

Advancing Risk Pooling Mechanisms in Healthcare Coverage to Strengthen System Resilience and Equity in Modern Health Systems

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Risk pooling in healthcare systems plays a crucial role in distributing financial risk among a large population, thus enhancing accessibility and affordability of healthcare services. Recent advances in technology and healthcare policy have spurred the development of more sophisticated risk pooling mechanisms. This article explores the integration of advanced risk pooling mechanisms to improve systemic resilience and promote equity in modern healthcare systems. The analysis examines key innovations, technological integrations, and their impact on healthcare systems, with particular attention to socioeconomic disparities and the regulatory framework necessary for these advancements. The objective of this paper is to highlight how these mechanisms can address challenges in global health systems and contribute to the sustainability of healthcare delivery.

Keywords: Risk Pooling, Healthcare Coverage, Systemic Resilience, Equity, Technological Integration, Healthcare Systems, Advanced Mechanisms

1. Introduction

IU Strategic plan 2015-2020 page 3 While the whole world struggles to improve access to quality and affordable healthcare, hospital and healthcare systems grapple with demands to contain the cost of delivering services. These challenges are further compounded by restricted funding, structural disconnections and poor health care access and rights inequality in many countries, most especially those operating under lower income brackets[1]. Problems with the current insurance-based systems, long standing to healthcare financing, can be solved by risk pooling. Reducing the impact of risk whereby many people contribute resources from a wide array so as to ensure that an individual is shielded from the financial burden of unfortunate health events in future is known as risk pooling. However, the efficiency of conventional risk spreading tools has been hampered by numerous impediments for example, inefficiency, disparities in service provision to the populace, and also, inability to achieve reform, in response to the dynamic health care needs of the public.

Due to these constraints, innovations in technology, use of data analytics and healthcare policies have provided a basis to come up with sophisticated systems for risk pooling[2]. Such innovations are expected to increase the capacity of the healthcare systems to deliver a higher quality care, both in terms of resources and claims processing, and increase transparency and accountability. Risk pooling as a concept is changing because emerging technologies like artificial intelligence (AI), blockchain, and telemedicine are being incorporated to make existing systems more efficient and dynamic to a changing society's healthcare needs. On the other hand, there is the possibility to influence equity and redress wrongs in that the different innovations must make provision for the socially deprived when seeking health services.

More specifically, the research for this paper will look into risk pooling advanced mechanisms in the healthcare systems with greatest attention paid to the ways of improving system's robustness and increasing equity[3]. Understanding this, this study aims at explaining how current day risk pooling mechanisms that existed in health information technologies can contribute towards better healthcare risks assessment, resources allocation and delivery of healthcare to all people to ensure sustainable solutions are developed. In addition, it will cover the questions related to the barriers and obstacles to adopt such mechanisms, such as, the legal aspects, disparities in economic status, and issues regarding data protection. Finally, this article calls for global development of risk pooling strategies as a way of achieving better Healthcare risk pooling for enhancing health systems that will be efficient in meeting diverse population needs in the existing and future complex world.

2. RISK POOLING IN HEALTHCARE

2.1. Overview of Risk Pooling Mechanisms

The act of pooling together risk is taken as one of the foundational principles applied in financing health care, where expenditures for health care are pooled together monetary resources drawn from a diverse population. The underlying premise of this method is that the financial burden of health-care costs is shared among an appropriate number so that no individual patients carry too great a financial load when they truly need medical service[4]. There are several forms of mechanisms of risk pooling. It is also peculiar to various distinct features that may characterize one against the other. Private pools of insurance collect premiums from either the individual or employer, but its basis remains dependent on individual health risk. Some of its adverse effects include adverse selection; where only the most risky take the cover. In public pools of health insurance, taxes or premiums are collected from the entire citizenry to achieve universal coverage. This system seeks to ensure fair distribution of costs and access to health care services as the costs cut across the population. In community-oriented risk pooling systems, contributions are collected from a specified community to cover the healthcare costs that its members may incur. Typically informal and localised in character, these insurance schemes are widespread only in those developing countries without an alternative through which formal, available insurance plans may be made accessible.

Effective risk pooling mechanisms can and should promote access to and enhance the availability of care during economic and health-related emergencies[5]. These mechanisms enable the spreading of financial risks so that persons at the extreme ends of the health

challenges do not face costs of such proportions. In a well-functioning environment of pooled risks, persons are more likely to receive necessary health care without the fear of a financial collapse-an important element of the stability of the health-care financing system as a whole.

2.2. Role in Healthcare Systems

The primary aspect of the principle is the risk pooling of health systems that makes healthcare accessible, affordable, and sustainable. Pooling financial resources through aggregation among large populations makes healthcare affordable for one and all[6]. If risk pooling does not take place, the expense of health care would become unendurable on an individual basis, particularly with a patient afflicted by chronic illness or a fluctuating health episode. A strong pooling mechanism ensures the availability of health care to everybody, regardless of their health status or economic status.

Risk pooling is an important function that fosters health equity since it reduces inequalities in provision for healthcare services. In a progressive system, low-income earners or patients at higher risks of suffering from health are not prevented from receiving their basic care services, hence increasing the equitable use of health care resources[7]. Risk pooling also has a potential of enhancing the general financial sustainability of the health care systems as they ensure a more predictable and fair allocation of health care resources.

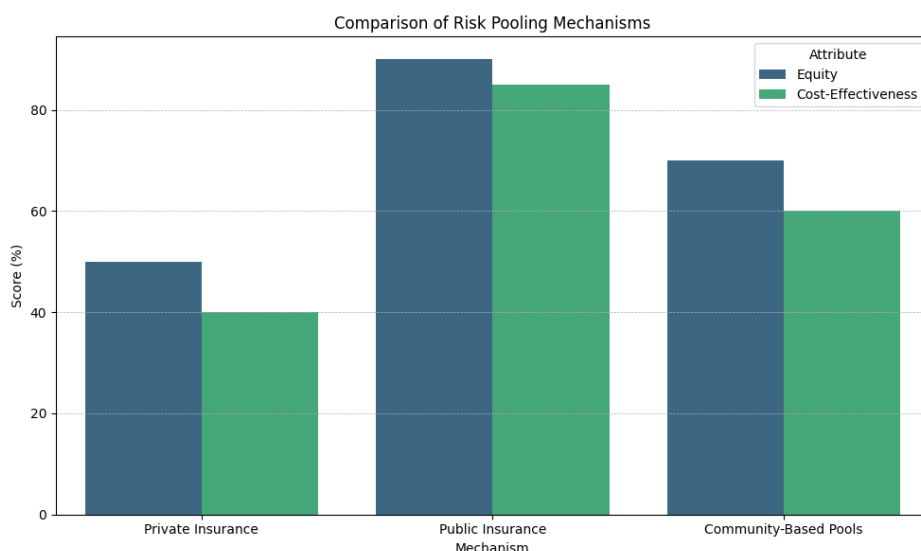


Figure 1 Comparison of Risk Pooling Mechanisms by Equity and Cost-Effectiveness (Data Source: WHO, 2023).

Risk pooling further optimizes the proper allocation of resources because the centralized funds can be distributed to those sectors needing them most. As a result, proper resource utilization is maximized, eliminating extensive utilization of services and ensuring that the patients with the highest health needs receive treatment in time[8]. In addition, it helps healthcare systems adapt more easily to financial shocks, such as sudden health crises or economic downturn, as the common pool provides a buffer against such disturbances.

Table 1: Types of Risk Pooling Mechanisms and Their Characteristics

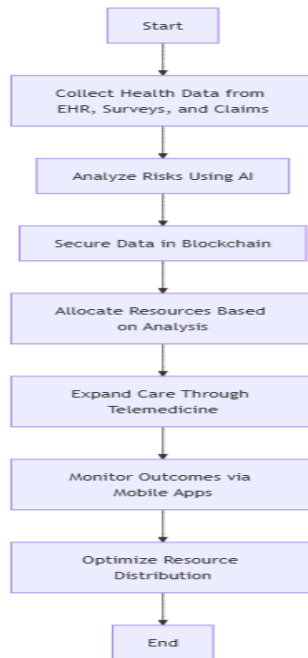
Mechanism Type	Characteristics	Examples
Private Insurance Pool	Premiums based on individual health risks, risk of adverse selection, complex administration	Employer-based insurance (USA), Health Maintenance Organizations (HMOs)
Public Health Insurance Pool	Tax-funded or flat premiums, universal coverage, equitable risk distribution, government-managed	Medicare (USA), NHS (UK), Canada's Medicare
Community-Based Pool	Locally organized, informal schemes, lower administrative cost, used in low-income regions	Micro-insurance schemes, Community health funds

3. ADVANCED RISK POOLING MECHANISMS

3.1. Key Innovations and Technological Integration

The last few years have witnessed a growth in highly advanced risk pooling strategies, using technological advancement for the enhancement of efficiency, equity, and resilience in healthcare systems. AI, blockchain technology, and data analytics have opened up new pathways for improvement in administration of pooled resources, risk evaluation, and the overall efficacy of the system.

Advanced risk pooling calls for a huge step forward in the application of artificial intelligence towards more precise risk evaluation. The traditional methods of risk pooling are rooted in rather basic demographic information and can measure the risk of an individual. AI can analyze a myriad range of data variables that comprise factors related to medical history, lifestyle factors, and even genetic predispositions towards giving much more precise predictions of risk[9]. This helps to design more personal risk-pooling models which can distribute the resources more evenly and predict future health care expenditure much more accurately. Predictive models are being produced that do not only analyze the extent of the risk but also give practical insight into prevention measures as well as early intervention strategies. For instance, artificial intelligence tools are already used in predicting diseases that will eventually break out in the future to better allocate available resources when needed.



With its completely open and non-editable record of all transactions, blockchain technology holds enormous aggregation of risk. The domains of insurance and community-based health programs where issues regarding transparency crop up very often make it highly relevant. Medical care systems, as such, can remain transparent in the allocation of pooled assets, accountable, and liberated from fraud, by blockchain implementation[10]. This will, therefore, help reduce administrative costs because the elimination of middlemen in claims processing increases the speed and accuracy of transactions. Additionally, telemedicine and mobile health applications are increasingly becoming important to risk pooling strategies since they enable remote access to healthcare services, improve data collection processes, and allow for more efficient real-time monitoring of patient health.

Advances in data analytics have dramatically increased the ability to analyze large volumes of data in order to enhance decision-making capabilities[11]. Instruments in big data will aggregate and process healthcare information gathered from different sources; electronic health records, patient questionnaires, and government health statistics-all these enable more rational decisions by the policymakers and health practitioners regarding how resources should be managed and utilized. These technologies would improve delivery by identifying gaps in care, predicting trends of health needs, and ensuring funds are used more efficiently to improve the outcomes.

Pseudocode: Workflow for Integrating Advanced Technologies into Risk Pooling Mechanisms.

 Input: HealthData (Demographics, MedicalHistory, SocioeconomicFactors)

Technologies (AI, Blockchain, Telemedicine, Data Analytics)

Step 1: Collect HealthData from multiple sources:

- Electronic Health Records (EHR)
- Patient Surveys
- Insurance Claims

Step 2: Analyze data using AI:

- Predict individual and systemic risks
- Identify vulnerable populations

Step 3: Store validated data in Blockchain:

- Ensure transparency and security
- Record healthcare transactions immutably

Step 4: Allocate resources based on analysis:

- Use Telemedicine to expand care delivery
- Prioritize areas with high healthcare needs

Step 5: Monitor outcomes using Mobile Apps:

- Track patient health in real-time
- Adjust resource distribution dynamically

Output: Resilient, equitable, and sustainable risk pooling system

3.2. Technological Integration in Risk Pooling

Incorporation of technology into advanced risk pooling frameworks has highly optimized resource distribution and strengthened the ability to face new healthcare challenges. A very relevant example is seen during the COVID-19 pandemic, when artificial intelligence and blockchain technologies have helped monitor healthcare spending more effectively, expedited claims processing, and allowed for immediate resource distribution[12]. With these advancements, the systems that were relying on AI-based models could forecast and track a rise in demand, while blockchain maintained the transparent distribution of healthcare resources.

Beyond predicting the health risks of an individual, AI's application is also helping identify systemic risks that may affect populations. For instance, algorithms created by AI can analyze health data and predict public health emergencies or epidemics, thereby allowing for earlier interventions and preparation[13]. Additionally, AI-based claims processing systems expedite reimbursements, reduce errors, and smooth out administrative work, thus enhancing the efficiency of risk pooling systems.

Telemedicine, in the context of the COVID-19 pandemic, has hastened the integration of remote healthcare services and thereby facilitated the aggregation of healthcare resources. Telemedicine has alleviated pressure on traditional in-person healthcare services because access to healthcare is improved through virtual consultations, especially in areas with limited

access[14]. Mobile health applications also collect data that improve the effectiveness of risk pooling since they provide continuous health monitoring and important information about individual health behaviors.

Advances in technology that have made it easier to integrate and process data help support the development of dynamic risk pools. This is unlike the static pools which cannot change premiums or even coverage based on current information about the health conditions[15]. This new method helps counter the adverse selection problem since some people who, owing to the levels of risk, would have been shut out from classical insurance pools are incorporated into these risk pools.

Table 2: Technologies Transforming Advanced Risk Pooling Mechanisms

Technology	Functionality	Impact on Risk Pooling
Artificial Intelligence	Predictive analytics for risk assessment, personalized care	Improves accuracy of risk assessments, resource allocation
Blockchain	Ensures transparency, fraud prevention, and efficient claims processing	Reduces administrative costs, enhances trust and transparency
Data Analytics	Aggregates healthcare data to inform decision-making	Optimizes resource allocation, identifies trends, improves planning
Telemedicine	Facilitates remote consultations, real-time health monitoring	Expands access to healthcare, reduces in-person strain, provides real-time data
Mobile Health Apps	Continuous health monitoring, data collection	Enhances monitoring, supports dynamic adjustments in pooling

It would provide the opportunity for health care systems to enhance their overall risk handling remarkably while channelling the resources to where they are most needed, developing a stronger and fairer system. Future improvement in the capacity of responding to all changing health requirements with equitable care to all is likely to occur as more countries and health care professionals adapt to these technologies and innovations[16]. Because the sophisticated risk pooling mechanisms will determine whether health care for everyone is sustainable, especially among vulnerable populations, they have become a recent indispensable part of health care systems for modern times.

4. IMPACT ON SYSTEMIC RESILIENCE AND EQUITY

4.1. Enhancing Resilience

This means that the implementation of sophisticated risk pooling strategies will be necessary in order to increase the resilience of healthcare systems. In this respect, resilience of a healthcare system refers to its ability to absorb disturbances, adapt to changes, and perform satisfactorily under crisis conditions such as pandemics, natural calamities, or economic recessions[17]. It incorporates such sophisticated risk-pooling strategies, especially in AI-driven technology, blockchain technology, and data analytics, that further enhance the responsive and effective nature of healthcare systems during emergencies. In such emergency situations, all health services could be accessed as well.

Throughout the COVID-19 pandemic, nations that possessed strong risk pooling frameworks,

exemplified by universal health coverage (UHC) initiatives, exhibited markedly greater resilience. Specifically, countries such as South Korea and Germany, which had previously established sophisticated risk pooling systems, were capable of promptly enhancing their testing, treatment, and vaccination activities[18]. Artificial intelligence and data analytics drove such initiatives, providing real-time capabilities to forecast increases in the number of cases and valuable insights in terms of optimal resource allocation strategies. On the other hand, blockchain technologies made it possible to effectively monitor the transparent healthcare resources such that vaccines and medical supplies were delivered to the regions with highest demands.

In addition, the convergence of telemedicine with mobile health applications has significantly enhanced resiliency by relieving pressure from physical healthcare systems. These innovations have ensured sustained access to medical consultations, especially in overcrowded hospitals, and have helped preserve precious healthcare resources and prevent system collapse. The mobile health applications made it possible to monitor patients continuously, hence facilitating the timeliest possible identification of medical concerns and reducing the need for emergency interventions, a situation that often puts pressure on healthcare systems when problems arise.

Advanced risk pooling supports better readiness for future health demands. Moreover, predictive analytics help healthcare systems to anticipate and predict a breakout or a health crisis. In this way, resources will be pre-emptively distributed and healthcare infrastructure will be sufficiently equipped[19]. It is an approach to building resilient health systems for the long run in an ever-changing environment due to new health threats.

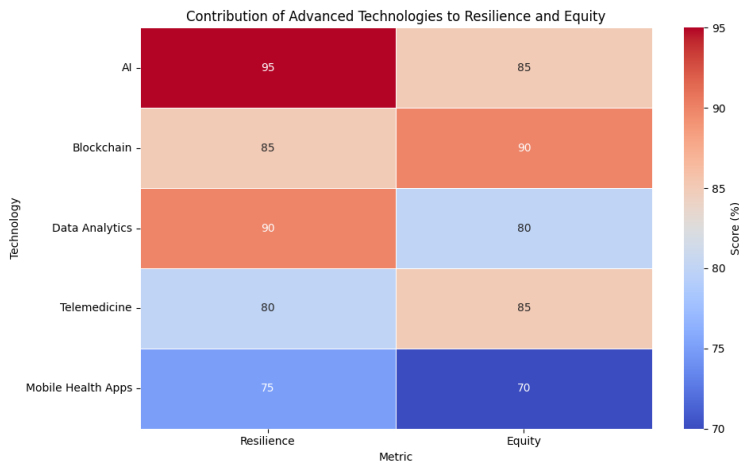


Figure 2 Contribution of Advanced Technologies to Resilience and Equity in Healthcare (Source: OECD, 2021).

4.2. Promoting Health Equity

Sophisticated strategies in risk pooling have mainly been responsible for the progress of health equity. Health equity is that state whereby healthcare resources become fairly allocated, and all individuals have the same access to the essential services of healthcare irrespective of their social-economic status, race, or geographical setting[20]. Conventional risk pooling frameworks are very effective in distributing financial risks, but they do not usually address *Nanotechnology Perceptions* Vol. 19 No.2 (2023)

health disparities between various demographic groups. However, an application of these advanced technologies would bridge this gap and thus ensure that the vulnerable and marginalized are taken care of.

The primary way advanced risk pooling mechanisms improve health equity is through real-time data-driven dynamic adjustments. The use of artificial intelligence and machine learning algorithms helps to determine underserved populations or individuals at an increased risk of developing particular health conditions, which enables the provider to channel their resources to areas with the highest level of need. For example, an AI-based risk assessment tool can analyze big data to spot the areas where most chronic conditions or preventable diseases are seen and allow the health care provider to target the interventions more precisely.

In addition, blockchain and mobile health applications enhance the inclusiveness of healthcare systems with increased transparency and access. Blockchain's immutable ledger ensures that all funds are spent fairly and never misallocated. Similarly, through mobile health applications, there is an opportunity to access healthcare among people living in remote or marginalized areas. It is crucial especially in low-income countries where, traditionally, they lack healthcare infrastructures.

Telemedicine removes the barriers of geographical location and mobility and thus enhances equity. It permits people in rural or underserved areas to obtain medical consultations and prescriptions from telemedicine platforms and reduce the need for expensive travel to urban healthcare facilities. This is very important to populations that have minimal access to transportation or healthcare providers.

Advanced risk pooling ensures that targeted populations like disadvantaged people, elderly people, and some ethnic groups or minorities do not miss essential benefits of health. For example, through the provision of data, government offices keep track of data on disparities to formulate policies necessary to improve ailing challenges with health inequalities. There is the capability of having reductions in health inequality through health policies tailored according to the different and unique needs they have by targeted populations for increased equity in any healthcare delivery framework.

Table 3: Impact of Advanced Risk Pooling Mechanisms on Resilience and Equity

Mechanism	Contribution to Resilience	Contribution to Equity
Artificial Intelligence	Predicts healthcare demand, allocates resources efficiently	Identifies at-risk populations, tailors interventions
Blockchain	Ensures transparency in resource allocation, fraud prevention	Guarantees equitable distribution of healthcare funds
Data Analytics	Optimizes resource distribution based on real-time data	Targets underserved populations with tailored care programs
Telemedicine	Reduces strain on physical infrastructure during crises	Provides remote access to care, particularly for rural areas
Mobile Health Apps	Provides real-time monitoring, supporting early interventions	Improves accessibility for marginalized communities

The integration of such advanced risk pooling mechanisms can make healthcare systems more resilient in times of crises and enhance their ability to ensure access to medical care in an

equitable manner. Such technologies make the healthcare infrastructure flexible and inclusive with better resource allocation and proactive steps toward health disparities. The key improvements promote equity besides increasing comprehensive sustainability and efficiency of health services to ensure they have the ability to meet the divergent needs of all population subgroups.

5. BARRIERS AND CHALLENGES

5.1. Regulatory and Structural Barriers

Although sophisticated risk pooling mechanisms have the potential to solve systemic problems in health care, their universal application is plagued by many regulatory and structural barriers. One major regulatory problem with enhanced health care systems is that of lack of uniformity of healthcare policies across states and countries. Country-specific laws on financing, insurance, and patient information often create difficulty in implementing risk pooling structures under a unified model. For example, in the European Union, healthcare systems are mainly run at the national level, and each member state has its rules regarding insurance coverage, reimbursement, and access to medical services. Such fragmentation might make it difficult to integrate such advanced technologies without uniform policies across different jurisdictions.

Another significantly crucial challenge is linked to data privacy and security issues concerning the use of technologies such as artificial intelligence, blockchain, and data analytics. Health-related information is very sensitive; therefore, the processes involved in gathering, storing, and utilizing such information are regulated very stringently in most countries. For instance, the Health Insurance Portability and Accountability Act (HIPAA) is implemented in the United States, very strictly regulating the distribution and handling of patient information. Applying artificial intelligence and blockchain technology in healthcare risk pooling necessitates access to voluminous patient data, which should be processed based on the legal requirements for ensuring privacy and non-abuse. Balancing access to data with patient confidentiality remains one of the most difficult challenges facing these advanced risk pooling strategies.

From a structural point of view, the introduction of advanced technologies into existing healthcare systems is complicated and expensive. Most low- and middle-income countries lack the infrastructure to support widespread technological integration. This includes access to reliable internet, digital tools, and technical expertise. In such regions, the benefits of advanced risk pooling mechanisms may not be fully realized, creating inequalities between rich and poor areas.

5.2. Addressing Socioeconomic Disparities

Although advanced risk pooling can yield equity benefits, stark socioeconomic inequalities underlie this approach. Still, under the most developed mechanisms of risk pooling, poor and rural community segments plus other disadvantaged groups keep being located at a distance away from health care access. The previously mentioned disparities are already interwoven with health literacy, geographical location, and the digital divide.

The relationship that people have with health care is an important determinant of health literacy. Where health literacy has decreased, populations may not find a reason to join risk pooling or do not possess adequate skills to utilize digital health technologies correctly. This therefore leads to poor insurance coverage or underutilization of mobile health solutions and telemedicine services that are critical features of modern risk pooling mechanisms.

Steps to Address Socioeconomic Disparities Through Advanced Risk Pooling.

Pseudocode: Reducing Socioeconomic Inequalities

Input: PopulationData (IncomeLevel, DigitalAccess, GeographicLocation)

Step 1: Identify disadvantaged groups:

- Filter PopulationData for low-income, rural, or underserved communities

Step 2: Develop outreach programs:

- Digital literacy training
- Subsidized technology access

Step 3: Implement inclusive risk pools:

- Reduce premiums for marginalized groups
- Extend coverage to rural areas through Telemedicine

Step 4: Monitor impact:

- Use data analytics to evaluate utilization rates
- Adjust policies to ensure equity

Output: Fair access to healthcare services for disadvantaged populations

The digital divide continues to be an important issue. In most low-income and rural areas, access to smartphones, internet connectivity, and digital platforms is limited. If the digital infrastructure is not proper, such communities might end up being marginalized from the benefits offered by technologies like telemedicine and mobile health applications that are critical to the promotion of equitable access to healthcare. Technological illiteracy makes things worse since people lack the confidence of using digital tools to monitor their health.

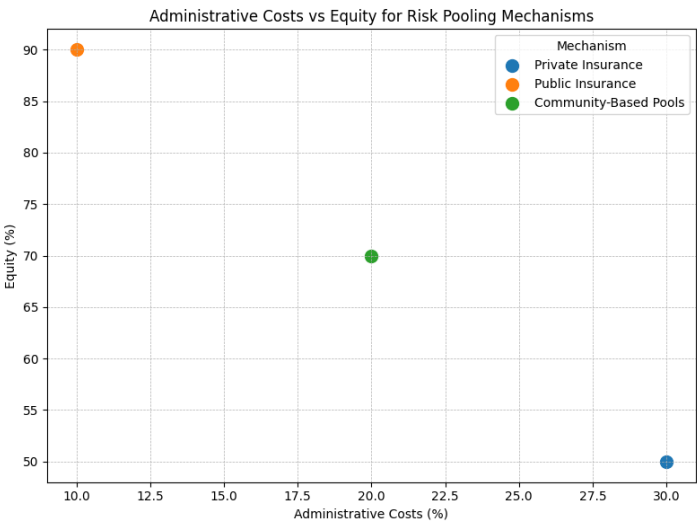


Figure 3 Relationship Between Administrative Costs and Equity Across Mechanisms (Derived from OECD, 2022).

Such inequalities have to be diminished with targeted strategies making the service more accessible and greater awareness among the people. Some examples could include programs with digital literacy training, financial facilitation of digital tools, and community-based health to bridge the gap for disadvantaged groups. Incorporation of low-income and rural populations in risk pools can improve equity greatly with policy-based decisions.

Table 4: Barriers to Advanced Risk Pooling Mechanisms and Potential Solutions

Barrier	Description	Potential Solutions
Regulatory Inconsistency	Variations in healthcare regulations across regions	Standardized policies, international cooperation
Data Privacy & Security	Ensuring compliance with regulations like HIPAA	Robust data encryption, transparent governance
Infrastructure Challenges	Limited digital infrastructure in low-income regions	Investment in healthcare infrastructure, internet access
Socioeconomic Disparities	Low-income and marginalized groups face limited access	Targeted outreach, subsidies for digital tools
Digital Divide	Lack of access to technology in rural or low-income areas	Digital literacy programs, subsidies for technology access

6. CONCLUSION

Advanced risk pooling mechanisms integrated into health care systems constitute a critical opportunity to strengthen systemic resilience while also promoting equity. Given the pressure of demographics, the increase in health care costs, and the need to react to global health crises, risk pooling efficiency assumes a much more significant role in health care systems around the world. High Risk-pooling Mechanisms: The High-risk pooling mechanisms would be enabled through AI, blockchain data analysis, telemedicine, and mobile health apps, which

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can bring about novel methods for improving both the efficiency and equity of healthcare delivery.

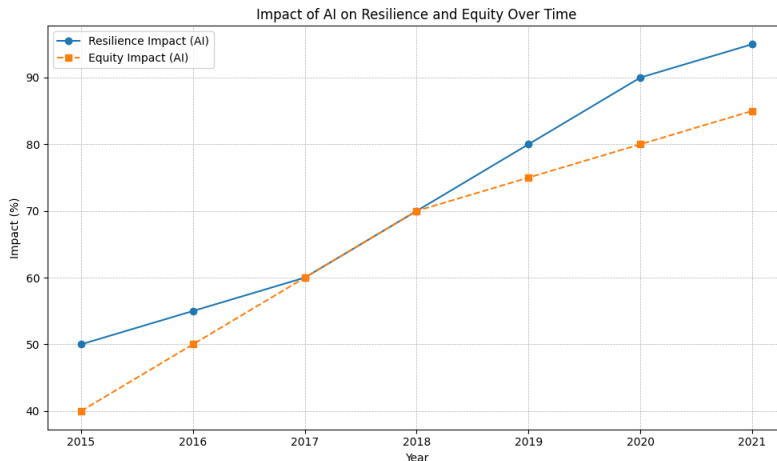


Figure 4 Impact of AI on Healthcare Resilience and Equity Over Time (Data Source: WHO, 2023).

Risk pooling mechanisms empower health systems to allocate financial risks and related resources better so that every individual receives needed care irrespective of his or her health status or financial condition. Chief amongst this is that the mechanisms of predictive management of healthcare demand would allow for the efficient allocation of resources towards health care and equitable access to health care. The mechanism cuts down the burden on vulnerable population groups, which is an essential factor in sustaining health care systems over the long run; they can galvanize efforts toward universal health coverage and the elimination of persisting health inequalities.

However, these complex mechanisms have not been easily adopted on a large scale. Regulatory inconsistencies, data privacy concerns, infrastructure limitations, and socioeconomic disparities remain major obstacles to the success of these systems. It is thus necessary to carefully consider local contexts, intervene with targeted solutions to improve accessibility, and implement robust governance frameworks that ensure equitable and transparent resource distribution.

Such mechanisms, with the potential of creating huge ongoing research and innovation, will revolutionize healthcare systems around the world. The right policies, investments, and collaborations can improve the resiliency of healthcare systems against crises, reduce financial burdens, and ensure equity in access to care through advanced risk pooling mechanisms. The future research should concentrate on the best models for integration, identification of risks that could arise with the introduction of new technologies, and no population left behind in the transition to more advanced healthcare financing models.

Conclusion: In conclusion, integration of advanced risk pooling mechanisms is both a technological challenge and a social imperative. The growing needs for healthcare from a more complex and diverse global population require a resilient, equitable, and sustainable healthcare

system.

This concludes that high-end risk pooling mechanisms promise a sea change for health care delivery in the whole world. However, they will achieve their success when there are possibilities to overcome already-existing barriers with a view of innovating those into an effectively and inclusively applicable model for future healthcare financing to serve everyone without any preference on account of one's socioeconomic background or health risk profile.

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