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The One Health (OH) Approach and the Sustainability of Healthcare Systems

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The One Health (OH) approach, based on the interdependence of animal, human, and environmental health, presents a fruitful framework for enhancing the economic sustainability of healthcare systems. At the same time, OH proposes a new epistemology of health, and reimagines it as an emerging attribute of complex adaptive systems, determined not only by disease-causing organisms or genes, but also by land cover, biodiversity, inequality, and interspecies relationships. In this paper, in addition to the OH evolving foundations as an epistemic paradigm, we discuss the ability of OH for meeting key global challenges such as emerging infectious diseases, antimicrobial resistance (AMR), and the burden of non-communicable diseases (NCDs) using integrated, intersectoral approaches. Leveraging case studies and tools of evaluation such as the Network for Evaluation of OH (NEOH), we evaluate the cost-effectiveness and preventive benefits of OH interventions. Drawing from evidence from programs implemented in Switzerland, England, Malta, and Serbia, we describe the capacity of OH in realizing public health savings, lessening healthcare burden, and improving system effectiveness. Despite its advantages, OH is still largely neglected in health economy modeling and policy integration. We evidence key gaps in the quantification of long-term financial benefits and harmonize OH approaches with healthcare financing policies and emphasize the need of more effective cross-sector governance, uniform metrics of evaluation, and fiscal frameworks inclusive of its preventive benefits of health policies. Integrating OH into healthcare systems can enhance resilience, maximize resource allocation, and enhance preparedness for future health emergencies—goals which are core for sustainable

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The One Health (OH) Approach and the Sustainability of Healthcare Systems

Authors
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Abstract

The One Health (OH) approach, based on the interdependence of animal, human, and environmental health, presents a fruitful framework for enhancing the economic sustainability of healthcare systems. At the same time, OH proposes a new epistemology of health, and reimagines it as an emerging attribute of complex adaptive systems, determined not only by disease-causing organisms or genes, but also by land cover, biodiversity, inequality, and interspecies relationships. In this paper, in addition to the OH evolving foundations as an epistemic paradigm, we discuss the ability of OH for meeting key global challenges such as emerging infectious diseases, antimicrobial resistance (AMR), and the burden of non-communicable diseases (NCDs) using integrated, intersectoral approaches. Leveraging case studies and tools of evaluation such as the Network for Evaluation of OH (NEOH), we evaluate the cost-effectiveness and preventive benefits of OH interventions. Drawing from evidence from programs implemented in Switzerland, England, Malta, and Serbia, we describe the capacity of OH in realizing public health savings, lessening healthcare burden, and improving system effectiveness. Despite its advantages, OH is still largely neglected in health economy modeling and policy integration. We evidence key gaps in the quantification of long-term financial benefits and harmonize OH approaches with healthcare financing policies and emphasize the need of more effective cross-sector governance, uniform metrics of evaluation, and fiscal frameworks inclusive of its preventive benefits of health policies. Integrating OH into healthcare systems can enhance resilience, maximize resource allocation, and enhance preparedness for future health emergencies—goals which are core for sustainable health economics and policy design.

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1 - Introduction

The global burden of infectious diseases has risen significantly in recent decades, driven by factors including zoonotic spillovers, antimicrobial resistance (AMR), climate change, deforestation, urbanization, and globalization (Brüssow (2023); Destoumieux-Garzón et Al. (2018); Elnaiem et Al. (2023); Mohamed and Wali (2023)). This rise is exemplified by major public health crises, such as the COVID-19 pandemic, which underscore the vulnerabilities of global healthcare systems to emerging and re-emerging infectious diseases (EIDs). These vulnerabilities are heightened by rapid, often uncoordinated, societal changes and environmental disruptions that foster the conditions for zoonotic spillovers and the spread of antimicrobial-resistant pathogens (Brüssow (2023); G-Science Academies (2022); Mohamed and Wali (2023)). At the same time, demographic transitions—including rapidly aging populations—and the increasing prevalence of non-communicable diseases (NCDs) such as diabetes, cardiovascular disease, and cancer, are dramatically altering the epidemiological and care landscapes in both high- and low-income contexts (Bygbjerg (2012); Goswami (2024)). The convergence of infectious disease threats, aging populations, and NCD burdens is creating unprecedented pressures on healthcare systems across the globe, necessitating an evaluation of integrated and sustainable strategies to address overlapping public health challenges.

The interplay between infectious diseases and NCDs is well-documented, particularly in low- and middle-income countries (LMICs). Chronic infectious diseases such as tuberculosis and HIV/AIDS amplify the risk or severity of NCDs, including diabetes and certain cancers, while NCDs themselves exacerbate susceptibility to infectious pathogens (Goswami (2024); Bygbjerg (2012)). This "double burden of disease" disproportionately affects LMICs, where healthcare systems are often unable to manage the demands of fragmented and competing vertical programs, leading to resource inefficiencies and undermining healthcare sustainability (Bygbjerg (2012)). Developed countries, while generally maintaining more resilient healthcare infrastructures, are also experiencing notable stress due to aging populations and increasing multimorbidity. For example, aging populations with prevalent NCDs, such as type 2 diabetes, are more susceptible to severe cases of respiratory infectious diseases like influenza and pneumonia, which in turn increase hospitalization demands and strain healthcare resources (Goswami (2024); Osakunor et Al. (2018)). Additionally, emerging infectious diseases like COVID-19 have disrupted routine healthcare services for chronic diseases in developed and developing countries alike, leading to long-term setbacks in NCD management and compounding health disparities (Goswami, 2024).

The OH framework provides a critical, interdisciplinary approach to managing these intersecting challenges by addressing the shared health risks across human, animal, and environmental domains (Brüssow (2023); Destoumieux-Garzón et Al. (2018); Heymann David et Al. (2017)). Specifically, OH emphasizes ecosystem health, pathogen surveillance, and zoonosis management at the human-animal interface, aiming to reduce risks such as zoonotic disease spillovers, deforestation, agricultural intensification, and climate change-related vector shifts (Destoumieux-Garzón et Al. (2018); Heymann David et Al. (2017); Mohamed and Wali (2023)). While its utility has been increasingly recognized in the context of infectious diseases and AMR, OH has yet to penetrate discussions of systemic, long-term healthcare challenges, such as aging populations, multimorbidity, and healthcare sustainability (Brüssow (2023); Destoumieux-Garzón et Al. (2018)). There is also a notable gap in the operationalization of OH strategies in high-resource settings, where its potential for pandemic preparedness, AMR management,

and integrated health solutions remains underutilized (Destoumieux-Garzón et Al. (2018); Goswami (2024)).

In developed countries, the epidemiological transition has shifted the focus of healthcare systems toward addressing chronic NCDs and aging-related concerns, turning infectious diseases into a secondary priority until major outbreaks (such as COVID-19) occur (Atella and Scandizzo, 2023). However, the interaction between acute infectious diseases and chronic conditions remains poorly understood and managed. For example, individuals with underlying cardiovascular disease or obesity often present elevated morbidity and mortality risks during seasonal influenza or emerging pandemics, as has been seen with COVID-19 (Bygbjerg (2012); Goswami (2024)). In addition, aging populations in financially capable countries often see fractures in their health systems' ability to meet the growing complexity of care, as multimorbidity from chronic conditions clashes with infections like sepsis or hospital-acquired infections that disproportionately affect the elderly (Bygbjerg (2012); Goswami (2024)). Incorporating OH principles into surveillance and diagnostic infrastructure, as well as aging-focused health delivery programs, may enable better preparedness and balanced resource allocation in these high-income settings (Bygbjerg, 2012).

The persistent fragmentation of healthcare delivery models continues to impede the effective response to overlapping disease burdens, as systems in both developed and developing countries struggle to integrate care for chronic and acute conditions. While vertical programs for infectious disease care, such as HIV-focused initiatives, have demonstrated effectiveness in addressing specific conditions, they often fail to address the syndemic interactions between infectious diseases and NCDs or other aging-related conditions (Brault, 2021). Comparisons between vertical and holistic program models for delivering healthcare show that more integrated approaches not only improve efficiency but also enhance long-term system resilience, particularly in resource-constrained environments. However, even in high-income settings, fragmented care and under-prepared public health systems have led to inefficiencies that significantly affect sustainability, particularly during times of crisis (Goswami, 2024).

This paper seeks to synthesize existing research on the intersections between the rising burden of infectious diseases, aging populations, the increasing prevalence of NCDs, and healthcare system sustainability, with particular emphasis on the role of OH frameworks. Previous studies provide strong evidence for the drivers of infectious disease emergence (Brüssow (2023); Destoumieux-Garzón et Al. (2018)), highlight the need for broader OH implementation (Destoumieux-Garzón et Al. (2018); Heymann David et Al. (2017)), and demonstrate the importance of integrated healthcare models in prioritizing chronic and acute care (Brault et Al. (2017); Bygbjerg (2012); Goswami (2024)). Yet, despite these insights, significant gaps remain in understanding how the conceptual underpinnings of OH can be operationalized in both high- and low-resource contexts to address the joint impacts of these interacting challenges.

In what follows, the paper is organized into six sections. Section 2 outlines the conceptual foundations of the One Health (OH) approach, examining its evolution, scope, and intersectoral rationale. Section 3 discusses the methodological framework, including the data sources and analytical strategies employed throughout the study. Section 4 presents the empirical findings, focusing on trends and disparities in health outcomes, service access, and public perceptions, with a particular emphasis on the Italian context. Section 5 explores the key policy and implementation challenges associated with operationalizing OH in Europe, including issues related to economic quantification, governance, and

alignment with EU sustainability strategies. Section 6 concludes with a synthesis of the main findings and policy recommendations, highlighting future research directions and the potential of OH to enhance systemic resilience and equity in healthcare.

2. The OH as an epistemic project

The concept of *One Health*—the recognition that human, animal, and environmental health are interconnected—has deep historical roots, but the term itself is relatively recent. Its intellectual foundations can be traced back to the 19th century, particularly to the German pathologist Rudolf Virchow, who famously asserted that "between animal and human medicine there are no dividing lines—nor should there be" (Schwabe, 1984). This integrative approach was later developed by veterinary epidemiologist Calvin Schwabe, who coined the term *"One Medicine"* in the 1960s, advocating for a unified approach to human and veterinary health.

The modern term OH began to gain traction in the early 2000s, particularly in response to emerging zoonotic diseases such as SARS, avian influenza, and Ebola. It was formally adopted in 2004 by the Wildlife Conservation Society (WCS) during a conference held in New York, where the "Manhattan Principles" were drafted—twelve recommendations calling for a holistic approach to preventing epidemic disease through interdisciplinary collaboration (WCS, 2004).[2]

Since then, the term has been institutionalized by major global health organizations. The World Health Organization (WHO), the World Organisation for Animal Health (WOAH), the Food and Agriculture Organization (FAO), and the United Nations Environment Programme (UNEP) have all endorsed the OH approach. In 2021, these organizations launched the *One Health High-Level Expert Panel (OHHLEP)* to develop a shared framework and define OH as "an integrated, unifying approach to balance and optimize the health of people, animals and ecosystems" (OHHLEP, 2022).

Today we define as OH approach a holistic and collaborative framework emphasizing the interconnectedness of human, animal, and environmental health. By addressing shared health threats such as zoonotic diseases, antimicrobial resistance (AMR), and environmental impacts, OH seeks to tackle health challenges that cannot be resolved by siloed interventions. Its application is particularly relevant in Europe, where cross-sectoral and cross-border collaboration is integral to tackling both local and systemic health risks. The increasing recognition of economic implications—such as the costs of inaction or the need for cost-effective interventions—has positioned OH as an essential method for achieving sustainable healthcare systems, particularly in the context of European Union (EU) policies and strategies. The OH approach is thus currently understood to be a holistic, interdisciplinary framework that captures the interrelated nature of human, animal, and environmental health. It confronts shared health hazards—such as zoonotic diseases, antimicrobial resistance (AMR), and environmental degradation—that leap across disciplinary and spatial boundaries and cannot effectively be addressed through silo-based interventions. Crucially, OH is interpreted not just as a policy tool or a

[2] In 2004, the Wildlife Conservation Society (WCS) brought together stakeholders to discuss global health challenges at the nexus of human, animal, and ecosystem health. The symposium "Building Interdisciplinary Bridges to Health in a Globalized World" at The Rockefeller University gave birth to 12 recommendations for establishing a more holistic approach to preventing epidemic / epizootic disease and for maintaining ecosystem integrity for the benefit of humans, their domesticated animals, and the foundational biodiversity, which since then went under the name of the "Manhattan Principles" (http://www.oneworldonehealth.org/sept2004/owoh_sept04.html). These detailed a collaborative, trans-disciplinary approach, coined 'One World - One Health', or simply 'One Health'.

technical framework, but a complex property that emerges from dynamic relationships and interdependency between biological, ecological, and societal networks, just like consciousness or ecosystem resilience. It is not a top-down imposed model in this vision, but a coordination and integration pattern of multiple sectors and stakeholders working toward a shared vision of well-being.

This frame of reference is especially pertinent to the European environment, where health management is increasingly depending on cross-border and cross-sectoral partnership to deal with local and system-level hazards. The realization of the cost of not acting—e.g., the cost of outbreaks or the untenable weight of disjointed healthcare interventions— has further boosted OH's status as a strategic instrument. Consequently, OH is not just crucial to enhance public and planetary health but also to enhance the resilience and sustainability of health systems, in accordance with overall European Union (EU) policies on sustainability, biosecurity, and health equity.

In sum, the OH framework has grown beyond being an intersectoral strategy between human, animal, and environmental health fields; it now reflects deeply an epistemological change in the very conception of health itself. This strategy is based on the realization that the health of any single component—human, animal, or environmental—cannot be properly addressed independently, but needs to be understood in the broader context of systemic interdependence and relationality.

The concept of a natural balance often invoked in discussions of OH may, on closer inspection, be a problematic simplification. While the image of an ideal equilibrium across human, animal, and environmental domains is rhetorically powerful, it risks promoting a form of undifferentiated holism that obscures the nuanced, layered interdependencies that characterize real-world health systems. Such a notion may inadvertently flatten the complex and often asymmetrical relationships that structure these systems, where factors like biodiversity loss, zoonotic disease spillovers, and social inequalities intersect in dynamic and context-specific ways. Rather than envisioning health as the attainment of a static biological equilibrium, it is more accurate—and more useful—to understand it as a state of integrative co-functioning, where various systems sustain each other through flexible, resilient, and adaptive interactions.

By emphasizing that human, animal, and environmental health are intimately linked, the OH notion naturally focuses on multidisciplinary collaboration and shared resources to mitigate threats. Examples of key focus areas include:

- Zoonotic Diseases: Diseases passed from animals to humans, such as Q fever and brucellosis, account for substantial societal and financial burdens. Preventative measures under OH, such as livestock vaccination or environmental controls, often have significant cost-savings compared to reactive human health interventions (Babo Martins, Rushton & Stärk (2017); Buttigieg, Savic and Aragrande (2018)).
- Antimicrobial Resistance (AMR): AMR is one of the most pressing global health threats. Integrated surveillance systems, as advocated by OH, combine data from human healthcare, veterinary medicine, and environmental monitoring to optimize the use of limited resources and provide shared benefits (Bennani et Al. (2021); Bronzwaer et Al. (2021)).
- Environmental and Climate Drivers: Changes to ecosystems, such as deforestation, farming practices, or climate change, exacerbate zoonotic risks and drive healthcare costs. The OH

strategies integrate these ecological factors into health planning (Mazzeo et Al. (2022); Bronzwaer et Al. (2021)).

In such an understanding, health comes not just in the form of the absence of disease, but as an expression of balance in an intricate system of living systems, each having the potential to impact and be influenced by the other.

More recent work formalizes this shift in emphasis by stating that applying the OH notion necessitates more than seeing the connections between things, and needs an acknowledgment of real interdependence, in which the health of each component depends on the integrity and health of the whole. Beever and Morar (2018) distinguish critically here, asserting that interconnection—simply relational adjacency—is inappropriately confounded with interdependence, implying mutual need and co-determination. Unless we recognize the distinction, OH will be notionally ambiguous or ethically incoherent, above all when dealing with multifaceted real-world issues (Beever & Morar, 2018).

The COVID-19 pandemic provided stark proof of such interdependence, exposing how anthropogenic disruption of ecosystems—through deforestation, wildlife trade, and urban encroachment—can instigate zoonotic spillovers, revealing the shortfalls of narrowly human-centered health systems. Goel et al. (2021) contend that the pandemic showed the shortfalls of traditional, mechanism-based health models based in Enlightenment-era academic silos. They support the application of a "relational paradigm," in which health is not viewed as an isolated biological state, but rather as an emergent state produced through dynamic interplay between organisms and environments. Such a paradigm necessitates transdisciplinary education and epistemological humility, given that traditional educational institutions tend to replicate constituencies for fragmented, reductionistic forms of knowledge poorly suited for responding to complex global health challenges (Goel et al., 2021).

Here, the OH approach supports an integrative conception of health as dynamic equilibrium, able to resist and accommodate endogenous and exogenous shocks. Resilience is an integral property of this integrative conception of health, in which the interplay among the different areas enables systems to resist stress and reorganize while retaining their core function. Such systemic resilience is then in stark contrast with linear, monocausal approaches to health, such as those not well adapted to the fluid and multifaceted nature of modern threats such as climate change, antimicrobial resistance, or food insecurity. In addition, OH encourages us to understand the dialectical relationship between nature and nurture as anything but an opposing binary, but rather an ongoing negotiation—a process in which health is the ability to be affected, to be able to be harmed, and then recover and change. This conception has appeal in the argument presented in Agarwal (2024) for the incorporation of whole person healthcare into an ecocentric framework explicitly attuned to the embedment of individuals in socio-environmental systems. Agarwal pushes for health as a universal planetary value, with the belief that well-being arises out of ecologically aware, justice-oriented interactions rather than discretely medicalized intervention (Agarwal, 2024).

The vision has specific ramifications in indigenous health paradigms, such as those detailed by Hueffer et al. (2019) in the Circumpolar North. Indigenous societies have traditionally approached health from holistic perspectives that echo OH paradigms, in their stress on relationality, communal resilience, and the sacredness of balance in ecosystems. Such traditions yield rich epistemological resources for the

building of more inclusive and adaptive paradigms for health, for example, as climate uncertainty and environmental deterioration amplify health inequities (Hueffer et al., 2019).

Then, Romizi et al. (2024) propose the next direction for OH is to further incorporate it into the larger "Planetary Health" approach, centered on ecological justice and sustainability. They believe to realize the potential for the paradigm, health professionals and decision-makers need to support interdisciplinary approaches, systemic transformation, and environmental stewardship. For them, well-being is inextricably linked with the integrity of the biosphere—a norm that should be the foundation for both public health as well as policy in the Anthropocene (Romizi et al., 2024). Together, these views reinforce the fact that the OH approach is not merely a science, or policy advance, but rather an epistemological shift—a new manner of thinking about life, about health, and about the shared, interdependent destiny of all living things.

In conclusion, the OH concept has gradually developed into a comprehensive epistemic and ethical framework for conceptualizing health beyond the confines of individual species. It frames health as a holistic, integrated system encompassing humans, animals, and the environment. Within this expanded paradigm, health is increasingly understood through two principal frameworks: firstly, as an anti-rival universal good that benefits all parties, and secondly, as an intrinsic component of a natural web of interconnected life forms. More broadly, health—understood as a state of interdependent well-being among humans, animals, and the natural world—can be regarded as a global common good. It is characterized by its non-rivalrous and non-exclusionary nature, relying on inclusive comprehensiveness and collective responsibility for its maintenance. Extending this perspective further, OH invokes the notion of a planetary commons: a shared ecological and ethical space where living and non-living entities exist in a dynamic state of interdependence, at times harmonious and at others in tension. Effective stewardship of this commons requires vigilant attention to the complex interdependencies involved and the universal values at stake, alongside morally informed behavioral, institutional, and policy approaches that can uphold both equity and ecological integrity.

2.1. Health as a social merit good

Health isa public good of anti-rival nature, i.e., a good whose use, access, or improvement of a health resource by one individual or group enhances, rather than reduces, its value or benefit for others. Thus, it can also be conceptualized as a social merit good that benefits society at large, is not reduced by greater inclusion, and indeed gets stronger with greater access and collective consumption.[3] Like other public goods of merit such as culture and trust, the value of health is not created by individual fruition alone, but by the web of direct and indirect relationships among members of a community.

In this context, a living being is not an isolated recipient of health but rather a constituent of a system in which the health of each individual is intricately intertwined with that of others. To fulfill a range of different and heterogeneous requirements, a subject is thus induced to conceive health in ways that are compatible and synergistic and see that his own health requirements are not separate from those of others. This results in a collective perception of a single condition of need and a realization that health is a shared concern. Consequently, health is not simply enjoyed by the individual, but is collectively

[3] A merit good is a product or service that is considered socially desirable by the government, and which tends to be under-consumed if left to the private market because individuals may underestimate its personal or social benefits (Mankiw, 2021). Examples include education, healthcare, and vaccinations. Governments often support merit goods through subsidies or direct provision to ensure broader access and consumption.

produced through intersubjectivity, where everyone identifies and attends to the others' needs within a shared system. The resultant mutuality of recognition of collective health needs produces a communion of concern based in the direct, system-based interdependence of the participants. It is through this connectedness that health becomes a social good of public and moral concern.

Within the OH context, health is not excludable and "anti-rival" in essential areas: disease control, ecosystem homeostasis, and antibiotic efficacy are best when supported by the greatest possible participation. Consequently, as Capps and Lederman (2014) persuasively argue, the paradigm of the OH requires that we reconceptualize biobanking and other public health assets not simply in public goods terms as a benefit to humans, but as "universal goods" that are of benefit to human, animal, and environmental stakeholders equally.

Alog similar lines, Degeling et al. (2016) stress that OH recasts the very idea of "health" itself: no longer a commodity that is controlled within species lines, but a value shared across multiple life realms and optimized through interspecies alliances and ethical deliberation that bridges life domains. That conception is most receptive to the general policy imperatives of universal health coverage, particularly in resource-poor countries, where legal and moral architecture that posits health as a universal right is increasingly required to stem mortality and enhance overall well-being globally (Ngwaba, 2019).

2.2. Health as a natural network among living things

As an epistemic project, the OH approach provides a new perspective by problematizing the anthropocentric and mechanistic conception of health through its network characteristics. From this point of view, OH proposes to go beyond the concept of health as a bounded entity confined to a single organism or species, to consider it a much more general, emerging property of the network of relations across biological, ecological, and social systems. Goel, Barbosa Mendes, and Snick (2021) illustrate this concept by addressing systemic health abnormalities like zoonotic pandemics, which occur through breakdowns of some of these interconnections. They advocate a relational paradigm that goes across disciplinary siloes and entails novel transdisciplinary education, research, and policy-making that acknowledges health to be a byproduct of intricate relations.

More generally, and even beyond its network characteristics, this perspective suggests that health can be characterized as an emergent property of complex systems of life that result not from any organ, gene, or environmental factor but from the dynamic interaction of biological, psychological, social, and ecological subsystems. Like consciousness, health resists reduction to simple, linear models and cannot be comprehended by isolating its elements. Instead, it results from the integration and coordination of multiple levels of activity within and between systems. In living organisms, therefore, health is not mere absence of disease or malfunction, but a condition of adaptive coherence—the organism's capacity to preserve internal stability (homeostasis) yet adjust flexibly to environmental change (allostasis). On a larger scale of organization, including communities or ecosystems, health likewise represents the system's ability to achieve resilience, regulate itself, and co-evolve relative to context.

This system's perspective reflects how consciousness is now conceptualized in neuroscience—that is, not a feature of any brain area or neuronal activity pattern, but a global integration of information within distributed systems. As consciousness "arises" when brain activity gets synchronized to give rise to integrated awareness, health arises when physiology, behavior, social circumstances, and environment come into harmony with one another in mutually supporting ways.

Both consciousness and health therefore exhibit central characteristics of emergent phenomena:

- Non-linearity: Small changes in a part of the system may have large, unforeseen effects elsewhere.
- Context-dependent influence: The value and meaning of elements (e.g., stress, inflammation) are a function of where they fit within the system.
- Self-organization: Patterns of order (such as immune regulation or psychological well-being) can emerge spontaneously out of complex interactions.
- Multi-scale dynamics: They occur across scales—from cells and organs to social systems and ecosystems.

According to this perspective, health is not just the aggregate of what can be measured (e.g., laboratory results or symptoms), but a qualitative, emergent description of system integrity. A person's or group's health reflects how intact the system is, how it adapts to stress, and how it maintains purposeful function over time.

This view is corroborated by recent discourse around planetary health, in the Gaia tradition, which makes a case for the application of ecosystemic thinking to conceptualize how some fruits of human behaviors like deforestation, industrial agriculture, and urban development destabilize natural health networks and initiate global crises.[4] These disturbances influence microbial ecologies, species habitats, and even climate cycles—and end up as powerful components of human health impacts. The OH model does not just pursue balance in a static sense, but embodies resilience through networked stability, where each node in the network supports and is supported by others.

The OH notion, viewed through the multifaceted prism of health as a public merit good, a network form of interdependence, and an emergent property of nature, thus presents a powerfully integrative epistemic view of life. It resists reductionism in favor of inclusive, ethically sound, and ecologically sensitive solutions that can inform policy and practice. By reformulating the very notion of health as a form of collective strength to be nurtured through stewardship and systems thinking, the OH paradigm brings us to a more just and sustainable concept of wellness.

On the practical side, and as a policy program that goes beyond pure epistemics, by assuming that human, environmental, and animal health are inherently connected, OH requires multi-disciplinary and multi-geographical co-governance. With increasing globalization, growth dynamics and preferential attachment influence how health may develop its complex structure as a merit social good and a network system.

With the expanding perception of connected health hazards fueled by zoonotic pandemics like COVID-19, antimicrobial resistance, and climate-related health shocks, fresh nodes in the OH defined health and health care networks emerge continuously. These could range from local public health organizations to wildlife disease surveillance units, indigenous systems of knowledge, NGOs, biotechnology companies, and policy institutions that are transnational. These entry nodes are incentivized by the allure that an OH system of health care would display as a deliverer of global public goods: disease avoidance, ecological resilience, and public confidence in science.

[4] We refer to the Gaia hypothesis, originally proposed by James Lovelock in the 1970s, which conceptualizes Earth as a self-regulating, complex system where living organisms interact with their inorganic surroundings to maintain conditions conducive to life.

This trajectory of development aligns with the observations of Goel et al. (2021), who characterize the OH framework as an epistemic space that attracts diverse stakeholders due to its comprehensive foundations and its tangible integrative potential. As the network expands, new actors are drawn to established, highly connected institutions such as the WHO, FAO, WOAH (formerly OIE), leading research centers, and funding bodies like the Gates Foundation and the World Bank. These central nodes possess institutional legitimacy, extensive knowledge capital, and significant financial resources, resulting in a hierarchical network structure. Within this structure, a minority of influential actors shape the framing of norms, research priorities, and funding allocations, while peripheral nodes tend to remain dependent or marginal.

According to Capps and Lederman (2014), current health governance systems cannot effectively serve the interests of humans, non-human species, and the environment in an equitable manner without deliberate restructuring around the principle of universal goods. In practice, node centrality produces a structural imbalance, concentrating influence unevenly in accordance with the power-law distribution described by network theory. Therefore, while OH promotes interdependence and collaboration, the prevailing network architecture of health governance and healthcare systems remains predominantly hierarchical and fragmented. Leadership tends to be unevenly distributed, exacerbating inequalities across the network. Dominant hubs—such as major global research collaborations or funding organizations—control agenda-setting, while smaller or local actors are often confined to roles as data providers or implementers.

This echoes similar critiques of global health governance, including those of Degeling et al. (2016), who contend that a true OH strategy must have ethical frameworks that are sensitive to and correct these imbalances. OH, embedding in globalization's network logic thus must anticipate a system that is more fluid and less predictable than earlier models of global health development. Instead of a single central system (e.g., WHO-based), the OH network must be polycentric, with multiple points of innovation, surveillance, and intervention—but bound together by several highly connected nodes. This implies, inter alia, multipolar development, with knowledge and interventions no longer originating from the Global North but also from regional nodes in Asia, Latin America, and Africa. Like global commerce among intermediate products, global health must also entail global flows of knowledge, samples, protocols, and personnel that produce distributed value chains of surveillance and response. Finally, locally based systems of health knowledges (e.g., indigenous ecological knowledges) must be incorporated into global systems by prevailing protocols of science and realize and represent a new form of epistemic exchange.

2.3. The OH Framework and the Exposome: An Integrated Systems Approach

While the OH approach offers a broad and systemic framework for understanding health as shaped by interspecies and ecosystem interactions, it frequently lacks the methodological tools necessary to comprehensively capture the full spectrum of environmental exposures experienced by individuals over time. This limitation arises from its traditional emphasis on population-level determinants and ecological interactions, rather than on the continuous, cumulative, and individualized exposures—such as chemical pollutants, dietary factors, psychosocial stressors, and lifestyle behaviors—that critically influence health trajectories throughout the human lifespan. Recently, this gap has been partially addressed by the Exposome framework, which provides a comprehensive methodology for measuring

and analyzing lifelong individual exposures, making it a natural and necessary complement to the OH perspective.

In 2005, Christopher Wild coined the term "exposome" as the result of cumulative environmental exposures over the course of life from the prenatal period onwards. Since then, this definition has been extended and refined by enumerating the constituent components of the exposome and suggesting metrics and measurement methodologies. In general terms, the exposome is an attempt to define in a more meaningful and documentative way the environmental variable in the equation phenotype = genotype + environment. It is semantically characterized by a parallelism with the genome and has been interpreted as an index of "nurture", as opposed to the genome as an index of "nature". The concept captures the essence of a person's formation, as the sum and integration of external forces that act on our genome throughout our lifespan. The exposome recalls the notion of human capital, a somewhat ambiguous term, which however can be interpreted as the embodiment of the genome and the exposome, both interacting to produce the unique quality of a life.

The idea behind the exposome is germane to the OH paradigm in more than one way. First, it captures the key notion of space-time interdependence, in that it considers that the state of health of an organism, and in general its physiognomy at any one time, reflect the cumulative effect of its historical exposure to a variety of events. Second, this is not only true for human beings, but for all living organisms, such as individuals (animals and plants) and as collective clusters, such as cities, farms and other aggregates whose exposome is the recapitulation of the organisms' history through the traces left by their interaction with their environment. Third, both individual and collective exposomes mirror ecological, social, and historic factors that create systemic vulnerabilities and resilience. Individuals as much as cities, farms, and institutions are metabolic organisms, each embodying a built-up history of exposures. This allows for systemic risk appraisal and holistic health planning across human, animal, and environmental levels. Through tracking and reconfiguring aggregate exposomes, we can design improved, health-supportive environments.

Integrating the OH network interpretation to exposomic theory gives us a compelling systems-level explanation of how health inequalities and environmental exposures are built into structural arrangements of global health networks. The exposome, as a record of long-term exposures to the environment, shows how structural inequities (e.g., pollution, infrastructure deficiencies, green space limitations, and occupational exposures) are unequally distributed geographically and by populations. When we look beyond just considering OH as a health paradigm, but rather as an evolving global network based upon preferential attachment, we can observe that it reflects much of the same inequitable drivers of exposomic burdens.

While global networks centralize power and visibility in dominant nodes (e.g., wealthy institutions, wealthier countries), burdens of exposure also centralize historically disadvantaged regions and communities—inflating biological inequality via the environment. The OH network's susceptibility to centralization thereby reflects the susceptibility of bodies and ecosystems to imbalanced exposures.

In sum, as a science and justice framework, the exposome can be interpreted as an integral part of the OH's paradigm as an equitable and ecologically consistent health system. This interpretation has important practical implications and involves, inter alia, *i)* promoting epistemic justice by recognizing diverse methods of knowledge acquisition, including local knowledge systems and experiential

understanding of the environment; *ii)* decentralizing agenda-setting such that exposure science and interventions based on OH are responsive to local exposure conditions and not just dominant institutions' priorities; *iii)* making investments in local systems to minimize structural disparities of exposures and to ensure that all global network nodes, not just central ones, are enabled to actively contribute to and benefit from OH knowledge and policy.

Within such an integrated conception, the exposome is both an indicator of environmental health risk and a diagnostic index of systemic injustice within the global architecture of OH. It measures the extent to which a genuinely resilient, equitable, and life-sustaining commons can be created by reorganizing both systems of exposure and knowledge systems.

3 The role of institutions in supporting and adopting the OH approach

The OH approach, by emphasizing the interconnectedness between human, animal, and environmental health, provides a critical framework for addressing complex health challenges. In Europe, healthcare systems face mounting pressures from pandemics, AMR-related burdens, and the effects of climate change, which have spurred interest in the OH framework to enhance resilience and sustainability. A crucial dimension of this relationship is the economic and financial impact of OH initiatives, as cost-effectiveness assessments, resource allocation decisions, and evaluations of financial risks shape the implementation and scalability of OH interventions. However, while OH has demonstrated potential in generating cost savings and improving outcomes through integrated approaches, there remains a limited understanding of how it directly supports the sustainability of European healthcare systems, particularly in economic terms.

The economic value of the OH approach has been explored across several domains, including disease prevention, integrated AMR surveillance, and zoonotic outbreak control. Multiple studies discuss the significant cost savings generated by preventive OH strategies compared to reactive, single-sector interventions. For instance, evaluations of zoonotic disease surveillance programs, such as Campylobacter monitoring in Switzerland, showcase that integrating human and animal health data results in more effective risk assessment, knowledge gains, and public health cost savings, albeit at higher surveillance operational costs (Babo Martins, Rushton & Stärk, 2017). Similarly, discussions of AMR monitoring, such as integrated surveillance efforts in England, find that OH frameworks improve operational efficiency and justify resource allocation through better use of cross-sectoral data while demonstrating cost-effectiveness in terms of outcomes (Bennani et Al., 2021). Moreover, global models estimating the return on investments for OH demonstrate financial benefits, such as the $6 billion annual savings projected from improved outbreak responses or the $30 billion saved by avoiding pandemics through preventive actions (Grace (2014), Machalaba et Al. (2017)). However, while these examples reflect the promise of applying OH principles, their geographic focus often lies outside Europe, or is limited to specific countries, leaving broader implications for European healthcare systems and regional sustainability unexamined.

One major contribution to evaluating OH impact comes from the standardization of methodologies, most notably through the "Network for Evaluation of One Health" (NEOH). This evaluation framework offers a systems theory-based approach, enabling the standardized assessment of OH initiatives through methods like semi-quantitative scoring (e.g., "OH-index" and "OH-ratio") and criteria-based evaluations (Haxton and Rivière-Cinnamond (2015); Rüegg et Al. (2018)). These tools

facilitate comparisons across sectors—such as healthcare, veterinary medicine, and agriculture—by quantifying the added value of OH interventions. The NEOH framework has been widely applied, contributing to the understanding of resource allocation, cost-effectiveness, and cross-sectoral benefits of OH programs in specific contexts. For example, using OH principles, the evaluation of brucellosis control in Malta and Serbia highlights opportunities to integrate prevention strategies to reduce costs (Buttigieg, Savic and Aragrande, 2018). While NEOH provides valuable insights into OH implementation, its outputs often do not address the long-term financial viability of integrated approaches within the scope of broader healthcare system sustainability. The methodologies tend to focus on project-level assessments and multisectoral benefits rather than responses to systemic challenges in European healthcare, such as addressing regional inequities or creating durable funding mechanisms for scalable OH interventions.

The alignment of OH strategies with European Union (EU) policies represents another critical dimension of its implementation. Several studies connect OH approaches with the frameworks of the Farm-to-Fork strategy, the EU AMR Action Plan, and the European Green Deal. These synergies illustrate the potential for OH to simultaneously address public health, food safety, and sustainability objectives within a shared policy context (Bronzwaer et Al. (2021); Mazzeo et Al. (2022); Taylor et Al. (2024)). For instance, integrated zoonoses management and food safety programs addressing EU Green Deal goals achieve dual benefits: reducing agricultural emissions while improving public health outcomes (Mazzeo et Al., 2022). Similarly, AMR control strategies under OH principles promote collaboration across agriculture, human health, and environmental sectors, as demonstrated in the European Joint Actions program and other EU-funded projects (Bronzwaer et Al. (2021); Jestin et Al. (2021)). However, much of the literature remains conceptual or descriptive, discussing policy alignment without extensively using economic modeling or financial assessments to justify the integration of OH into healthcare sustainability strategies (Bronzwaer et Al. (2021); Mazzeo et Al. (2022)). Although programs like the OH European Joint Programme have bolstered harmonization of laboratory methods and integrative surveillance initiatives, they fall short of linking these outcomes directly to financial sustainability at the healthcare system level (Taylor et Al., 2024).

Case studies from within Europe further reinforce the potential—but also the limitations—of OH's economic applications. For example, AMR surveillance in England (Bennani et Al., 2021) and zoonotic surveillance of Campylobacter in Switzerland (Babo Martins, Rushton & Stärk, 2017) offer valuable evidence for the economic justification of surveillance programs. However, these evaluations often occur within isolated, disease-specific settings, and their findings are not always extrapolated to the broader context of healthcare systems or regional strategies across Europe. Similarly, studies exploring brucellosis control in Malta and Serbia or broader zoonotic disease control in EU-funded projects highlight the importance of adopting OH at a disease-prevention level, while acknowledging gaps in scalability or accessibility for resource-limited healthcare systems within the region (Buttigieg, Savic and Aragrande (2018); Jestin et Al. (2021)).

An overarching challenge for the field thus far remains the effective quantification of OH's long-term and indirect benefits. Several studies emphasize the difficulty of assigning monetary values to broader outcomes such as resilience, improved risk mitigation, and ecosystem health. For example, while OH surveillance programs yield significant intangible gains, such as enhanced risk knowledge or reduced system fragility to future health threats, these benefits are often incompletely incorporated into

cost-benefit assessments (Babo Martins, Rushton & Stärk (2017); Buttigieg, Savic and Aragrande (2018)). Additionally, addressing disparities between wealthier and lower-resourced regions in Europe poses a critical obstacle to scaling OH initiatives equitably. Without robust financial assessments that account for regional socioeconomic differences, scaling OH solutions across Member States may result in uneven healthcare system sustainability outcomes (Mazzeo et Al., 2022).

Overall, while the OH approach has generated strong conceptual and evidence-based foundations for advancing multi-sectoral health strategies, its application to ensuring the economic sustainability of healthcare systems is nascent. Limited Europe-specific financial models explicitly connect OH initiatives to long-term healthcare system outcomes, and much of the current research relies on disease-specific or policy-oriented discussions without directly assessing integration into entire system frameworks. Intangible benefits like system resilience to health crises or reduced disease burden are noted as critical advantages of OH, yet robust methodologies for monetizing such benefits remain lacking. To advance the field, future research should prioritize comprehensive economic and financial assessments of OH that explicitly link integrated interventions with long-term sustainability metrics for European healthcare systems.

4. The Role of OH in Supporting the Economic and Financial Sustainability of Healthcare Systems

The OH approach offers a critical framework to support the economic and financial sustainability of healthcare systems by addressing root causes of health challenges, promoting preventive strategies, and fostering cross-sectoral collaboration that optimizes resource use. Healthcare systems in Europe face rising costs and systemic vulnerabilities due to emerging zoonotic diseases, antimicrobial resistance (AMR), pandemics, and climate-related health crises. OH's integrated focus on human, animal, and environmental health not only enables a more holistic response to these challenges but also creates economic opportunities by improving cost-effectiveness, reducing the financial risks of inaction, and supporting sustainable resource allocation.

4.1 Cost-Effectiveness and Public Health Savings

Preventive policies under OH frameworks have consistently been shown to offer significant cost savings compared to reactive approaches. One of the key economic arguments in favor of OH is that investments in prevention at the source, particularly in animal and environmental health sectors, result in a disproportionately larger reduction in healthcare costs down the line. For example, zoonotic disease control programs that implement preventive interventions, such as livestock vaccinations and hygienic farm practices, reduce the risks of spillover to human populations, thereby limiting the costs of managing zoonotic outbreaks in healthcare systems. Studies such as the evaluation of Campylobacter surveillance in Switzerland highlight these dynamics, finding that integrated OH approaches—while requiring higher up-front investment in surveillance and data sharing—result in more effective risk assessments and better mitigation strategies than siloed interventions, ultimately benefiting both public health and long-term financial sustainability (Babo Martins, Rushton & Stärk, 2017).

Additionally, reducing the prevalence of zoonoses and AMR under OH frameworks help alleviate a significant economic burden on healthcare systems. In Europe, AMR alone costs an estimated €1.5 billion annually in healthcare expenses and productivity losses. The OH interventions such as antibiotic

stewardship programs in human, veterinary, and agricultural settings not only reduce the spread of AMR but also improve the cost-efficiency of healthcare by limiting the use of expensive, last-line antibiotics and preventing extended hospital stays due to resistant infections (Taylor et Al., 2024). Cost-benefit analyses of specific programs further underscore the advantages of aligning animal and human health strategies; for instance, brucellosis vaccination programs in livestock not only protect animal health but also reduce costly healthcare interventions for humans exposed to the disease, as seen in Malta and Serbia (Buttigieg, Savic and Aragrande, 2018).

In the context of large-scale public health crises, OH approaches can prevent outbreaks that cause significant economic disruption. Global economic models cited in OH literature estimate that a $25 billion investment in OH initiatives over a decade could yield approximately $125 billion in benefits by preventing zoonotic pandemics, such as those caused by SARS, Q fever, or Ebola (Grace (2014); Machalaba et Al. (2017)). In Europe, this macroeconomic principle can be applied to develop targeted, regionally focused prevention efforts, potentially averting the economic losses experienced during recent crises like the COVID-19 pandemic.

4.2. Mitigating Financial Risks of Inaction

The OH interventions also serve as a buffer against financial threats and systemic instability generated from lack of action with respect to health problems, resulting from lack of knowledge and the increasing complexity of health causes and effects. Escalating healthcare costs as well as serious economic loss stem from zoonotic outbreaks, antimicrobial resistance, and environmental degradation in the absence of coordinated, preventive measures. Direct healthcare spending as well as indirect productivity loss, loss in trade, loss in tourism, loss in agricultural production, are some economic implications of zoonotic outbreaks. Zoonotic crises, for example, can cause billions of euros in terms of loss in GDP if left unchecked, in addition to requiring emergency injections into healthcare systems not adequately equipped to meet the spikes in demand.

The OH framework offers financial advantages by shifting from reactive, short-term responses—which are often more expensive—to preventive, long-term solutions that create economic stability. For example, managed zoonotic disease outbreaks have been shown to cost significantly less than uncontrolled ones. In the case of the Netherlands' Q fever epidemic, late human health responses created far greater healthcare costs than if livestock vaccination and control measures had been initiated earlier (Machalaba et Al. (2017); Mazzeo et Al. (2022)). The OH strategies focused on reducing deforestation, urbanization of animal habitats, and intensification of livestock farming also have economic benefits that go beyond healthcare savings by reducing environmental damages and enhancing ecosystem resilience.

In the context of AMR, continued inaction could result in staggering costs to healthcare systems. If AMR rates are left unchecked, projections indicate healthcare systems will face exponentially rising costs from failing antibiotics, with an estimated reduction of €2.5 trillion in global GDP by 2050. The implementation of integrated surveillance and antibiotic stewardship across health, agricultural, and environmental sectors under OH principles mitigate this financial risk by reducing the likelihood of resistant strains emerging and spreading (Bronzwaer et Al. (2021); Jestin et Al. (2021); Mazzeo et Al. (2022)). For European healthcare systems, the proactive implementation of OH measures ensures that resources are targeted at reducing long-term financial burdens, preventing excessive reliance on emergency response funding when systems are overwhelmed.

4.3. Optimizing Resource Allocation and System Resilience

The OH approach inherently supports more efficient and equitable resource allocation across sectors, which is vital for maintaining sustainable and resilient healthcare systems. By coordinating efforts across human, animal, and environmental health domains, OH prevents resource duplication while allowing investments in one sector to generate shared economic benefits across others. For instance, integrated surveillance of antimicrobial usage (AMU) and resistance (AMR)—such as the system implemented in England—illustrates how combining data from human healthcare, veterinary medicine, and agricultural settings improves decision-making, increases cost-efficiency, and enhances operational efficiency for all sectors involved (Bennani et Al., 2021). The pooling of resources across traditionally siloed disciplines maximizes returns on investments and reduces the financial inefficiencies of unilateral action.

The OH approaches also link public health outcomes to broader EU sustainability goals, such as those outlined in the European Green Deal and the Farm-to-Fork strategy. By integrating health, agricultural, and environmental objectives, OH aligns with Europe's larger sustainability agenda. For example, reductions in air and water pollution via sustainable agricultural practices not only contribute to environmental targets but also decrease the burden of pollution-related diseases (e.g., chronic respiratory illnesses), reducing long-term healthcare costs. Programs such as zoonotic disease management under the EU-supported OH European Joint Programme demonstrate the potential for combining cross-sector goals while ensuring that investments in health and sustainability generate compounding benefits (Jestin et Al. (2021); Taylor et Al. (2024)).

From a structural perspective, improved resilience is another key economic advantage of OH. By addressing systemic vulnerabilities before they escalate into crises, OH reduces healthcare system fragility. The COVID-19 pandemic revealed that healthcare systems actively integrating preventive measures are better equipped to handle surges in demand and adapt to sudden changes. The OH approaches focusing on resilience, such as diversified antibiotic stewardship programs and comprehensive disease surveillance systems, ensure that healthcare systems can absorb shocks from zoonotic spillovers or AMR surges without suffering catastrophic economic consequences. Operational efficiencies derived from OH interventions add financial flexibility to healthcare systems, enabling them to direct resources to where they are most needed during emergencies (Babo Martins, Rushton & Stärk (2017); Bennani et Al. (2021)).

4.4. Economic Models and Return on Investment (ROI) for OH

Economic models applied to OH demonstrate the potential for substantial returns on investment (ROI). For example, cost-benefit analyses of integrated AMR strategies routinely illustrate the downstream cost savings generated by early investment in surveillance, education, and regulation targeting antibiotic misuse across human, veterinary, and agricultural sectors (Babo Martins, Rushton & Stärk (2017); Machalaba et Al. (2017); Mazzeo et Al. (2022)). Public health savings are accompanied by societal benefits, such as increased productivity due to fewer workdays lost from zoonotic infections or AMR-associated illnesses, as well as broader benefits to food security, trade, and tourism when animal health improves.

While conceptual economic frameworks propose ROI measurements for OH, there remains a need for locally specific financial models in Europe. Existing evidence primarily highlights disease-specific

returns (e.g., brucellosis prevention (Buttigieg, Savic and Aragrande, 2018)) or global-level projections (Grace (2014); Machalaba et Al. (2017)). Future research must incorporate region-specific regulations, scaled policy impacts, and healthcare system priorities within Europe to better describe the economic contribution of OH to healthcare sustainability.

5. Open Questions and Gaps in Research on the Role that OH Approach can have on Healthcare Systems

The current literature presents worthwhile information regarding economic costs and finance in the OH strategy, centered mainly on cost-effective precautions, prevention measures, and policy consistency. Nonetheless, OH ideas and practices still lack a rigorous theoretical framework, and many crucial questions have not yet been resolved, with significant areas needing a more systematic research agenda to be implemented. What follows is an overview of what are deemed most significant research gaps and future research, as they are grouped under principal unresolved matters.

5.1. Systematically Quantifying the Economic Impact of OH in Healthcare Systems

The economic potential of OH interventions is increasingly recognized in the literature, particularly in areas such as cost savings from zoonotic disease prevention and improved resource allocation for antimicrobial resistance (AMR) surveillance. Studies such as those by Babo Martins, Rushton & Stärk (2017), Grace (2014), Machalaba et Al. (2017), Mazzeo et Al. (2022), and provide evidence of the value of OH strategies in these domains. However, despite these contributions, there remains a notable lack of systematic and comprehensive financial models that explicitly quantify the economic returns of OH interventions, particularly within the context of European healthcare systems. Much of the existing research is conceptual or based on global case studies, leaving European-specific and healthcare system–focused evaluations relatively underdeveloped.

In addition to measurable economic outcomes, OH interventions are often associated with intangible benefits such as increased system resilience, improved intersectoral collaboration, and enhanced risk mitigation. These aspects are acknowledged in the literature (e.g., Babo Martins, Rushton & Stärk (2017); Rüegg et al., 2018) but are seldom integrated into quantitative analyses. As a result, the full value of OH approaches is likely underestimated in current evaluations.

One major gap in the literature concerns the limited development of detailed economic models tailored to European healthcare systems. While the Swiss case study on Campylobacter surveillance (Babo Martins, Rushton & Stärk, 2017) provides a cost-benefit appraisal, its findings are context-specific and do not generalize to systemic healthcare outcomes at the European level. Similarly, studies such as those by Machalaba et Al. (2017) and Mazzeo et Al. (2022) primarily offer conceptual frameworks without embedding real-world healthcare data into their analyses.

Another underexplored area relates to the range of health threats considered in economic assessments of OH. While zoonoses and AMR remain the dominant focus, there is limited attention to the economic implications of OH initiatives targeting climate-related health conditions, pollution-induced diseases, and other emerging syndromic threats, particularly within Europe.

To address these limitations, future research should focus on the development of comprehensive financial models that assess both direct healthcare savings and broader systemic benefits from OH

interventions. These models should be tailored to the diversity of European healthcare systems and incorporate different regulatory and funding scenarios. Furthermore, methodological innovations are needed to quantify the intangible and long-term benefits of OH, such as using multi-criteria decision analysis or system dynamics modeling. Expanding the scope of economic evaluations to include non-infectious, environmentally driven health threats will also be essential for capturing the full value of OH strategies in an era of global ecological and epidemiological change.

5.2. Barriers to Scaling and Implementing OH Initiatives in an Economically Equitable Manner

The expansion and institutionalization of OH strategies across European healthcare systems encounter significant barriers, particularly concerning economic equity and operational feasibility. Although the literature acknowledges financial and resource disparities among European Union Member States, there is a lack of systematic investigation into how these disparities affect the feasibility and effectiveness of OH implementation at national and subnational levels. For instance, while some contributions (e.g., Buttigieg, Savic, & Aragrande (2018); Mazzeo et Al. (2022)) highlight the risk that wealthier countries may more readily adopt resource-intensive OH interventions, such as advanced antimicrobial resistance (AMR) surveillance, the consequences for less-resourced countries remain insufficiently explored. This uneven capacity risks reinforcing pre-existing health and infrastructural inequalities within the EU.

Operational challenges also arise in fostering intersectoral collaboration, which is a cornerstone of OH approaches. Studies by Bennani et al. (2021), Haxton and Rivière-Cinnamond (2015), and Rüegg et al. (2018) underscore the necessity of cross-sectoral integration—including cooperation between human health, animal health, and environmental agencies—but typically stop short of offering concrete strategies for overcoming financial fragmentation or misaligned incentives. Issues such as cost-sharing mechanisms, institutional accountability, and governance frameworks remain underdeveloped both conceptually and empirically.

Among the key evidence gaps is the inequity in OH implementation due to resource asymmetries. Wealthier Member States may deploy comprehensive OH initiatives, while lower-income countries are limited to more rudimentary forms of surveillance or intervention, often lacking the infrastructure necessary for intersectoral data integration or coordinated response. This situation not only limits the scalability of OH at the European level but also compromises the efficacy of cross-border public health responses.

In addition, while funding models such as pooled financing and pay-for-performance mechanisms have been proposed (Grace (2014); Mazzeo et Al. (2022)), empirical evaluations of their implementation and effectiveness in real-world European healthcare contexts are virtually absent. Without such assessments, it remains unclear whether these models can guarantee equitable allocation of resources or incentivize meaningful collaboration across sectors and jurisdictions.

Governance also represents a major challenge. Current OH literature offers limited insights into how institutions can align priorities, ensure procedural transparency, and resolve accountability disputes when responsibilities and costs are shared across multiple sectors. The absence of robust governance frameworks weakens the institutional capacity to sustain OH initiatives over time and across diverse political and regulatory environments.

In summary, OH presents a redefined concept of health and envisions a planetary network of individual and shared exposomes, yet it embodies a dual and problematic nature. While it holds potential to advance interspecies equity and ecological resilience, it also risks reinforcing systemic hierarchies akin to those in global markets and digital platforms. To realize its transformative potential, deliberate efforts must address its tendency toward inequality by:

- Promoting epistemic justice and equitable resource distribution.
- Democratizing agenda-setting to reflect diverse priorities.
- Empowering local and regional health systems as autonomous contributors to global health knowledge.

Such intentional recalibration is essential for OH to evolve from a fragmented system into an inclusive, resilient commons that supports the shared future of all life.

Future research should prioritize comparative analyses of regional disparities in OH scalability, particularly between economically divergent Member States or between urban and rural areas within countries. Testing innovative funding mechanisms—such as shared financing pools for zoonotic surveillance or performance-based incentives for AMR reduction—in real-world settings would provide crucial empirical grounding for policy recommendations. Finally, further work is needed to identify and refine governance models that can facilitate the equitable and efficient adoption of OH across Europe, drawing on both successful and unsuccessful implementation cases to inform best practices.

5.3. Strengthening the Alignment of OH with Policy and Sustainability Goals

While the conceptual compatibility between OH and major European policy frameworks—such as the European Green Deal and the Farm-to-Fork Strategy—is frequently acknowledged in the literature (Bronzwaer et Al. (2021); Mazzeo et Al. (2022)), the integration of OH into concrete policy implementation remains underdeveloped. Most existing contributions focus on theoretical synergies, without offering detailed analytical frameworks that link OH interventions to existing EU strategies in terms of cost-effectiveness, implementation logistics, or financial implications for healthcare systems.

Moreover, regulatory misalignments between sectors, such as agriculture, veterinary services, and healthcare, are only superficially addressed. For instance, although Mazzeo et Al. (2022) briefly highlight potential regulatory frictions, a systematic analysis of how intersectoral policy conflicts may impede the adoption or scalability of OH strategies is lacking. This is particularly problematic in contexts where divergent incentives or mandates across sectors hinder coordinated responses to zoonotic risks, antimicrobial resistance (AMR), or environmental health threats.

The current evidence base reveals several significant gaps. First, there is limited operationalization of OH's alignment with EU policy goals; much of the discourse remains at an abstract level, offering little guidance on how OH approaches can be embedded within existing institutional frameworks. Second, no comprehensive evaluations exist that examine the ways in which sector-specific regulations may constrain or facilitate the integration of OH principles. Third, although EU strategies are often referenced in OH discussions, few studies quantify the economic impact of policy-aligned OH interventions—such as estimating healthcare cost savings from preventive measures inspired by the Farm-to-Fork Strategy.

Addressing these gaps requires the development of robust analytical models capable of demonstrating how OH contributes to EU policy targets—such as greenhouse gas reduction, AMR containment, or biodiversity protection—while concurrently reducing healthcare expenditures and societal costs. These models should assess not only ecological and health outcomes but also the fiscal and administrative feasibility of implementation.

Additionally, empirical case studies examining policy coordination, or lack thereof, between relevant sectors are essential. Such analyses should identify both the enabling conditions and the institutional barriers that shape OH implementation in different regulatory environments. These case studies would offer actionable insights for policy harmonization and intersectoral governance reform.

Finally, targeted pilot programs explicitly linking OH interventions to EU policy instruments—such as subsidies for sustainable farming or Horizon Europe health research funds—could serve as testbeds for evaluating policy alignment in practice. By conducting cost-benefit analyses of these programs, researchers and policymakers could generate the empirical evidence needed to justify broader integration of OH into the European policy landscape and to design mechanisms that promote both public health and environmental sustainability in a fiscally responsible manner.

5.4. Enhancing Evidence-Based Decision-Making Tools and Frameworks for Funding OH Initiatives

Recent years have witnessed considerable progress in the development of evaluation frameworks for OH, with initiatives such as the Network for Evaluation of One Health (NEOH) contributing to a more structured understanding of OH's systemic value. However, most existing frameworks prioritize qualitative or semi-quantitative assessments of interdisciplinary integration, institutional cooperation, and health system benefits (Haxton & Rivière-Cinnamond, 2015). These approaches, while valuable in articulating the holistic rationale for OH, often lack sufficient integration of financial indicators such as return on investment (ROI), long-term cost projections, or budgetary trade-offs. As a result, their utility in informing resource allocation decisions within healthcare budgeting processes remains limited.

Moreover, current tools offer few capabilities for systematically prioritizing OH interventions based on economic efficiency or comparative cost-benefit analyses. Policymakers operating under fiscal constraints are therefore left with insufficient guidance when evaluating the relative value of competing health, agricultural, and environmental interventions. Tools that facilitate decision-making across sectors—using standardized financial metrics such as cost-effectiveness ratios or ROI estimates—are either underdeveloped or entirely absent in the context of OH evaluation.

This lack of financial integration presents a critical evidence gap. Most existing frameworks, including NEOH, emphasize system-level outcomes and governance quality, but do not align well with the financial criteria typically used in healthcare planning and investment decisions. Furthermore, there is a lack of comparative tools that allow policymakers to evaluate the relative benefits of OH initiatives within broader public policy portfolios, which often involve competing priorities and limited resources.

To address these shortcomings, future development of OH evaluation frameworks should incorporate tools capable of capturing both qualitative and quantitative dimensions of value. One avenue would be to expand existing frameworks, such as NEOH, to include explicit cost-effectiveness and ROI assessment modules. Such integration would enhance the relevance of these frameworks for budgetary decision-makers and increase their practical applicability in funding allocation processes.

In parallel, the creation of prioritization tools—such as interactive models or simulations—based on real-world European healthcare and environmental data would allow for the comparison of financial viability and trade-offs among various OH interventions. These tools should be designed to operate across policy domains and to reflect the complexity of resource allocation in integrated systems.

Finally, there is a pressing need to establish a standardized evidence base of economic metrics applicable across OH initiatives. The use of consistent financial indicators would facilitate cross-country comparisons, improve transparency in decision-making, and enable the broader scaling of OH strategies within the European Union. By aligning OH evaluation tools more closely with the requirements of evidence-based public finance, it will be possible to advance both the legitimacy and the sustainability of OH investments.

5.5. Measuring and Achieving Long-Term Resilience in Healthcare Systems through OH

The enhancement of health system resilience is often cited as a central justification for the implementation of OH strategies. Several studies (e.g., Babo Martins, Rushton & Stärk (2017); Grace (2014); Rüegg et Al. (2018)) highlight the potential of OH approaches to strengthen healthcare systems' ability to anticipate, absorb, and adapt to complex health threats, particularly those at the human–animal–environment interface. Nevertheless, the current body of literature falls short of offering robust methodological frameworks for measuring resilience or assessing its evolution following OH integration. Most existing contributions focus on narrow outcomes—such as the cost savings associated with specific surveillance programs—while neglecting broader system-level capacities, such as adaptability to future zoonotic outbreaks or overall reduction in system fragility.

The conceptual link between resilience and financial sustainability, although widely acknowledged, remains underexplored in quantitative terms. Few studies investigate how improvements in resilience resulting from OH interventions may contribute to long-term cost containment, operational efficiency, or resource optimization within healthcare systems. This limits the ability of policymakers to evaluate the strategic return on investment of OH approaches beyond their immediate epidemiological effects.

A critical gap in the literature lies in the absence of well-defined and operationalized resilience indicators within the OH context. Currently, there is no standardized framework for capturing multi-dimensional aspects of resilience—including financial, organizational, and systemic outcomes—that result from OH implementation. Furthermore, while several studies examine disease- or program-specific benefits, such as in the case of Campylobacter surveillance (Babo Martins, Rushton & Stärk, 2017), they do not assess whether such interventions translate into broader improvements in healthcare system sustainability.

Additionally, the interaction between resilience gains and fiscal outcomes remains insufficiently theorized and empirically validated. Without this connection, it is difficult to make a compelling economic case for investing in OH strategies as a tool for long-term system stability.

Future research should aim to fill these gaps by developing and validating resilience metrics tailored to the OH framework. These indicators should capture both immediate capacities (e.g., response to acute outbreaks) and long-term systemic robustness (e.g., reduced dependence on emergency interventions, improved continuity of care). Longitudinal studies evaluating the system-wide impacts of OH strategies—across domains such as affordability, infrastructure resilience, and care integration—would provide a more comprehensive understanding of their contribution to healthcare sustainability.

Moreover, modeling efforts should be directed toward quantifying how resilience-enhancing OH interventions influence long-term fiscal trajectories in healthcare systems. By linking operational resilience to macroeconomic planning, such analyses would offer critical insights into how OH can serve not only as a health strategy but also as a fiscally prudent investment in the structural stability of European health systems.

6. Conclusion

The OH approach is a new paradigm that promises to be transformative on both the epistemic and the policy making front. As a new theory of health as a social merit good emerging from a commons of interdependences and deeper structure of nature and nurture, OH proposes an entirely new way to look at the relationship between humans and the environment, as well as to the whole meaning of life on the planet. As a practical guide to health policies, OH presents great opportunities for fostering economic and financial health system sustainability through cost savings, financial risk mitigation, resource optimization, and systemic resilience. Integrated, cross-sectoral interventions applied by OH promise to yield large cost savings from prevention of diseases, decrease healthcare and society burdens from threats such as AMR and zoonotic diseases, and bring public health outcomes into alignment with more general sustainable goals. Greater, more holistic financial modeling suited specifically to European health systems, as well as policy and funding mechanisms ensuring fair availability and scalability across all geographical areas, are necessary for more complete realization of OH's economic potential.

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