no significant effect.
- OUT_OF_POCKET_EXPENDITUR (-1): Coefficient = 0.552017, t-statistic = 2.11249 (significant).
  - o Healthcare spending is persistent over time, with a 1-unit increase at lag 1 leading to a 0.55-unit increase now.
- OUT_OF_POCKET_EXPENDITUR (-2): Coefficient = −0.354311-0.354311−0.354311, t-statistic = −1.48704-1.48704−1.48704 (not significant).
  - o The second lag has no meaningful effect.

Antibiotic Resistance is Persistent:

- Lagged antibiotic resistance (lag 1) has a strong positive effect on current resistance, suggesting a persistence in antibiotic resistance over time. This might reflect structural issues, such as continued misuse or over-prescription of antibiotics.

Healthcare Spending is Persistent:

- Out-of-pocket expenditure on healthcare also shows persistence, with spending in one period significantly influencing spending in the next. This might indicate systemic issues in healthcare financing.

Weak Interdependence Between the Variables:

- Neither variable has a strong or consistent effect on the other. For instance:
  - o Past out-of-pocket expenditure weakly influences antibiotic resistance at lag 2.
  - o Antibiotic resistance has no meaningful effect on healthcare spending.

Persistence in Variables:

- Antibiotic resistance and healthcare expenditure are strongly influenced by their own past values, highlighting self-reinforcing trends.

Weak Cross-Variable Effects:

- There is minimal evidence that antibiotic resistance directly drives out-of-pocket healthcare spending or vice versa.

DISCUSSION

Adult Mortality Rates and GDP per Capita:

This has a strong negative correlation of -0.77143 in India with the mortality rate independent variable and GDP per capita dependent variable, which means a higher death rate activates loss on either side appreciably down. This can be also interpreted in the socio-economy contexts of India.

Rising mortality especially with the working-age population reduces labour, thus resulting in lower productivity and economic output. The long-term effect that loss of skilled workers can have in industries and even on economic growth can be vast. Higher mortality rates are found often in areas where the status of healthcare, sanitation, and even education are low-relative measures with GDP per capita. GDP low creates a vicious cycle of poorly funded health care, increasing mortality.

India has travelled much but public health remains grossly underfunded ~2.1% of GDP. Mortality from preventable diseases is much higher in these poverty-stricken states- better known as the poor ones (Bihar and Uttar Pradesh, as examples). This lack of investment in health translates to higher mortality and lower GDP per capita for these states. For example, Kerala and Tamil Nadu, which have efficient healthcare systems, show lower mortality and have a greater GDP per capita. However, states suffering from a high rate of either infant or maternal mortality generally do not have a high GDP per capita. India's demographic dividend is because a considerable proportion of the entire population lies in the working age group.

Transformation in health premises and access in rural and underserved areas may be one way that may be viewed to decrease mortality and even increase GDP per capita. When investment in preventive health care such as vaccination and sanitation is made, the returns are enormous. Increased GDP per capita translates to more health expenditure through much reduction in mortality; thereby locking health development and economic development in a positive loop. Among all these improvements, it would have to be said that reductions in mortality among infants, mothers, and working-age adults bring the maximum benefit in terms of increased GDP per capita for India.

Bridging the gap between the two states can effectively address the correlation at a national level. Reduced deaths from preventable causes (e.g., communicable diseases, malnutrition, and lack of healthcare access) would take care of the majority of the low-hanging fruits of improved health and GDP.

Regression Analysis:

The R square value is 0.595107, which means that the change in the mortality rate can explain 59.51% of the variability in GDP per capita.

Such that typically, a lower mortality rate is associated with a higher GDP per capita, because with a lower mortality rate comes better healthcare systems, healthier workforces, and higher life expectancy, all contributing towards economic activity and growth. Though it explains relatively more of the variation in GDP per capita (59.51%), 40.49% of unexplained variation indicates that other factors, such as education, infrastructure, trade, governance, and technological advancement, also have important roles in economic growth. Likely, a negative relationship exists, as mortality rates decrease, GDP per capita increases. This coincides with the trend of global development, where health improvements lead to productivity and economic performance gains.

Insights from the VAR model:

1. Past Values of GDP per Capita Affecting Adult Mortality Rates: Negative Lag-1 and Positive Lag-2 Effects:

Negative Lag-1 Effect: The lag effect indicates that an increase in the previous year's GDP per capita (Lag-1) negatively correlates with the adult mortality rate. It can be attributed to the fact that while the economy of India grows and the GDP per capita goes up, the health infrastructure gets more resources. More facilities and treatments are provided, along with better public health policy measures. For example, increased incomes can bring the health care system within reach and nutrition may improve, thus reducing mortality among adults.

Lag-2 Positive: Higher GDP per capita during the last two years or so (Lag-2) may be lagged by a rise in adult mortality. This could indicate that rapid growth, when not inclusive, might so seize most of the population and thereby deny people access to healthcare services. As some regions or groups may benefit from the growth more than others, inequalities in health outcomes could widen, leading to a rise in adult mortality rates. For instance, areas with limited healthcare infrastructure may struggle to keep up with the demands placed by urbanization or economic development.

2. Past Values of Adult Mortality Rates Influencing GDP per Capita (Positive Lag-1 and Negative Lag-2 Effects):

Positive Lag-1 Effect: An increase in adult mortality rates in the past year (Lag-1) has positive effects on GDP per capita in the short term. This may seem peculiar but may imply in the Indian context that in the short run adult mortality could reflect system inefficiencies in the health sector and thus the government spends more on healthcare. This higher level of investment may even result in employment generation, stimulation of healthcare-related economic activities, and subsequent higher GDP. Alternatively, it could be suggestive of a specific outbreak/disease or health crisis, driving mortality, which may artificially increase government expenditure and the resultant economic activities.

Negative Lag-2 Effect: Over two years, the increase in adult mortality is adversely correlated with GDP per capita. This may also indicate that a prolonged high mortality rate among adults might damage the economy in general. A fit workforce is essential to a nation's productivity in the economy, and much higher mortality rates decrease the labour force which can further weaken productivity.

Such an increase in diseases-tuberculosis, diabetes, heart disease, or destruction of health systems-can have very long run adverse effects on the economy of India. It can also imply that health infrastructure is not being invested in thereby depleting human capital and in return hurting the economy. GDP per head and adult mortality rate have this very reciprocal relationship. Reciprocal Influence: A causal interaction that suggests a feedback loop where both variables pull on one another. A growing economy, for one, can allow for better health care and a reduction of adult mortality rates at the same time.

On the other hand, if the adult mortality rates rise because of systemic health problems- for example, on account of poor public health policies or inadequate healthcare infrastructure such will translate to a smaller workforce or even total economic production, that is, reduced output and therefore affect GDP. In India, this is well appreciated with a wide range of regional disparities in terms of the quality of health care and economic development. For instance, economically better-off regions tend to have lower mortality due to good healthcare availability and nutrition, while economically backward regions thus have high mortality rates lag on economic development due to lesser population in the region.

Antibiotic Resistance and Out of pocket expenditure:

In the Indian context, the relationship between antibiotic resistance (independent) and out-of-pocket expenditure (dependent) with a correlation value of -0.96072 can be explained as:

As the threat of antibiotic resistance grows, public health systems may intervene through subsidies for necessary treatments, thereby decreasing the out-of-pocket burden on households. For example, Hospital treatment is free or at a minimal cost in government hospitals or NHM-run antibiotic stewardship programs is consistent with the negative association seen

Even after the emergence of drug resistance, people in rural and low-income settings may forego medical care simply because they cannot afford it, thereby reducing reported out-of-pocket expenditures. The access to antibiotics as an over-the-counter medicine in India does not support the relationship outlined above. Increased misuse of antibiotics will only add to resistance but may not decrease OOP costs. The public healthcare expenditure in India amounts to a meagre ~2.1% of the GDP. It makes systemic support to offset OOP costs inadequate. They may cause increased out-of-pocket expenditures, as patients need more expensive or longer courses of treatment. Increases in antibiotic resistance will tend to increase health inequities, with the wealthy able to access effective treatment and the poorer populations bearing higher mortality.

Such a relationship can at best be partly true for any setting in which public health systems adequately compensate for costs for resistant cases. Unless backed by robust public health interventions, growing antibiotic resistance is likely to increase the out-of-pocket expenditure as patients pay for second-line or third-line antibiotics and longer treatments. Strengthening public health systems, investing in AMR awareness, and expanding insurance coverage can be some useful mechanisms.

While the strong negative correlation might hold in specific cases (e.g., public subsidies), the Indian context may deviate due to weaker public health infrastructure and higher reliance on private healthcare. Additional data and nuanced modelling would be needed to validate this relationship fully for India.

Regression Analysis:

Overall, a high R-squared value such as 0.960724 in regression analysis indicates that nearly 96 percent of the variations in the out-of-pocket expenditure (dependent variable) are explained by the percentage of antibiotic resistance (independent variable). Thus, this shows a strong correlation between the two variables.

High dependence of out-of-pocket expenditure on antibiotic resistance can be interpreted to mean that as resistance increases, expenditures on health may also increase due to expensive treatments or prolonged illness requiring more costly and time-consuming interventions because of reduced efficacy of antibiotics. Obviously, in many low- and middle-income countries, these out-of-pocket ratios are so high that they encourage patients to consult informal doctors or use unregulated care. This very cycle enhances the misuse of antibiotics and promotes further resistance, creating a vicious loop.

Insights from the VAR model:

1. Persistence of Antibiotic Resistance:

The strength of the effect of lagged antibiotic resistance (lag 1) on current antibiotic resistance is so large that resistance would be truly internalized, possibly by continuing factors like over-prescriptive use of antibiotics or ineffective regulations. Persistence means that none of the immediate control measures would be adequate; instead, longer and up greater strategic initiatives would be needed to control antibiotic resistance.

2. Persistence in Out-of-Pocket Healthcare Expenditure:

- The persistence of out-of-pocket health spending is such that all have very high autocorrelation, implicit positive (lag 1). Such persistence indicates that out-of-pocket payments, as being one factor of financing healthcare, have a long-lasting effect on people, over time indeed. It must be supposed that the public healthcare systems or insurance provisions have not enlarged sufficiently to break this vicious circle.

3. Weak Cross-Variable Relationships:

- Not much evidence lies to support the receipt that spending on antibiotics causes some significant changes in out-of-pocket expenditures, nor does healthcare spending majorly contribute towards antibiotic resistance. However, more modest positive past healthcare spending affects antibiotic resistance, but this intensity seems insufficient to imply that healthcare expenditure itself has a cause-effect relationship with antibiotic resistance. This infers that conditions affecting the two would probably be independent of each other.

4. Self-Reinforcing Trends (Autocorrelation): Antibiotic resistance and out-of-pocket expenditure are showing strong autocorrelation, implying that the series have self-reinforcing trends. That means once raised levels of either resistance or healthcare spending are rise, levels above the mean continue very strongly to be above the mean, and so forth.

CONCLUSION

The study attempted to understand the complex connection between mortality rates, GDP, antibiotic resistance, and out-of-pocket healthcare expenditure in India. Based on statistical analysis, the study has uncovered considerable relationships and findings concerning the economic burden that mortality and antibiotic resistance impose on the Indian healthcare system and economy.

Data consistency is a major limitation of the study in and across different regions of India. Regional differences in economic status, access to healthcare facilities, and extent of data reporting may skew results. Models were based on generic assumptions that did not capture all the indefinable intricacies of the Indian healthcare system, such as the informal marketplace for healthcare or specific policy interventions such as the National Health Mission.

Capture most of the regional disparities within India in future research efforts to achieve a much better understanding. Long-term studies that could effectively follow a cohort across time could shed some light on how reforms in health policy and economic growth will affect both mortality and antibiotic resistance outcomes in the country of India. Because most studies research the utility of public health programs in rural spaces, this one could examine the extent to which these programs mitigate the negative impacts of high mortality and antibiotic resistance on economic performance.

There should be policy intervention to increase spending on healthcare facilities, particularly in rural and economically disadvantaged areas, to improve health disparities in mortality outcomes. Economic policies that promote equitable growth would decrease income inequality and improve access to health care, thereby raising economic growth. For example, immunization campaigns and better sanitation could have a substantial economic return because they ultimately reduce health costs and boost productivity. Bridging the gap between the economically developed and underdeveloped states constitutes one pillar in resolving the general health-economic relationship. The strategies need to be there about specific economic disadvantages in accessing health care. Preventable causes of death such as infectious diseases, malnutrition, and inadequate health care can be managed quite cheaply to create significant health outcomes and improved economic performance.

In India, differential mortality rates highlight the increased need for better healthcare policies and infrastructure for income. Improving health disparities and investing in preventive health will most certainly change the paradigm from poor health to low economic growth. Thus, saving lives and laying the touchstone for economically sustainable development. Hence, the combined effort between healthcare and economic policies is critical for India's future prosperity. It includes, among others, Key Findings, Mortality rates hurt economic productivity as much as high mortality rates correlate with lower GDP per capita. Out-of-pocket healthcare costs go up through antibiotic resistance. These findings are in line with previous studies focusing on the negative economic impact of mortality and the economic burden of antibiotic resistance. However, India's specific situation regional health disparities, and dependence on private health need more nuanced policy recommendations. To lessen the financial burden of antibiotic resistance, India needs to strengthen public health systems, regulate antibiotic sales, invest in AMR awareness, and extend the coverage of health insurance products, thus reducing household financial stresses. Therefore, India is very well placed to create good public health and a more robust economy as it addresses health infrastructure and growth simultaneously.

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APPENDICES

Year	Mortality rate, adult, male (per 1,000 male adults)	GDP per capita (constant 2021 PPP$)
1991	265.42	2166
1992	262.89	2238
1993	260.62	2297
1994	258.15	2401
1995	256.43	2532
1996	255.37	2670
1997	254.87	2726
1998	254.6	2840
1999	254.1	3035
2000	252.63	3094
2001	250.4	3186
2002	245.4	3249
2003	240.24	3444
2004	235.41	3655
2005	230.67	3882
2006	240.24	4132
2007	225.79	4383
2008	225.38	4455
2009	225.4	4739
2010	225.04	5071
2011	223.43	5265
2012	219.76	5478
2013	214.49	5753
2014	208.24	6103
2015	202.43	6513
2016	197.78	6968
2017	195.41	7356
2018	194.11	7746
2019	193.51	7964
2020	202.33	7433
2021	253.83	8088
2022	242.88	8594

Year	Out-of-pocket expenditure (% of current health expenditure)	Antibiotic resistance percentage (Fluoroquinolones)
2000	71.7	48
2001	74.11	50
2002	73.37	54.2
2003	73.72	53.6
2004	72.48	55
2005	73.15	56.8
2006	72.26	58.25
2007	70.82	59.3
2008	69.15	60
2009	66.76	63.25
2010	65.18	65.6
2011	62.22	66.8
2012	63	68.3
2013	69.07	69.4
2014	67.01	70
2015	64.66	75.64
2016	63.21	80
2017	55.11	84.34
2018	53.23	88.95
2019	52	92.34
2020	49.45	96.5
2021	49.82	98

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