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ORIGINAL ARTICLE

Development strategies for reducing infant mortality: A focus on healthcare infrastructure and policy in emerging Asian countries

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ABSTRACT

The journey towards better healthcare sustainability in Asian nations demands a comprehensive investigation into the impact of urban governance, poverty, and female literacy on infant mortality rates. This study undertakes a rigorous exploration of these key factors to pave the way for evidence-based policy interventions, utilizing data from a panel of six selected Asian countries: Pakistan, China, India, Indonesia, Malaysia, and the Philippines, spanning the years 2001 to 2020. The findings reveal that adequate sanitation facilities, higher female literacy rates, and sustained economic growth contribute to a reduction in infant mortality. Conversely, increased poverty levels and limited women's autonomy exacerbate the infant mortality rates observed in these countries. The Granger causality analysis validates the reciprocal relationship between urban sanitation (and poverty) and infant mortality rates. Furthermore, the study establishes a causal relationship where female literacy rates Granger-cause infant mortality rates, and conversely, infant mortality rates Granger-cause women's autonomy in these countries. The variance decomposition analysis indicates that sustained economic growth, improved female literacy rates, and enhanced women's empowerment will likely impact infant mortality rates in the coming decade. Consequently, in low-income regions where numerous children face potentially

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hazardous circumstances, it is imperative to allocate resources towards establishing and maintaining accessible fundamental knowledge regarding sanitation services, as this will aid in reducing infant mortality rates.

KEYWORDS

urban governance; healthcare sustainability; infant mortality rates;poverty; female literacy; women's autonomy; Asian economies

1. Introduction

Child survival is a key focus within the United Nations' Sustainable Development Goals (SDGs), specifically SDG-3. The objective outlined in this goal is to reduce child mortality to 12 deaths per 1,000 live births and neonatal mortality to 25 deaths per 1000 live births by 2030 (United Nations, 2015). Despite notable advancements in various areas, many developing countries have high infant mortality rates. In 2015 alone, there were 4.45 million newborn deaths worldwide, resulting in a mortality rate of 32 deaths per 1000 births (Lu et al., 2020). Over the past few decades, infant mortality rates have significantly declined globally, with the United States leading the way. From 1960 to 2013, the infant mortality rate in the United States dropped dramatically from 122 to 24 deaths per 1000 live births. Additionally, the United Nations emphasized the importance of meeting SDG-6 and target 6.2, which aim to ensure access to sanitation and improve hygiene practices by eliminating open defecation by 2030. SDG-5 focuses on gender equality and women's empowerment in various domains, including education and health. The overarching goal of SDG-1 is to eradicate poverty in all its forms worldwide and address socioeconomic and environmental challenges (United Nations, 2015). Notably, enhanced sanitation services and increased female literacy rates have significantly reduced global child mortality rates (Abdelhady et al., 2022; Shorette and Burroway, 2021).

By 2030, the universal provision of safe and hygienic water, sanitation, and personal hygiene services is expected to be achieved worldwide (Shrestha et al., 2023). Notably, this initiative will prioritize marginalized and vulnerable groups, such as women, girls, and those in precarious circumstances, to address the issue of open defecation (Goyal and Dharwal, 2023). It is projected that by the mid-2030s, more than 1.08 billion people globally will still lack access to safe drinking water and basic sanitation (Cohen, 2006). According to the World Health Organization (WHO), approximately 3.4 million individuals, predominantly children, die yearly due to waterborne diseases. Mortality rates associated with diseases related to inadequate water and sanitation are rising. More than half of all households worldwide lack access to sewage systems, and nearly half do not have access to latrines. Only a quarter of the population has access to underground sewers, and just one-fifth has access to open drains or sewers (WHO, 2022). The Millennium Development Goals (MDGs), established in 2000, aimed to raise awareness of global health and social justice issues and track global progress in addressing these challenges. Particularly in the fight against poverty and the promotion of social justice. The seventh goal of the MDGs targeted a 50% reduction in the percentage of the population without basic amenities and proper hygiene practices by 2015. Over three million people in Pakistan fall ill yearly due to water contamination. Like other developing nations, Pakistan faces a significant burden of waterborne illnesses. It allocates only a

tiny fraction of its overall budget to water and sanitation infrastructure (Cooper, 2018; Hakro, 2012; Economic Survey of Pakistan, 2020). The data presented in **Table 1** reveals a compelling overview of how economic factors are intertwined with health outcomes in several Asian economies. The countries under examination include Pakistan, India, Indonesia, China, the Philippines, and Malaysia.

Table 1: Comparative analysis of key economic factors associated with health.

Countries	Years	USS	FLR	WBLIS	IMR	POV
Pakistan	2010	49.672	41.015	44.375	87.100	8.300
Pakistan	2020	68.397	46.490	55.625	67.200	4.400
India	2010	42.416	59.277	62.500	58.200	21.900
India	2020	71.268	65.790	74.375	34.300	21.900
Indonesia	2010	61.230	89.677	64.375	33.900	13.300
Indonesia	2020	86.462	94.552	64.375	23.900	9.400
China	2010	75.689	92.711	69.375	15.800	17.200
China	2020	92.376	95.159	75.625	7.900	0.600
Philippines	2010	68.537	96.787	72.500	31.700	25.200
Philippines	2020	82.256	96.852	78.750	3.600	16.700
Malaysia	2010	98.842	90.747	46.875	8.100	7.600
Malaysia	2020	99.579	93.646	50.000	8.600	8.400

Source: World Bank (2020). Note: USS shows urban sanitation and services as % of urban population, FLR shows female literacy rate as % of female population aged between 15 to 24 years, WBLIS shows women business and law index score represented with women's autonomy (1 = minimum women representation to 100 maximum), IMR shows infant mortality rate per 1000 live births, and POV shows poverty headcount ration in %.

One of the critical metrics examined is USS, which assesses urban sanitation and services as a percentage of the urban population. In 2010, Pakistan had a USS of 49.67%, while by 2020, this figure had risen to 68.40%. This significant improvement suggests that Pakistan invested in enhancing urban sanitation and services, potentially contributing to improved public health. Another crucial indicator is FLR, which measures the female literacy rate as a percentage of the female population aged 15 to 24. India's FLR in 2010 stood at 59.28%, but by 2020, it had risen to 65.79%. This indicates progress in female education, which can have far-reaching implications for maternal and child health.WBLIS, representing women's autonomy in business and law, is another insightful metric. China's score in this index was 92.71 in 2010, reflecting a high level of women's participation in these areas. By 2020, China had increased its score to 95.16, showcasing a sustained commitment to gender equality.IMR, or infant mortality rate, is a critical health indicator. In 2010, Indonesia had an IMR of 33.90 per 1000 live births. By 2020, this had dropped to 23.90, suggesting improved healthcare for infants, potentially due to economic advancements.Lastly, the poverty headcount ratio, represented by POV, gives insights into economic disparities. The Philippines' poverty rate was 25.20% in 2010, but it decreased significantly to 16.70% by 2020. This suggests that economic improvements may have contributed to reduced poverty and potentially better access to healthcare.

Urban and rural areas are witnessing deterioration in water and sanitation infrastructure, posing a threat to public health. Drinking water contaminated with chemicals can contribute to transmitting

waterborne diseases such as cholera. These chemicals encompass enterobacter, salmonella, and clostridium (Jabeen et al., 2011). In Pakistan, approximately 16 million individuals lack access to clean water, while inadequate sanitation is also a significant concern. Astonishingly, 84% and 89% of the world's water sources fail to meet the guidelines for safe human consumption set by the World Health Organization (Zahid, 2018). Access to clean water, proper sanitation facilities, and hygiene education are foundational to the well-being and prosperity of every community. The significance of water for human survival is widely recognized. In order to ensure the safety of drinking water and prevent the proliferation of waterborne diseases, it is essential to establish adequate sanitation and hygiene facilities (Adelodun et al., 2021; Ferreira et al., 2021). In 2016 alone, inadequate access to clean water and sanitation directly contributed to 1.6 million deaths and 105 million disability-adjusted life years (DALYs) (Molina et al., 2021). Poverty and poor health are intertwined and mutually reinforcing. Maintaining good health is crucial for engaging in various activities such as breastfeeding, attending school, working, generating income, and nurturing a family (Khan et al., 2019; Woodward et al., 2023). Unfortunately, approximately one billion people survive on less than $1 daily. An additional two billion live on less than $2 per day, leaving little room for long-term savings or immediate payment of healthcare expenses. In the world's poorest nations, protein-energy malnutrition and deficiencies in essential micronutrients are major contributors to death and illness (Vishwakarma and David, 2021; Adeyeye et al., 2023). Pregnancy and childbirth consistently rank among the leading causes of illness and mortality globally, affecting millions of pregnant women and infants yearly (Roos-Hesselink et al., 2019; Kumar et al., 2023).

The academic community, including our research, has recognized the need to address several key research questions to enhance the effectiveness of healthcare management policies. These questions align closely with the academic community's concerns and form the basis of our research:

1. Our study investigates whether an increase in female literacy rates, promoting women's autonomy, contributes to a reduction in infant mortality rates. This inquiry underscores the potential impact of empowering women through education, enabling them to make informed decisions and improve their health and well-being. Educated and empowered women are more likely to prioritize their family's health, thus potentially leading to reduced infant mortality rates.

2. Another critical aspect of our research explores the relationship between poverty alleviation and the reduction in infant mortality. Elevated poverty levels and malnutrition have detrimental effects on household resources, particularly impacting the health of children who require optimal nutrition for survival. Our study emphasizes the government's pivotal role in breaking the cycle of poverty, including the establishment of social safety nets for women and children. Healthier women are more likely to prioritize their health and that of their families, which can contribute to the reduction in infant mortality.

3. To further our understanding, we delve into the extent to which adequate urban sanitation facilities contribute to decreased infant mortality rates. Proper planning and implementation of health and hygiene measures can help prevent adverse healthcare outcomes and enhance the overall health of children and adolescents. Our research aims to assess the significance of adequate urban sanitation facilities in reducing infant mortality rates, shedding light on their role in this context.

4. Lastly, our study explores the significant relationship between financial expansion and infant mortality rates. This question underscores the importance of allocating a sufficient percentage of the healthcare budget to develop healthcare infrastructure. Our research highlights that significant investment in healthcare infrastructure can substantially reduce infant mortality rates, emphasizing the need to prioritize healthcare expenditure, particularly in countries experiencing economic growth.

The significance of providing clean water and sanitation services for improving public health is widely acknowledged by various agencies and practitioners in the field of social welfare worldwide. Ensuring access to these services, particularly for vulnerable populations, has become an urgent social welfare issue. This study investigates infant mortality rates in a selected panel of Asian countries to understand the impact of urban sanitation, poverty incidence, and women's autonomy. The specific objectives of this investigation are as follows:

1. To investigate the relationship between infant mortality rates and the availability of sanitation facilities, female literacy rates, and economic development in six selected Asian economies, including Pakistan, China, India, Indonesia, Malaysia, and the Philippines.

2. To examine the association between women's autonomy, economic progress, and the reduction of infant mortality rates.

3. To investigate the relationship between poverty incidence and infant mortality rates across nations.

4. To estimate the parameters, the study employs the second-generation panel cointegration test. Additionally, panel causality estimates are utilized to analyse causal inferences, and the innovation accounting matrix is employed to predict the interrelationships between the variables.

This study contributes by addressing information gaps and incorporating variables like female literacy and gender equality, echoing findings by Riddle et al. (2023), Patel et al. (2023), and Braverman-Bronstein (2023). We highlight the importance of improved urban healthcare sanitation, especially for women and children, reducing infant mortality rates. Additionally, we underscore the link between rising poverty and healthcare system deterioration, advocating for sustainable policies with social safety nets for equitable healthcare access. Lastly, we emphasize the role of economic growth in bolstering healthcare expenditure, crucial for robust healthcare systems and improved health outcomes.

2. Literature review

As we delve into the realm of healthcare management policies, it becomes evident that a thorough examination of the existing body of knowledge is essential. This literature review section serves as a comprehensive analysis of pertinent research, shedding light on critical themes and questions that are central to the broader academic dialogue. Pakistan's urbanization is worsening its water and sanitation issues. Rural women and children often have to go far to get drinking water. Jabeen et al. (2011) researched the health implications of insufficient water and sanitation in Abbottabad City, Pakistan. The findings showed that the district's urban and rural sections had subpar water

and sanitation services, with rural regions faring worst. Several potentially harmful pollutants were discovered in drinking water, putting the population at risk. The issues of water, sanitation, and poverty in Pakistan were analysed by Hakro (2012). Theories unified issues throughout the economic, political, and cultural spectrum. Given the intricacy of these interrelationships, the country's water and sanitation problems must be addressed systemically. These reports detail Pakistan's severe water and sanitation problems and highlight the need to upgrade infrastructure and reduce the likelihood of contamination. The research highlights improved public health outcomes and reduced negative impacts on vulnerable groups, especially women and children.

More than 94% of the people in Punjab, Pakistan, have access to better water systems, according to the provincial government. However, only 72% of the regions in the region have access to better sanitation services (Government of the Punjab, 2015). Despite its abundant surface and underground water sources, Khalil et al. (2017) stress that Pakistan's chronic water shortage significantly threatens its future prosperity. A serious threat is posed by waterborne infections such as rotavirus-related childhood diarrhea. The economic toll and death toll from such illnesses may be substantial.Most fatalities from diarrhea are the result of ingesting contaminated water or food. Water, sanitation, and hygiene (WASH) services are more widely available in Punjab than in Khyber Pakhtunkhwa (KPK). According to a Health Survey done by the government of KPK in 2017, 89% of households had improved their water sources, and 86% had improved their sanitation systems. However, significant obstacles still stop women and girls from using public restrooms. Women in homes without sanitation facilities typically use private areas like bathrooms or courtyards to defecate, with the excrement being thrown away in public places (Ahmed et al., 2015). The effects of these behaviors on women and girls' mental and physical health may be severe. Access problems, waterborne infections, and gender inequality are just some of the concerns brought to light by these results. Sanitation, water availability, and cultural and societal hurdles must be addressed if Pakistan is to improve the health and happiness of its citizens, especially its women and girls. Population increase, industrial and agricultural activity, and inappropriate waste management are the leading causes of water pollution in Pakistan, according to Nawaz andAli (2018). Water quality degrades due to the country's poor water sanitation system. Drinkable water contains pesticides, harmful metals, human waste, and industrial effluents. Drinking dirty water may quickly spread diseases, including polio, diarrhoea, cholera, and typhoid. These waterborne illnesses claim a significant number of lives each year. Based on the literature reviewed, the researchers developed the following hypotheses:

H1: Providing safe and clean sanitation services will reduce infant mortality rates.

Access to improved sanitation facilities improves infant health outcomes, decreasing mortality rates.

H2: Continued economic development will positively influence healthcare reforms across countries.

Economic growth provides the necessary resources and infrastructure to support healthcare systems, leading to improved health outcomes.

These hypotheses highlight the potential benefits of investing in sanitation services and economic development to address the challenges associated with infant mortality and healthcare management.

By improving sanitation infrastructure and promoting economic growth, it is anticipated that significant progress can be made in reducing infant mortality rates and enhancing healthcare systems in the six Asian countries.

Lucas et al. (2019) conducted a study examining the potential reductions in child mortality associated with achieving the objectives of the SDGs related to the environment. They found that approximately 26% of global child mortality is attributed to various controllable environmental factors, which are addressed by different SDGs. The study projected that child mortality per 1000 live births could decrease from 59 in 2010 to 31, 45, and 71 in 2030, corresponding to the achievement of specific SDG targets. Van Zanten and van Tudler (2020) researched the relationship between governance and the SDGs. Their study analysed 876 articles published between 2005 and 2019 to explore the connection between specific economic activities and the SDGs. The findings revealed that agricultural, industrial, and manufacturing activities significantly negatively impact environmental development. On the other hand, research focusing on the value of service activities highlighted their positive contributions to society and the economy.Khan et al. (2014) conducted a study to explore the relationship between rural poverty, agricultural development, and income inequalities in Pakistan from 1990 to 2010. Their findings revealed that rural development had a negative impact on poverty and income inequality while being positively associated with agricultural expansion. However, after considering the effects of sanitation and education, the study showed that debt and healthcare expenditures positively influenced poverty levels in Pakistan. Asumadu-Sarkodie and Osuwu (2016) focused on Ghana and investigated the causal relationship between child mortality, fertility, income, and government spending. Using time-series data from 1971 to 2013, they employed the ARDL technique to analyse the relationship. Their research demonstrated a long-run equilibrium link between the mortality and fertility rates, food production indexes, income, and government expenditures. They also found a two-way relationship between government expenditure and the fertility rate. **Table 2** provides a summary of existing literature on improved healthcare policies worldwide.

Table 2: Health and sanitation services review.

Authors	Country	Findings
Nawaz et al. (2021)	Pakistan	Child mortality rates may be lowered significantly by investing in better sanitary infrastructure. Children are particularly vulnerable to waterborne illnesses and other infections when basic sanitation is lacking, such as clean water and sanitary facilities.
Ahmed et al. (2020)	Pakistan	Increased public education and awareness may significantly reduce water pollution and public health. Water contamination has many causes, and education may help people learn about them. The best way to reduce water pollution is for people to be aware of the problem, make educated decisions, and take effective action.
Khalil et al. (2022)	Pakistan	Safe drinking water is essential for public health. Clean water and sanitation services may help prevent water-related ailments and reduce disease spread.
Imran et al. (2023)	Pakistan	Public health may be improved by managing solid waste, replacing coal with renewable fuel, and enforcing strict environmental laws.

Table 2. (Continued).

Authors	Country	Findings
Swe et al (2021)	51 Low & lower Middle Income Countries	Better sanitation has been linked to a decrease in poverty rates. As a result of reduced disease transmission due to improved sanitation, health outcomes and healthcare costs improve. As a result, this has the potential to help alleviate poverty.
Revilla and Ram (2021)	100 low-middle-high income countries	Education and general awareness are two factors that directly influence human capital. Investments in clean water systems, hygiene education, and public awareness campaigns all help raise people's health literacy.
Gillani et al. (2021)	Bangladesh, India, Indonesia, Malaysia, Pakistan, Sri Lanka, The Philippines, Iran and China	Rising earnings and economic productivity have been linked to better living conditions. As a result, families can put more money into their children's diets. Adequate nutrition is essential for a child's healthy growth and development, and it also helps ward against malnutrition and its associated health problems.
Libanio (2021)	Brazil	Economic growth usually results in more manufacturing and farming, urbanisation, and living standards. The need for water in agriculture, industry, and households rises due to these reasons. Growing economies place a greater strain on the available water supply.
Mandal et al. (2019)	India	Higher mother education reduces infant mortality. Maternal education improves prenatal, postnatal, and newborn nutrition, hygiene, and early disease diagnosis. Higher-educated mothers are more likely to seek medical therapy for their children because they know best practices.
Yadav et al. (2021)	India	Feminist empowerment and education have improved mother health. Due to education, women have better healthcare access and knowledge. They may also spot issues throughout pregnancy and delivery, enabling early treatment and greater mother health.
Mbau et al. (2023)	One hundred thirty-one peer-reviewed public health articles	Quality services make a healthcare system effective. Standardizing and prioritizing evidence-based practices may enhance patient outcomes and satisfaction.

Based on the cited literature, the study formulates the following hypotheses:

H3: Female literacy rate and women's autonomy are likely helpful to reduce infant mortality rates.

This hypothesis suggests that when women have higher literacy rates and increased autonomy, they are more likely to make informed healthcare decisions, reducing infant mortality rates.

H4: Poverty increase would hinder global attempts to offer inexpensive healthcare.

According to this assertion, growing poverty affects the long-term stability of healthcare systems, reducing access to treatment and worsening health outcomes.

3. Data, variables, and methods

The study examined the long-run relationship between infant mortality rate and several factors, including urban cleanliness, women's business index score, poverty, female literacy rate, and GDP per capita. The analysis focused on six selected Asian countries: Pakistan, China, India, Indonesia, Malaysia, and the Philippines. The data for these variables were obtained from the World Bank (2022). **Table 3** provides a list of variables along with their expected theoretical relationships.

Table 3: List of variables.

Variables	Measurement	Unit	Definition	Expected sign
Infant Mortality Rate	IMR	Per 1,000 live births	It is defined as the number of newborn infants that die before the age of one year per 1,000 live births in a particular year.	
Urban Sanitation Services	USS	% of urban population	Percentage of urban residents utilizing safe sanitation services. Flushing to a piped sewage system and mine latrines	Negative
Economic Growth per capita, Growth Rate	GDPPC	Annual percentage growth rate	Gross domestic product (GDP) growth rate, i.e., market value of presently produced products and services given by all citizens,	Negative
Female Literacy Rate	FLR	% of female population aged between 15 to 24 years.	Female literacy rate is the proportion of individuals aged 15-24 who can read and write a basic daily statement.	Negative
Poverty	POV	% of population	That is the proportion of people who live below the poverty level.	Positive
Women Business and Law Index Score	WBLIS	Index Score (1 = minimum and 100 maximum)	The score quantifies the impact of legislation and regulations on women's economic potential. The total score is calculated by averaging the scores from each of the eight components, with a maximum possible score of 100.	Negative

Access to safe drinking water, sanitation, and hygiene practices is crucial to human health and well-being. It directly impacts various aspects of people's lives, including their health, productivity, education, and overall quality of life. The availability of clean water and proper sanitation facilities is essential for individuals to maintain their health, engage in productive work, succeed in education, and maintain their dignity and self-worth (Islam, 2021). Unsafe drinking water can pose significant health risks, particularly waterborne diseases like diarrhoea. Improper handling and contamination of the water used for various purposes like drinking, irrigation, and bathing can spread diseases through exposure to faecal matter. Water pollution can occur due to human activities (e.g., nitrate from agricultural runoff) and naturally occurring contaminants (e.g., arsenic, fluoride),

posing threats to human health. Inadequate sanitation and water supply can contribute to the spread of diseases such as trachoma and schistosomiasis. However, with improved infrastructure and better access to sanitation and clean water, the risk of these diseases can be significantly reduced. The MDGs aimed to address these issues, and during the MDG timeframe (1990–2015), there was a 50% decrease in diarrheal mortality due to significant improvements in water and sanitation facilities. This advancement was made possible mainly due to the construction of integrated sanitation and water systems (Cawood andRabby, 2021). Protecting people from water-borne infections, improving sanitation, and encouraging healthy lifestyles hinge on ensuring people have access to clean water.

In order to establish whether or not the time series data has a unit root, the research employs unit root tests. If a time series has a unit root, the series is trending through time rather than stagnating. A stationary time series, on the other hand, remains constant across time. These tests can help determine the need to differentiate the variables in order to achieve stationarity. If the variables are determined to have unit roots, then additional investigation is needed to identify their long-term interrelationships. Long-term correlations between the variables are analysed using the Fisher-Johansen cointegration test. Although the variables may not be stationary, cointegration indicates that they have a stable long-run connection. Understanding the long-term dynamics of variables requires identifying their cointegration, which may be done using this test. The study used the dynamic ordinary least squares (DOLS) method for parameter estimation (Stock andWatson, 1993).The sequence of integration or cointegration status is irrelevant to include delayed and lead variables, i.e.,

$$IMR_{i,t} = \alpha_0 + \alpha_1 USS_{i,t} + \alpha_2 GDPPC_{i,t} + \alpha_3 FLR_{i,t} + \alpha_4 POV_{i,t} + \alpha_5 WBLIS_{i,t} + \varepsilon_{i,t} \quad (1)$$

where, IMR shows infant mortality rate, USS shows urban sanitation services, GDPPC shows GDP per capita, FLR shows female literacy rate, POV shows poverty headcount, WPIS shows women's power, and ε shows error term.

Under the standard neoclassical conductions, the following expectations is expressed, i.e.,

$$\frac{\partial (IMR)_{i,t}}{\partial (USS)_{i,t}} < 0$$

The improvement in the urban sanitation services brings the improvement in declining the infant mortality rates.

$$\frac{\partial (IMR)_{i,t}}{\partial (GDPPC)_{i,t}} < 0$$

The higher the per capita income of the countries, the greater reduction in the infant mortality rates.

$$\frac{\partial (IMR)_{i,t}}{\partial (FLR)_{i,t}} < 0$$

The higher the female literacy rate, the lower the infant mortality rates.

$$\frac{\partial(IMR)_{i,t}}{\partial(POV)_{i,t}} > 0$$

The greater the incidence of poverty, the greater rate of infant mortality, and the greater the women's involvement in the business and law, the greater reduction in the infant mortality rates.

$$\frac{\partial(IMR)_{i,t}}{\partial(WBLIS)_{i,t}} < 0$$

Further, the study utilized the Granger causality test to examine if variables have a long-term causal relationship. Ultimately, variance decomposition analysis (VDA) was employed to predict correlations between variables over the following decade. The research utilized projections for 2023–2030 to speculate on the trajectory and extent of exogenous factors' influence on different nations.

4. Results and discussion

Table 4 presents the descriptive statistics for the factors examined in the study. The average infant mortality rate is 39.024 deaths per 1000 live births. The highest observed value is 104.700 deaths, while the lowest is 3.600. The standard deviation of the infant mortality rate is 27.890, indicating a significant degree of variability across the countries studied. The average coverage of urban sanitation services is 67.003% of the urban population. The maximum value observed is 99.579%, indicating high access to essential sanitation services in some countries. The minimum value is 17.593%, suggesting a lower level of access in certain nations. The standard deviation for urban sanitation services is 21.146%, reflecting variations in coverage among the countries. The average female literacy rate for ages 15 to 25 is 78.296%. The highest observed value is 90.747%, indicating a relatively high literacy level among young females in some countries. The lowest value recorded is 35.367%, highlighting the challenges and disparities in female education. The standard deviation for female literacy rate reflects the variability in literacy levels across the countries studied. The average GDP growth rate is around 3.934%, indicating the average annual increase in the countries' economic output. This metric provides an indication of economic development and progress over time. The average poverty incidence is 16.762%, suggesting the percentage of the population living below the poverty line. This indicates the extent of poverty within the countries studied. An index score with an average value of 61.208 measures women's autonomy. This score reflects women's degree of empowerment and decision-making ability in various aspects of their lives. The descriptive statistics provide an overview of the key variables and their characteristics across the selected Asian countries. These statistics highlight the disparities, challenges, and potential areas for improvement in stated areas.

According to **Table 5**, the study found several significant associations between variables and infant mortality. The study shows an inverse association between urban cleanliness (measured by urban sanitation services) and infant mortality. This suggests that better urban sanitation is associated with lower infant mortality rates. Improved access to clean water and sanitation facilities

in urban areas improves infant health outcomes. The study found an inverse relationship between female literacy and infant mortality. This indicates that higher female literacy levels are associated with lower infant mortality rates. Educated women are more likely to have better knowledge and resources to care for their children's health, leading to improved outcomes. The study suggests a negative association between sustained economic development and infant mortality. This implies that as countries experience economic growth and development, there is a decrease in infant mortality rates. The health of infants is typically favorably impacted by societal advancements in healthcare, nutrition, and general living situations. Women's independence was proven to have a protective effect on infant mortality. Infant mortality rates seem to be lower in places where mothers have more freedom to make decisions for themselves. Women who have agency over their own lives are more likely to make educated decisions for their families, which benefits their children. This suggests that higher infant mortality rates are linked to greater poverty levels. Infants living in poverty may have worse health outcomes because of inadequate medical treatment, nutrition, and substandard living circumstances. The study notes a correlation between women's education, economic growth, and personal freedom. This shows that increased female literacy rates help the economy and give women more agency. The findings suggest that improving urban cleanliness, promoting female literacy, fostering sustained economic development, and enhancing women's autonomy are vital in reducing infant mortality rates and improving overall health outcomes across nations. Addressing poverty and ensuring access to healthcare services for economically disadvantaged populations are crucial steps in reducing infant mortality.

Table 4. Descriptive statistics.

Methods	IMR	USS	FLR	GDPPC	POV	WBLIS
Mean	39.024	67.003	78.296	3.934	16.762	61.208
Maximum	104.700	99.579	98.241	13.63	37.200	78.750
Minimum	3.600	17.593	35.367	–10.78	0.600	38.125
Std. Dev.	27.890	21.146	21.923	3.449	9.745	12.315
Jarque-Bera	12.738	2.690	19.778	105.834	6.809	8.623

Source: Author's estimation.

Table 5. Correlation matrix.

Variables	IMR	USS	FLR	GDPPC	POV	WBLIS
IMR	1					
USS	–0.861	1				
FLR	–0.908	0.693	1			
GDPPC	–0.150	–0.064	0.185	1		
POV	0.387	–0.681	–0.206	0.236	1	
WBLIS	–0.427	0.081	0.533	0.309	0.276	1

Source: Author's estimation.

The findings of the unit root tests performed to determine the order of integration among the study's variables are shown in **Table 6**. Unit root tests can reveal whether the variables exhibit stationarity or display a stochastic trend. All the variables above are differenced stationary in the unit root testing. Taking the initial difference implies the absence of a stochastic trend in the variables.

Cointegration analysis cannot be performed unless the underlying variables are stationary. Since the variables are found to be differenced stationary, the cointegration procedure can be employed to obtain more precise estimates. Cointegration analysis makes understanding the dynamics of long-term connections between variables possible. Cointegration allows researchers to look at the links between variables over the long term and draw conclusions about those ties.

Table 6. Unit root estimates.

Variables	Unit root tests	Level		1st difference		Order of integration
		t-statistics	Probability	t-statistics	Probability	
IMR	Levin, Lin & Chu t-statistics	–0.109	0.456	–2.360	0.009	I(1)
FLR	Levin, Lin & Chu t-statistics	2.847	0.997	–5.573	0.000	I(1)
GDPPC	Levin, Lin & Chu t-statistics	5.664[a]	1.000	–5.434[b]	0.000	I(1)
POV	Levin, Lin & Chu t-statistics	0.360	0.640	–4.458	0.000	I(1)
WBLIS	Levin, Lin & Chu t-statistics	2.899	0.998	–16.189	0.000	I(1)
USS	PP - Fisher Chi-square	0.001	1.000	44.497	0.000	I(1)

Source: Author's estimation. Note: I(1) shows differenced stationary. [a] shows series checked at 'individual intercept'. [b] shows series checked at 'none'.

The estimated cointegration results are shown in **Table 7**. Cointegration analysis helps spot the existence of long-term connections between variables. Based on the statistics of the trace test and the maximum Eigen test, the table shows that there are six cointegrating equations. This indicates the existence of long-lasting, statistically significant connections between the variables. By spotting these cointegrating correlations, we may learn more about the long-term dynamics and interactions of the model's variables. It is helpful since it shows the interconnected nature of the variables and how changes in one may affect the others over time.

Table 7. Johanson fisher panel cointegration testestimates.

No. of cointegration equations	Trace testvalue	Prob.	Maximum eigen value	Prob.
None	59.42	0.000	59.42	0.000
At most 1	287.4	0.000	209.9	0.000
At most 2	186.6	0.000	121.6	0.000
At most 3	89.81	0.000	74.09	0.000
At most 4	31.09	0.001	26.68	0.008
At most 5	20.73	0.054	20.73	0.054

Source: Author's estimation.

The findings from **Table 8** indicate that improved urban sanitation services and sustained economic development significantly and negatively impact infant mortality. As urban sanitation

services improve and economic development continues, the infant mortality rate decreases. These results support that access to proper sanitation and economic progress are crucial in improving population health and reducing infant mortality. Additionally, female literacy is found to have a critical role in reducing infant mortality, with a larger effect than urban sanitation services. The findings suggest that educated women contribute significantly to their family's and community's health. Their knowledge and involvement in health and hygiene services positively impact healthcare infrastructure and contribute to achieving sustainable healthcare goals. These findings are consistent with previous research, such as the study by Ortigoza et al. (2021), which highlighted the positive impact of women's engagement in the labour force, higher education attainment, and political autonomy on reducing infant mortality. It aligns with findings by Kumar et al. (2021) that highlighted the role of socioeconomic variables like mothers' education and cleanliness in lowering infant death rates. According to Patel et al. (2020), the findings support the claim that lowering infant mortality and attaining a sustainable healthcare agenda requires bolstering urban cleanliness, maintaining economic growth, and expanding female literacy. Key results and viewpoints on the connection between maternal education, women's empowerment, healthcare access, poverty reduction, and infant mortality are highlighted by Ţarcă et al. (2021), Wei et al. (2021), and Rahman and Alam (2021). Understanding the complex causes of infant mortality and the need to treat them for long-term healthcare plans is aided by these research findings. Patel et al. (2020) highlighted maternal education's importance in lowering infant mortality rates. That is why it is clear that educating moms is so essential for kids' health. Women's empowerment, economic growth, and increased public healthcare use all contribute to long-term healthcare sustainability. Education, counseling, changes in healthcare delivery, folic acid, and dietary supplements are all suggested by Ţarcă et al. (2021) to lower infant mortality. The health of mothers and newborns is a primary focus of these programs. Reducing poverty is advocated by Wei et al. (2021), who propose empowering women via increased access to primary education, economic resources, decision-making authority in healthcare, and healthcare facilities. They contend that improving health outcomes may be achieved by empowering women in these communities by reducing poverty. However, Rahman andAlam (2021) argue that rapid urbanization and rising birth rates might undermine efforts to provide quality, affordable healthcare to all people, including children. However, they also stress the need to ensure women have access to quality education to increase their economic independence and decrease infant mortality.

Table 8. Panel DOLS estimates.

Variables	Coefficient	Std. Error	t-Statistic	Prob.
USS	–0.089	0.004	–18.503	0.034
FLR	–0.4361	0.001	–224.876	0.002
GDPPC	–0.788	0.010	–74.439	0.008
POV	0.160	0.003	42.997	0.014
WBLIS	0.164	0.001	129.50	0.004
Statistical Tests				
R^2	0.996	Adjusted R^2		0.990

Source: Author's estimation.

Furthermore, the results show a worrying correlation between low income and high infant death rates, suggesting that continuing poverty is a significant barrier to attaining a long-term healthcare strategy. Women's health suffers when the autonomy index for women is low, and this, in turn, contributes to higher infant mortality rates throughout the globe. These findings align with those of Asif et al. (2022), who discovered that lowering child mortality rates was directly related to raising women's and girls' access to education, economic independence, and the availability of crucial services and autonomy. Inadequate medical treatment and reproductive health procedures, on the other hand, are linked to an increased risk of newborn mortality. The findings corroborate those of Lee et al. (2021), who found that inequality in wealth, racism, and the availability of reproductive health care all have a role in increasing the prevalence of preterm birth, infant mortality, and mother death. This highlights the vital need to address the socioeconomic determinants of health to ensure the sustainability of the healthcare system. Bugelli et al. (2021) provide more data confirming these findings by showing that healthcare inequities slow the achievement of a long-term health objective, which in turn increases the risk of infant mortality. Improvements in children's education, income, housing, and access to healthcare have contributed to a decline in their death rate. Finally, the study's findings shed light on how low household income and negative views of women's independence all have a role in increased infant mortality rates. The study highlights the significance of adopting steps to improve women's schooling, financial independence, access to medical care, and family planning to address socioeconomic health determinants. Infant mortality rates and developing a long-term healthcare strategy rely heavily on these kinds of work. The research confirms and expands upon these observations, illuminating essential connections between various variables and children's health outcomes.

Furthermore, the Granger causality results presented in **Table 9** show a bidirectional relationship between urban sanitation services, the incidence of poverty, and infant mortality rates. This suggests that inadequate urban sanitation and higher poverty rates have a detrimental impact on healthcare infrastructure. Conversely, higher infant mortality rates negatively affect the urban healthcare agenda and exacerbate poverty among households. Therefore, adequate planning of health and hygiene interventions and the provision of social safety nets to impoverished households are crucial for reducing child mortality rates globally.

Furthermore, a bidirectional relationship exists between female literacy rates, economic growth, women's autonomy, and urban sanitation. This indicates that these factors contribute to improved health and hygiene, which fosters increased female literacy, sustained economic growth, and women empowerment. A two-way causality was found between poverty and economic growth, with higher poverty incidence hindering a country's economic progress. At the same time, economic growth also influences poverty rates through inadequate provision of social safety nets. The study also identified unidirectional causality running from female literacy to infant mortality rates, from infant mortality rates to women's autonomy, from urban sanitation to poverty, and from poverty to female literacy rates. This highlights the importance of improving female literacy rates, empowering women, enhancing health and hygiene services, and reducing poverty as critical strategies for reducing infant mortality rates worldwide.

Table 10 presents the results of the inter-temporal forecast for the variables under consideration. The findings indicate that economic growth is expected to reduce infant mortality rates significantly. From the 2nd period to the 10th period, there is a projected decline from 90.208% to 61.351% in

infant mortality rates, with a variance shock of 19.402%. Furthermore, urban sanitation services are projected to influence infant mortality rates, increasing from 0.048% in the 2nd period to 11.729% in the subsequent 10th period. Women's autonomy is expected to contribute to a variance of 4.509% in influencing the infant mortality rate by the 10th period. On the other hand, the impact of the female literacy rate on reducing infant mortality rates is relatively lower, with a projected decrease of only 0.572% over the ten years. These results suggest that economic growth, followed by urban sanitation services and women's autonomy, significantly reduces infant mortality rates over time. While the impact of female literacy is relatively modest in comparison, it still contributes to the overall reduction in infant mortality rates.

Table 9. Granger causalityestimates.

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Decision
USS ↔ IMR	10.856 88.577	13.167 118.522	0.000 0.000	Bidirectional causality
FLR → IMR	3.121	2.682	0.007	Unidirectional causality
POV ↔ IMR	3.407 2.677	3.069 2.080	0.002 0.037	Bidirectional causality
IMR→ WBLIS	2.875	2.348	0.018	Unidirectional causality
FLR ↔ USS	2.716 8.063	2.132 9.380	0.033 0.000	Bidirectional causality
GDPPC↔USS	3.870 2.856	3.697 2.322	0.000 0.020	Bidirectional causality
USS→POV	3.291	2.912	0.003	Unidirectional causality
WBLIS ↔ USS	15.423 3.503	19.357 3.199	0.000 0.001	Bidirectional causality
POV → FLR	3.883	3.714	0.000	Unidirectional causality
FLR → WBLIS	200.609	270.385	0.000	Unidirectional causality
POV ↔ GDPPC	2.644 2.901	2.036 2.384	0.041 0.017	Bidirectional causality

Source: Author's estimation. Note: ↔ shows bidirectional causality, → shows unidirectional causality.

Table 10. VDA estimates of infant mortality rates.

Period	S.E.	IMR	USS	FLR	GDPPC	POV	WBLIS
1	4.061679	100	0	0	0	0	0
2	5.679610	90.20803	0.048744	0.262236	8.594334	0.078940	0.807717
3	6.841333	83.22825	0.641756	0.409103	13.77349	0.073019	1.874376
4	7.686929	77.26807	1.666321	0.563446	17.61100	0.108017	2.783143
5	8.300746	72.85624	2.985939	0.648119	19.82356	0.214052	3.472098
6	8.758227	69.55035	4.574668	0.672372	20.80818	0.426896	3.967536
7	9.111550	66.98510	6.336346	0.657581	20.96597	0.764542	4.290454
8	9.398953	64.87044	8.173165	0.625851	20.63707	1.225772	4.467701
9	9.645415	63.02534	9.993529	0.594276	20.06472	1.791974	4.530158
10	9.865931	61.35178	11.72971	0.572979	19.40207	2.433930	4.509529

Source: Author's estimation.

The primary limitations of this study are cantered around its exclusive concentration on six specific Asian economies. This underscores the necessity for a more comprehensive analysis encompassing the entirety of the Asian economic landscape. In light of the findings, it is evident that the study's hypotheses stand validated.

5. Conclusions and policy recommendation

The research examines the dynamic relationship between urban sanitation, female literacy, economic development, poverty rates, women's autonomy score, and infant death rates in six selected Asian countries from 2001 to 2020. The study aims to contribute to the ambitious Sustainable Development Goal (SDG) set by the UN in 2015, which seeks to ensure everyone's access to safe drinking water and sanitation by 2030. Although progress has been made in the past decade, significant challenges remain as hundreds of millions worldwide still need access to basic sanitation facilities. The research investigates the interplay between various factors and infant mortality rates within the selected countries. The findings of the study indicate that improvements in urban sanitation facilities, higher female literacy rates, and sustained economic development have a significant impact on reducing infant mortality rates. Conversely, an increase in poverty rates and a low women's autonomy score are associated with higher infant death rates across nations. The Granger causality estimates reveal a bidirectional relationship between urban sanitation and newborn mortality rates and a bidirectional relationship between infant mortality rates and poverty. The research also validates the feedback loop between female literacy rates and urban sanitation, economic development and urban sanitation, women's autonomy and urban sanitation, and poverty and economic growth. Higher female literacy is related to reduced infant mortality, which is linked to women's independence, and urban sanitation is impacted by poverty, which is linked to female literacy. According to VDA estimates, economic growth, urban cleanliness, and women's independence will most impact infant death rates. In light of these results, it is clear that addressing these determinants is crucial for considerably bettering baby health outcomes. This study adds to our knowledge of the interconnected dynamics between urban sanitation, female literacy, economic growth, poverty alleviation, women's agency, and infant mortality rates. SDG's aim of universal access to clean drinking water and sanitation by 2030 is highlighted, along with the need for focused initiatives and policies to address these variables.

Newborn mortality rates are shown to be inversely related to access to basic sanitation facilities. This highlights the importance of policymakers focusing on improving sanitation infrastructure and providing subsidies for facilities connected to sanitation services. It is crucial to prioritize the construction and maintenance of accessible toilets and implement health and hygiene initiatives, particularly in low-income areas where children are more likely to be exposed to unsanitary conditions. The study underscores the significance of cleanliness in preventing child mortality. It provides valuable insights and recommendations for policymaking and research related to SDG 6 and other relevant goals. Raising public awareness about the importance of sanitation and conducting public education initiatives are necessary to promote improved sanitation practices. While improved sanitation access brings significant social benefits, it also comes with a high cost for the private sector involved in sanitation facility construction. Therefore, government efforts should be directed towards enhancing sanitary services. Given that the female literacy rate critically impacts child mortality, it is essential to develop educational policies and programs that

promote maternal educational attainment. This is particularly relevant for women who face various barriers preventing them from enrolling in school. Policies and initiatives to reduce and eradicate poverty, particularly in rural areas, must be encouraged and supported. In conclusion, the research findings emphasize the importance of addressing sanitation issues, promoting female literacy, and reducing poverty to tackling child mortality effectively. These findings can guide policymakers in implementing relevant sub-policies to support the broader objectives of improving child health and achieving sustainable development goals. The following sub-policies are in place to address the issues identified:

Improving the quality of birth care, increasing vaccination rates, and allocating sufficient funds for family planning are crucial measures to lower infant mortality rates.

Empowering women by unlocking their potential in both public and private spheres through skill training, education, and access to finance is essential. This empowerment enables women to make better reproductive healthcare decisions, improving women's healthcare outcomes.

Enhancing the availability of clean drinking water and sanitation services significantly reduces child mortality.

Increasing the literacy rate among young people is a priority as it allows both women and men to understand the complex nature of childbirth and maternal health, leading to better health outcomes.

Implementing programs focusing on birth spacing, malaria prevention, exclusive breastfeeding, and poverty alleviation contribute to improved healthcare for mothers and children.

The increased social status of women resulting from improved literacy empowers them to make informed decisions regarding feeding and vaccination, leading to improved nutritional status among children.

It is crucial to eliminate health-related inequalities and ensure equitable healthcare infrastructure to enable people to live healthy lives.

Collaboration among lawmakers, government agencies, and community activists is necessary to ensure the effectiveness of infant mortality programs. Continuous improvement efforts should be made to achieve favourable healthcare outcomes. Addressing poor socioeconomic and educational status is essential, as they are associated with a higher risk of adverse pregnancy outcomes and infant mortality. Education directly impacts the health and well-being of expectant women, babies, their families, and their communities. Providing social safety nets to lower-income families is critical in improving overall family health. By implementing these sub-policies, progress can be made in reducing infant mortality rates and improving healthcare outcomes for mothers and children.

Authors contribution

Conceptualization, SS, LK, AAN, IN, HS; Methodology, SS, LK, IN, AAN, RHB, KZ, HS; Formal Analysis, SS, LK, IN, AAN, RHB, KZ, HS, MH; Resources, SS, AAN; Writing-Reviewing and Editing, SS, LK, IN, AAN, HS, MH; Software, LK, KZ; Investigation, LK, IN,, RHB, KZ, HS, MH; Data Curation, LK, IN, RHB, HS, MH; Validation, IN, RHB, KZ, HS, MH; Supervision, AAN.

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Conflicts of interest

The authors declare no conflict of interest.

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