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Examining the Effects of Innovation Access Safety and Sustainability Practices on Global Health Outcomes

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ABSTRACT

Pharmaceutical innovation plays a critical role in improving global health outcomes by enabling the development of advanced medicines, vaccines, and healthcare technologies. However, the benefits of innovation are not solely determined by technological advancement but are also influenced by access, safety, and sustainability practices within pharmaceutical systems. **This study aims** to quantitatively examine the effects of innovation adoption, access and equity, pharmaceutical safety, and sustainability practices on global health impact, as well as to investigate the mediating role of pharmaceutical safety in the relationship between innovation adoption and global health outcomes. **Using secondary** data obtained from international health and development organizations, this study applies PLS-SEM with SmartPLS to test the proposed research model. **The findings** indicate that innovation adoption, access and equity, pharmaceutical safety, and sustainability practices each have a positive and significant effect on global health impact. Furthermore, pharmaceutical safety is found to partially mediate the relationship between innovation adoption and global health impact, highlighting the importance of robust safety mechanisms in translating innovation into meaningful health benefits. **This study contributes** to the literature by integrating innovation, equity, safety, and sustainability into a unified empirical framework and offers policy-relevant insights for strengthening global pharmaceutical systems to achieve equitable and sustainable health outcomes.

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1. INTRODUCTION

Pharmaceutical innovation has long been recognized as a fundamental driver of global health improvement, contributing to increased life expectancy, reduced mortality rates, and enhanced quality of life across populations [1]. Advances in drug discovery, vaccine development, biotechnology, and digital health solutions have enabled health systems to address both communicable and non-communicable diseases more effectively. In the context of the United Nations' Sustainable Development Goals (SDGs), pharmaceutical innovation plays

a crucial role in supporting SDGs 3 on Good Health and Well-Being, which emphasizes ensuring healthy lives and promoting well-being for all at all ages [2]. Innovation adoption within pharmaceutical systems is therefore increasingly viewed as a strategic pathway for achieving global health targets and strengthening health system resilience.

However, recent global health developments indicate that the benefits of pharmaceutical innovation are unevenly distributed and do not automatically translate into equitable health outcomes [3]. Significant disparities persist in the availability, affordability, and accessibility of essential medicines, particularly between high-income and low- and middle-income countries [4]. These inequalities directly challenge SDGs 10 on Reduced Inequalities and undermine the universal health coverage agenda embedded within SDGs 3. The COVID-19 pandemic starkly illustrated how unequal access to vaccines and treatments can exacerbate global health inequities, despite unprecedented levels of pharmaceutical innovation. As such, access and equity have emerged as critical conditions that determine whether innovation adoption can meaningfully contribute to improved global health impact [5, 6].

Beyond access-related challenges, pharmaceutical safety has become an increasingly prominent concern in the era of accelerated innovation and rapid market introduction of new medical products. While expedited regulatory pathways can enhance responsiveness to public health emergencies, they may also heighten risks related to adverse drug reactions, insufficient long-term safety data, and uneven pharmacovigilance capacity across countries [7]. These safety challenges pose direct threats to patient well-being and public trust in health systems, potentially counteracting the intended benefits of innovation. From an SDGs perspective, pharmaceutical safety is integral to achieving SDGs 3, as unsafe medicines and inadequate regulatory oversight can lead to preventable harm and increased disease burden. Consequently [8], pharmaceutical safety may function not only as a direct determinant of health outcomes but also as a mediating mechanism that influences how innovation adoption affects global health impact [9].

In parallel, growing global awareness of environmental sustainability and long-term public health resilience has drawn attention to sustainability practices within pharmaceutical systems [10]. Unsustainable manufacturing processes, improper disposal of pharmaceutical waste, and excessive use of antibiotics contribute to environmental pollution, antimicrobial resistance, and broader ecological degradation. These issues intersect with SDGs 12 on Responsible Consumption and Production and SDGs 13 on Climate Action, while simultaneously affecting population health outcomes [11]. Without sustainable practices, short-term health gains achieved through pharmaceutical innovation may generate long-term negative externalities that undermine both environmental integrity and human well-being [12]. Integrating sustainability considerations into pharmaceutical innovation is therefore essential for ensuring that health improvements are durable and aligned with the broader SDGs agenda [13, 14].

Despite the recognized importance of innovation, access, safety, and sustainability in shaping global health outcomes, existing empirical research has largely examined these dimensions in isolation [15]. Limited quantitative evidence is available that simultaneously assesses their combined effects and underlying mechanisms at the global level. In particular, the mediating role of pharmaceutical safety in the relationship between innovation adoption and global health impact remains underexplored [16, 17]. Addressing this gap, the present study aims to examine the effects of innovation adoption, access and equity, pharmaceutical safety, and sustainability practices on global health outcomes, while investigating the mediating role of pharmaceutical safety. By employing secondary cross-country data and PLS-SEM using SmartPLS [18], this study contributes to a more integrated understanding of how pharmaceutical systems can support the achievement of the SDGs through equitable, safe, and sustainable innovation.

2. RESEARCH METHOD

The research method of this study examines the relationships among pharmaceutical innovation adoption, access and equity, pharmaceutical safety, sustainability practices, and global health outcomes using a quantitative empirical approach. By utilizing cross-country secondary data and an analytical framework that captures direct and indirect effects, this method enables an assessment of interactions within pharmaceutical systems across different national contexts [19]. The approach emphasizes theory-driven model development, standardized measurement, and robust statistical analysis to ensure reliable and valid findings. In addition, the selected method is suitable for analyzing complex models with mediating relationships and supports generalizable conclusions relevant to global health policy within an SDGs-oriented perspective.

2.1. Research Design and Theoretical Foundation

This study employs a quantitative explanatory research design aimed at examining the causal relationships between pharmaceutical innovation adoption, access and equity, pharmaceutical safety, sustainability practices, and global health impact [20]. The explanatory design is selected to test theory-driven hypotheses derived from prior global health, innovation, and sustainability literature. The theoretical foundation of this study integrates insights from innovation diffusion theory, health equity theory, and sustainable development theory [21]. Innovation diffusion theory suggests that technological advancement generates societal benefits only when innovations are effectively adopted within institutional systems. Health equity theory emphasizes that access to healthcare resources is a prerequisite for translating innovation into population-level outcomes. Meanwhile [22], sustainable development theory highlights that long-term health improvements depend on environmentally and socially responsible practices. Together, these perspectives provide a comprehensive framework for understanding how pharmaceutical systems contribute to global health outcomes in line with the SDGs, particularly SDGs 3 (Good Health and Well-Being), SDGs 10 (Reduced Inequalities), SDGs 12 (Responsible Consumption and Production), and SDGs 13 (Climate Action) [23].

2.2. Literature-Based Model Development and Hypotheses

Prior empirical studies have consistently demonstrated that pharmaceutical innovation adoption enhances health system performance by improving treatment effectiveness, expanding therapeutic options, and reducing disease burden. Countries with higher innovation capacity and adoption levels tend to experience better population health indicators, suggesting a positive association between innovation and global health outcomes [24]. However, the literature also emphasizes that innovation alone is insufficient. Research on access and equity indicates that disparities in medicine availability and affordability significantly limit the real-world benefits of innovation [25]. Inequitable access to essential medicines undermines universal health coverage and exacerbates global health inequalities, directly challenging the objectives of SDGs 3 and SDGs 10.

In parallel, studies on pharmaceutical safety highlight the importance of regulatory capacity, quality control, and pharmacovigilance systems. While rapid innovation can introduce highly effective therapies, inadequate safety oversight may increase adverse drug reactions and public health risks [26]. Recent studies suggest that pharmaceutical safety may act as a mechanism through which innovation influences health outcomes, rather than merely serving as a standalone determinant. Furthermore, the sustainability literature underscores the long-term health implications of pharmaceutical production and consumption patterns [27]. Unsustainable manufacturing processes, improper waste disposal, and excessive antibiotic use contribute to environmental degradation and antimicrobial resistance, posing systemic threats to global health. Aligning pharmaceutical practices with sustainability principles supports durable health outcomes and reinforces SDGs-aligned development [28]. Based on this integrated body of literature, this study proposes a model in which innovation adoption, access and equity, pharmaceutical safety, and sustainability practices directly influence global health impact, while pharmaceutical safety additionally mediates the relationship between innovation adoption and global health impact [29].

2.3. Conceptual Research Framework

The conceptual research framework of this study consists of four exogenous constructs-Innovation Adoption, Access and Equity, Pharmaceutical Safety, and Sustainability Practices and one endogenous construct, Global Health Impact [30]. These constructs represent the key dimensions of pharmaceutical systems that collectively influence population-level health outcomes. Innovation Adoption reflects the extent to which pharmaceutical advancements are introduced and utilized within health systems, while Access and Equity capture the availability and affordability of essential medicines across different population groups. Sustainability Practices emphasize environmentally responsible pharmaceutical activities, including production, distribution, and waste management, whereas Pharmaceutical Safety represents the strength of regulatory oversight and pharmacovigilance systems in ensuring the safe use of medicines.

Within this framework, Pharmaceutical Safety is further specified as a mediating variable between Innovation Adoption and Global Health Impact, indicating that the influence of innovation on health outcomes is not purely direct. Instead, innovation is expected to generate stronger and more sustainable health benefits when supported by effective safety governance that ensures quality, efficacy, and patient protection. By positioning Pharmaceutical Safety as a mediator, the framework highlights its dual role as both a protective mechanism for public health and an enabling condition that enhances the effectiveness of pharmaceutical innovation. Overall,

this conceptual structure underscores the interconnected roles of innovation, equity, safety, and sustainability in shaping global health impact within an integrated and SDGs-oriented analytical model.

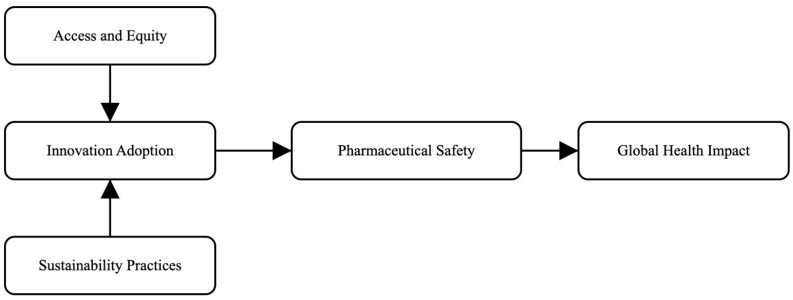

Figure 1. Conceptual Research Model

Figure 1 illustrates the relationships among the key constructs in this study, where Access and Equity and Sustainability Practices influence Innovation Adoption, which subsequently affects Global Health Impact through the mediating role of Pharmaceutical Safety [31]. This model indicates that the adoption of health-related innovations contributes to improved global health outcomes only when supported by equitable access, sustainable practices, and adequate pharmaceutical safety, emphasizing the interconnected roles of innovation, regulation, equity, and sustainability in shaping population-level health outcomes [32].

2.4. Data Sources and Sample

This study utilizes secondary cross-country data obtained from internationally recognized organizations, including the World Health Organization (WHO), World Bank, Global Innovation Index (GII), and global environmental sustainability databases [33]. These sources provide standardized indicators suitable for cross-national comparison and policy-oriented analysis. The unit of analysis is the country. Countries are included in the sample based on the availability of complete data for all constructs and indicators. This approach ensures comparability and minimizes bias arising from missing data. The final sample represents countries across different income groups and geographic regions, allowing for a comprehensive assessment of global pharmaceutical systems [34, 35].

2.5. Variables and Operationalization

All constructs are operationalized as reflective latent variables, consistent with established practices in global health and innovation research. Indicators are selected based on theoretical relevance and prior empirical validation [36]. To enhance comparability, all indicators are standardized prior to analysis.

Table 1. Operational Definitions and Variables

Construct	Description	Example Indicators
Innovation Adoption	Degree of adoption and diffusion of pharmaceutical innovations	R&D expenditure, new drug approvals
Access and Equity	Availability and affordability of essential medicines	Medicine coverage, affordability index
Pharmaceutical Safety	Strength of drug regulation and safety monitoring	Pharmacovigilance systems, safety reporting
Sustainability Practices	Environmental responsibility in pharmaceutical systems	Waste management, antibiotic stewardship
Global Health Impact	Population-level health outcomes	Life expectancy, mortality rates

Table 1 explains the operational definitions of the variables used in this study along with their example indicators. Innovation Adoption reflects the degree of adoption and diffusion of pharmaceutical innovations,

measured through indicators such as R&D expenditure and new drug approvals [37]. Access and Equity represents the availability and affordability of essential medicines, captured by medicine coverage and affordability indices. Pharmaceutical Safety refers to the strength of drug regulation and safety monitoring, assessed through pharmacovigilance systems and safety reporting. Sustainability Practices describe environmental responsibility within pharmaceutical systems, indicated by waste management and antibiotic stewardship. Finally, Global Health Impact represents population-level health outcomes, measured using indicators such as life expectancy and mortality rates [38, 39].

2.6. Data Analysis Technique

Data analysis is conducted using PLS-SEM with SmartPLS [40], following a two-stage procedure:

- Measurement Model Evaluation, assessing indicator reliability, internal consistency reliability, convergent validity, and discriminant validity.
- Structural Model Evaluation, examining path coefficients, coefficient of determination (R^2), effect sizes, predictive relevance, and hypothesis testing.

PLS-SEM is particularly suitable for this study due to its ability to handle complex models, mediation effects, and non-normal data distributions commonly found in cross-country datasets [41].

2.7. Mediation Analysis

The mediating role of pharmaceutical safety is examined using the bootstrapping procedure in SmartPLS with 5,000 resamples [42]. This non-parametric resampling technique is widely recommended in PLS-SEM because it does not assume data normality and provides robust estimates of standard errors, t-statistics, and confidence intervals for indirect effects. Through this procedure, the stability and statistical significance of the mediation effect can be reliably assessed across repeated subsamples. The indirect effect of innovation adoption on global health impact through pharmaceutical safety is calculated as the product of the path coefficient from innovation adoption to pharmaceutical safety and the path coefficient from pharmaceutical safety to global health impact, as expressed by the following equation:

$$\text{Indirect Effect} = \beta_{\text{Innovation}\rightarrow\text{Safety}} \times \beta_{\text{Safety}\rightarrow\text{Health}} \tag{1}$$

A statistically significant indirect effect indicates the presence of mediation [43]. Furthermore, when the direct effect of innovation adoption on global health impact remains significant alongside the indirect effect, the mediation is classified as partial, suggesting that pharmaceutical safety functions as an important mechanism that enhances, rather than fully explains, the relationship between innovation adoption and global health outcomes.

3. RESULTS AND DISCUSSION

The empirical analysis demonstrates that pharmaceutical innovation adoption, access and equity, pharmaceutical safety, and sustainability practices are interrelated determinants of global health outcomes. The findings indicate that innovation contributes positively to population health, yet its effectiveness is substantially strengthened when supported by equitable access to medicines and robust safety mechanisms. Access and equity emerge as a critical factor in ensuring that health benefits reach broader populations, while pharmaceutical safety plays a dual role by directly protecting patient well-being and by enabling innovation to generate meaningful health impacts. In addition, sustainability practices are shown to support long-term health performance by reducing environmental and systemic risks, underscoring the importance of integrating innovation, equity, safety, and sustainability within a unified pharmaceutical system perspective aligned with the SDGs.

3.1. Descriptive Statistics

Descriptive analysis was conducted to examine the general characteristics of the study variables across countries. The results indicate substantial variation in pharmaceutical innovation adoption, access and equity, pharmaceutical safety, sustainability practices, and global health impact. This variation reflects differences in national pharmaceutical system capacities and health outcomes, justifying the use of a structural modeling approach to examine causal relationships [44].

3.2. Measurement Model Evaluation

The measurement model was evaluated prior to hypothesis testing to assess indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. All indicators demonstrated satisfactory reliability, with outer loading values exceeding the recommended threshold of 0.700 [45]. Convergent validity was confirmed as all constructs achieved Average Variance Extracted (AVE) values greater than 0.500. In addition, internal consistency reliability was established using Cronbach's Alpha and Composite Reliability (CR), with all values surpassing the minimum recommended level of 0.700, indicating that the measurement model is reliable and suitable for further structural analysis [46, 47].

Table 2. Reliability and Convergent Validity

Construct	Cronbach's Alpha	CR	AVE
Innovation Adoption	0.821	0.873	0.581
Access and Equity	0.834	0.882	0.596
Pharmaceutical Safety	0.846	0.891	0.602
Sustainability Practices	0.808	0.864	0.559
Global Health Impact	0.862	0.902	0.622

Based on Table 2, the results of the reliability and convergent validity assessment indicate that all constructs in the measurement model meet the recommended criteria [48]. Cronbach's Alpha values range from 0.808 to 0.862, exceeding the minimum threshold of 0.700, which confirms satisfactory internal consistency reliability for all constructs. Similarly, CR values are between 0.864 and 0.902, further demonstrating strong construct reliability. In terms of convergent validity, all constructs achieve AVE values above the recommended cutoff of 0.500, with values ranging from 0.559 to 0.622. These findings confirm that the indicators adequately represent their respective constructs, indicating that the measurement model is reliable and valid, and therefore suitable for subsequent structural model analysis [49].

3.3. Discriminant Validity

Discriminant validity was assessed using the Heterotrait–Monotrait (HTMT) ratio. All HTMT values were below the conservative threshold of 0.900, indicating that each construct is empirically distinct [50].

Table 3. HTMT Discriminant Validity

Constructs	IA	AE	PS	SP	GHI
Innovation Adoption (IA)	-	-	-	-	-
Access and Equity (AE)	0.642	-	-	-	-
Pharmaceutical Safety (PS)	0.718	0.694	-	-	-
Sustainability Practices (SP)	0.601	0.623	0.671	-	-
Global Health Impact (GHI)	0.754	0.781	0.796	0.709	-

As shown in Table 3, discriminant validity was evaluated using the HTMT ratio, and the results indicate that all HTMT values are below the conservative threshold of 0.900. The HTMT values among the constructs range from 0.601 to 0.796, demonstrating that each construct is empirically distinct from the others. Specifically, the relationships between Innovation Adoption, Access and Equity, Pharmaceutical Safety, Sustainability Practices, and Global Health Impact do not exhibit excessive overlap, confirming adequate discriminant validity [51]. These findings suggest that the constructs capture unique conceptual dimensions within the measurement model, thereby supporting the robustness of the model and its suitability for subsequent structural model analysis.

3.4. Structural Model Evaluation

Collinearity assessment revealed that all Variance Inflation Factor (VIF) values were below 5.000, indicating no multicollinearity concerns. The structural model was then evaluated using path coefficients, coefficients of determination, effect sizes, and predictive relevance. The model explains 56.300% of the variance in Global Health Impact (R^2 = 0.563), indicating moderate to substantial explanatory power [52].

3.5. Hypotheses Testing

Hypotheses were tested using a bootstrapping procedure with 5,000 resamples. The results are summarized in Table 4 [53].

Table 4. Structural Path Coefficients

Hypothesis	Path	β	t-value	p-value	Decision
H1	Innovation Adoption → Global Health Impact	0.231	3.482	<0.001	Supported
H2	Access and Equity → Global Health Impact	0.297	4.115	<0.001	Supported
H3	Pharmaceutical Safety → Global Health Impact	0.264	3.907	<0.001	Supported
H4	Sustainability Practices → Global Health Impact	0.198	2.764	0.006	Supported
H5	Innovation Adoption → Pharmaceutical Safety	0.356	5.221	<0.001	Supported

Based on Table 4, the results of the hypotheses testing using the bootstrapping procedure with 5,000 resamples indicate that all proposed relationships are statistically significant and supported. Innovation Adoption has a positive and significant effect on Global Health Impact (β = 0.231, t = 3.482, p <0.001), while Access and Equity demonstrates the strongest direct influence on Global Health Impact (β = 0.297, t = 4.115, p <0.001). Pharmaceutical Safety also shows a significant positive effect on Global Health Impact (β = 0.264, t = 3.907, p <0.001), confirming its critical role in health outcome enhancement. Additionally, Sustainability Practices significantly influence Global Health Impact (β = 0.198, t = 2.764, p = 0.006), indicating that environmentally responsible practices contribute meaningfully to long-term health performance [54]. Furthermore, Innovation Adoption exerts a strong positive effect on Pharmaceutical Safety (β = 0.356, t = 5.221, p <0.001), supporting its mediating role within the structural model. Overall, these findings confirm that all hypothesized paths are significant at the 5% level, demonstrating the robustness of the proposed research model [55].

3.6. Mediation Analysis

The mediating role of Pharmaceutical Safety was examined using the bootstrapping approach. The indirect effect of Innovation Adoption on Global Health Impact through Pharmaceutical Safety was calculated as [56]:

$$\text{Indirect Effect} = 0.356 \times 0.264 = 0.094 \tag{2}$$

The indirect effect was statistically significant (p <0.001), while the direct effect of Innovation Adoption on Global Health Impact remained significant. This indicates partial mediation, supporting Hypothesis H5 [57].

3.7. Discussion

The findings of this study provide strong empirical evidence that pharmaceutical innovation adoption, access and equity, pharmaceutical safety, and sustainability practices play complementary roles in shaping

global health outcomes [58]. The positive effect of innovation adoption on global health impact confirms that pharmaceutical innovation remains a critical driver of improved population health; however, the presence of partial mediation indicates that innovation alone is insufficient to generate optimal outcomes. Its benefits are significantly enhanced when supported by robust pharmaceutical safety systems, extending innovation diffusion theory by demonstrating that regulatory and safety mechanisms are essential pathways through which innovation translates into tangible health gains. At the same time, access and equity emerged as the strongest predictor of global health impact, underscoring persistent disparities in medicine availability and affordability [59]. This finding reinforces the centrality of equitable access in achieving SDGs 3 (Good Health and Well-Being) and SDGs 10 (Reduced Inequalities), highlighting that even highly innovative systems may fail to deliver population-level benefits when access barriers persist.

Furthermore, pharmaceutical safety demonstrated both direct and mediating effects, emphasizing its dual role in protecting patient well-being while enabling the effective realization of pharmaceutical innovation. This result aligns with growing global concerns regarding accelerated drug approvals and uneven pharmacovigilance capacity, particularly in low- and middle-income countries. In addition, the significant effect of sustainability practices highlights the importance of environmentally responsible pharmaceutical systems in supporting long-term health outcomes. This finding supports the integration of SDGs 12 (Responsible Consumption and Production) and SDGs 13 (Climate Action) into global health strategies, confirming that sustainability is a fundamental component of health system resilience. Overall, this study contributes to the literature by presenting an integrated, SDGs-oriented empirical model that quantitatively links pharmaceutical innovation, equity, safety, and sustainability to global health outcomes.

4. MANAGERIAL IMPLICATIONS

The results of this study highlight that pharmaceutical innovation alone is insufficient to generate optimal global health outcomes without effective adoption mechanisms and supporting institutional capacity. For policymakers and pharmaceutical industry leaders, this implies the need to prioritize strategies that facilitate the integration of innovation into healthcare systems, including streamlined regulatory processes, incentives for innovation uptake, and investments in health infrastructure. Importantly, innovation strategies should be designed in parallel with robust safety frameworks to ensure that accelerated adoption does not compromise patient well-being.

The strong influence of access and equity on global health impact underscores the managerial importance of addressing affordability and distribution barriers. Governments and health system managers should implement pricing regulations, subsidy schemes, and pooled procurement mechanisms to expand access to essential medicines, particularly in low- and middle-income countries. From an industry perspective, adopting differential pricing models and strengthening public–private partnerships can enhance market reach while supporting equitable health outcomes, thereby advancing SDGs 3 and SDGs 10.

Finally, the significant effects of pharmaceutical safety and sustainability practices indicate that these dimensions should be embedded within core management and governance strategies rather than treated as compliance requirements. Strengthening pharmacovigilance systems, improving post-market surveillance, and integrating environmentally responsible manufacturing and waste management practices can enhance long-term health system resilience. By aligning innovation, equity, safety, and sustainability within a unified managerial framework, stakeholders can maximize the health impact of pharmaceutical systems while supporting the broader SDGs agenda.

5. CONCLUSION

This study empirically examines the effects of pharmaceutical innovation adoption, access and equity, pharmaceutical safety, and sustainability practices on global health outcomes using a cross-country quantitative approach and PLS-SEM. The results demonstrate that all four dimensions significantly contribute to global health impact, confirming that improvements in population health require not only technological advancement but also equitable access, strong safety governance, and sustainable pharmaceutical practices. Addressing a key research gap, this study responds to the limited empirical literature that simultaneously integrates innovation, access, safety, and sustainability within a single analytical framework, as previous studies have often examined these dimensions independently, resulting in fragmented insights into pharmaceutical system performance.

By adopting an SDGs-oriented perspective, this research provides a more holistic understanding of

how pharmaceutical systems function as interconnected mechanisms influencing global health outcomes. The primary novelty of this study lies in identifying pharmaceutical safety as a mediating mechanism between innovation adoption and global health impact. This finding advances innovation diffusion theory by demonstrating that innovation translates into tangible health benefits more effectively when supported by robust regulatory and pharmacovigilance systems, highlighting that safety should be viewed as a strategic enabler of innovation rather than a purely regulatory constraint.

From a practical standpoint, the findings underscore the importance of coordinated pharmaceutical governance. Policies and managerial strategies that prioritize innovation adoption without addressing access barriers, safety oversight, and sustainability risks are unlikely to yield optimal health outcomes. Aligning these dimensions supports progress toward SDGs 3, SDGs 10 (Reduced Inequalities), SDGs 12 (Responsible Consumption and Production), and SDGs 13 (Climate Action). Despite its contributions, this study has limitations, as reliance on secondary cross-country data limits the ability to capture intra-country variation and causal dynamics over time. Future studies could employ longitudinal designs, incorporate institutional and governance variables, or examine moderating effects of income level and regional context to deepen understanding of heterogeneity in pharmaceutical system performance.

6. DECLARATIONS

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6.2. Author Contributions

Conceptualization: IN; Methodology: TN; Software: KV; Validation: MS and MH; Formal Analysis: TN and MH; Investigation: KV; Resources: IN; Data Curation: MS; Writing Original Draft Preparation: MH and TN; Writing Review and Editing: MS and KV; Visualization: IN; All authors, MH, MS, IN, TN, and KV, have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

6.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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