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ORIGINAL RESEARCH

Comparing the Evolving Dynamics of the Mandatory-Voluntary Financing Mix in OECD Countries: A Composite Measure

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Abstract
Universal Health Coverage in OECD countries is achieved through a mix of government-based schemes and private health insurance markets (PHI). In response to global challenges, similar reform waves were implemented across countries with different health systems. Similar reforms might lead to a similar and increasingly complex health system financing structure over time. Equity and efficiency issues might arise at the interaction between government schemes and PHI. We outline the theoretical and methodological steps to construct a composite measure of the health system financing mix in 12 OECD countries between 1995 and 2022. Using OECD data, we employed principal component analysis to reduce the dimensionality of seven financing and coverage indicators that explain the maximum variance in healthcare financing. The resulting composite measure is the weighted sum of two components, defined as mandatory contributory government schemes and voluntary private health insurance market, accounting for 37% and 22% respectively of the explained variance among the seven indicators. In 2022, the composite measure scores between a minimum value of 1.3 and a maximum value of 8.2. The Phillips and Sul (*Econometrica*, 75(6), 1771-1855, 2007) convergence test and club clustering analyses reveal a common long-term convergence trend in the health system financing mix across OECD countries. This is mainly driven by a reduction in the reliance on voluntary PHI in countries with social health insurance. This descriptive measure offers a tool to systematically compare the evolving organization of health system financing across countries over time. Understanding the long-term dynamics of the health system financing mix might offer cross-country lessons to inform future reforms.

Keywords Healthcare financing · Health policy · Health systems · Public–Private mix

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1 Introduction

Health system financing in OECD countries has transformed across four subsequent waves of health system reform (Berardi et al., 2024b; Cutler, 2002). The *first wave (1960–1980)* witnessed the establishment of universal health systems with the goal of ensuring equal access. The *second wave (1980–1995)*, saw governments implement measures such as control, rationing, and expenditure caps in response to escalating public expenditure. The *third wave* (1995–2008) aimed at enhancing efficiency by fostering competition among providers or insurers within national health systems. The *fourth wave (post 2008)* has further prioritized controlling the escalation of public spending implementing austerity measures following the effect of the global financial crisis. As a result of successive reform waves, health systems in OECD countries exhibit a complex mix of government schemes, whether tax-financed or contribution-based, and private health insurance, whether mandatory or voluntary (Barros & Siciliani, 2011). The design of health financing systems plays a crucial role in determining how health system objectives such as equity and efficiency are achieved.

Inefficiencies and inequalities can significantly impact voluntary private insurance markets (PHI). Inefficiencies such as moral hazard and adverse selection hinder optimal market functioning (Pauly, 1974). Equity issues stem from the segmentation of risk and income among PHI enrollees, as well as the disparity between those with and without voluntary PHI (North, 2020). Government regulation is crucial to prevent market failures resulting from imperfect information (Arrow, 2001). Mandatory schemes effectively prevent adverse selection and enhance equity, but they may limit consumer choice and reduce efficiency incentives, especially in single-payer systems (Oliver, 2009). Multiple-payer systems can improve efficiency through prudent care purchasing and increased consumer choice (Schut et al., 2023). Nonetheless, they can also pose risk selection issues, particularly in the absence of a robust risk adjustment system (van de Ven et al., 2015).

However, voluntary private health insurance can alleviate strain on government budgets, bridge gaps in publicly financed health coverage, and serve as an alternative to out-of-pocket payments (North, 2020). Despite these potential benefits, the interplay between mandatory government schemes and voluntary PHI can negatively impact health system performance. For instance, disparities in treatment between public and private patients may arise in public hospitals (Berardi et al., 2024a). Public resources can be diverted away from government schemes to voluntary PHI, with mixed evidence of benefits (Yang et al., 2024). Segmented healthcare markets, distributing financing across multiple government schemes and private entities, can also result in higher administrative costs (Cebul et al., 2008).

Despite being a critical determinant of equity and efficiency, the systemic structure of health systems financing has received relatively little attention in the literature (Barros, 2007). To our knowledge, only two previous indices have measured the variation in the public–private financing mix across countries until 2008 (Barros, 2007; Götze & Schmid, 2012). The first one constructed a standard instability index, providing a single score of variation between two consecutive time periods, which can limit its use in longitudinal research (Barros, 2007). The second one provides a hybridity index using Euclidean geometry, which, lacking dimensionality reduction, may become difficult to implement considering that multiple dimensions are relevant for defining mixed health system financing (Götze & Schmid, 2012). Across countries, the balance of mandatory, government-established schemes and voluntary PHI is the result of reform decisions. It is important to provide a quantifiable measurement to track financing shifts that may occur in a specific

year and country, in order to measure the effects of financing reforms on health systems performance.

As the pace and frequency of exogenous shocks increase, the balance of funding sources is often influenced by policy drifting or problem pressure, rather than based on informed decision-making (Mou, 2012). For instance, in response to the 2008 economic crisis, many countries had to control government budgets and increase out-of-pocket (OOP) expenses to reduce the growth in public spending (Thomson et al., 2022). The COVID-19 pandemic and the following price inflation crisis exacerbated waiting times and workforce shortages, and intensified the strain on public budgets, thereby incentivizing individuals' PHI uptake (Anderson & Mossialos, 2022). Overall, the growth of government healthcare spending is projected to outpace total health spending by 2030, suggesting the need of further financing reforms (Lorenzoni et al., 2019). Therefore, systematically measuring the balance between mandatory and voluntary health financing across countries and over time is crucial to improve evidence-based policy making, avoiding unintended consequences of past financing reforms and measuring the effects of these financing reforms on important health system performance outcomes such as equity and efficiency.

We aim to: 1) construct a composite measure to describe the extent to which health systems rely on a financing mix of mandatory government-based schemes, including mandatory private health insurance, and voluntary private health insurance in 12 OECD countries for the period 1995 and 2022, covering the third and fourth waves of health systems reforms as observed by (Berardi et al., 2024b; Cutler, 2002); 2) compare our health system financing mix composite measure to two previous indices that measure the same construct but use different methodologies (Barros, 2007; Götze & Schmid, 2012). We contribute to this previous literature by reconceptualizing the concept of funding mix in healthcare, developing a longitudinal measure using Principal Component Analysis (PCA), and identifying the drivers of the funding transition. Understanding the long-term dynamics of the mandatory-voluntary financing mix will inform policy decisions, provide cross-country learning, and may assist in identifying equity and efficiency issues associated with past financing reforms. Although measuring the effects of the financing mix is beyond the scope of this paper, a composite measure that provides a yearly score for each country can provide a common foundation for further systematic research into the performance implications of evolving financing schemes within and across countries.

The remainder of the paper is as follows: Sect. 2 presents a conceptual framework for defining health system financing; Sect. 3 outlines the data and methods used to construct a composite index of the financing mix; Sect. 4 presents the results, including descriptive statistics, principal component analysis, and the final composite measure, as well as sensitivity analysis and robustness checks; Sect. 5 discusses the theoretical and methodological contributions and policy implications; Sect. 6 presents the limitations; and finally, Sect. 7 reports concluding remarks.

2 A Conceptual Framework for Defining and Measuring the Health System Financing Mix

In this section, we aim to outline a conceptual framework to develop a composite measure of the mandatory-voluntary financing mix in OECD health systems. Following the first wave of reform with few constraints on demand or supply of medical care, subsequent reforms aimed to reduce the comprehensiveness of universal public health coverage

through supply-side expenditure controls and demand-side cost sharing. Leading to gaps in services and longer wait times, individuals increasingly adopted PHI to fill these gaps, resulting in greater mixed health system financing as private funding supplemented public systems (Berardi et al., 2024b; Cutler, 2002). These reforms waves have directly or indirectly altered the balance between public and private sector involvement, resulting in a complex and overlapping mix of public and private financing sources. Studying the financing mix is relevant because the interaction between mandatory and voluntary schemes can impact the performance of health systems in terms of equity and efficiency (Berardi et al., 2024a; North, 2020; Yang et al., 2024).

Principal-agent theory provides a theoretical foundation for understanding how multiple financing sources create complex relationships with misaligned incentives (Arrow, 2001; Grossman & Hart, 1992). In mixed financing systems—featuring mandatory government schemes, compulsory and voluntary PHI, which our index aims to measure—there are multiple overlapping principal-agent relationships among governments, insurers, providers, and patients. Each financing source creates its own set of principal-agent relationships with distinct incentive structures, increasing monitoring complexity and transaction costs, which can affect the performance of health systems. However, the relationship between financing structure and health system performance has been relatively understudied, largely due to the complexities involved in quantitatively measuring the complex financing arrangements across countries (Gabani et al., 2023).

To our knowledge, only two previous empirical studies measured the public–private funding mix across countries. Barros (2007) constructed a standard instability index and a similarity index of financing structures, including general taxation, social insurance contributions, private insurance, and out-of-pocket payments, highlighting a slow but steady convergence in the mix of funding sources for most OECD countries between 1975 and 2005, irrespective of their prevailing funding system. Furthermore, Götze and Schmidt (2012) developed an index of hybridity to measure the deviation from equal distribution among these main four financing sources, and capturing delta convergence among countries, identifying three different trends over time: (1) a development from relatively hybridized to monopolistic funding structures up to 1980, (2) a long hybridization period between 1980 and 2000, and (3) a movement back to more ideal–typical schemes between 2000–2008. While both indices seem to yield contrasting results in the period since 2000, they reveal that monopolization and convergence can occur simultaneously in OECD healthcare systems. These two previous indices that measured the financing mix across countries were based upon the traditional distinction between public and private sources of health financing (Barros, 2007; Götze & Schmid, 2012).

Focusing on the four main sources of financing, previous theoretical and empirical literature defines the heath system financing mix broadly as the interface of public and private sectors (Barros & Siciliani, 2011; Culyer, 1982; OECD, 1992; OECD, 1994; Colombo & Tapay, 2004; Rothgang et al., 2010). Following this logic, most previous comparative frameworks have categorized systems based on their prevailing models such as NHS, SHI and PHI (Cuadrado et al., 2019; Cuckler et al., 2013; Judge, 1988; Lee et al., 2008; Reibling et al., 2019; Toth, 2016). Previous literature is limited in their ability to describe and measure the complexity of health systems financing mix in OECD countries. Developing quantitative indicators, supplemented by qualitative information, is important to enable a thorough analysis and comparison of mixed health systems and their impact on performance (Waitzberg et al., 2024).

Building on previous studies that primarily focused on the first three waves of health system reform, we propose an alternative measure of the financing mix in health care systems

to better understand the complex changes in health care financing across both the third (1995–2007) and fourth waves (2008 onwards) of reform (Berardi et al., 2024b), including the period following the global financial crisis. This analysis covers 12 OECD countries, specifically Australia, Canada, Denmark, France, Germany, Italy, Japan, South Korea, Switzerland, the Netherlands, the UK, and the US. As the boundaries between public and private financing appear increasingly blurred (Paolucci, 2011), we argue that multiple dimensions are relevant when referring to the funding mix in healthcare financing, beyond the mere distinction between public and private sectors. In what follows, we outline each of the dimensions that are important for defining health system financing, as informed by previous health system theoretical literature (Barros & Siciliani, 2011; Colombo & Tapay, 2004; Paolucci, 2011; Rice, 2021; Toth, 2016; OECD, Eurostat & World Health Organization, 2017).

The first relevant dimension is the public and private nature of the health insurance (Toth, 2016). Public health insurance is characterized by the compulsory nature of financing contributions, while private health insurance and out-of-pocket contributions are paid on voluntary basis (Barros & Siciliani, 2011). However, this distinction is less straightforward for mandatory private health insurance. Indeed, its definition as public or private sector health insurance is commonly left to the analyst decision (OECD, Eurostat & World Health Organization, 2017). In the sample of OECD countries included in this analysis, all health systems display shares from expenditure on compulsory government schemes, voluntary health care schemes, and OOP spending (Table 1). Australia, the UK, and Denmark do not have compulsory social health insurance schemes. Less than half of the included countries, such as Canada, the UK, Italy, Japan, and Denmark, does not provide compulsory private insurance schemes (Table 1). The compulsoriness of the contributions has an impact on the redistribution effects, reflecting either a more collective or individual nature of financing (Rice, 2021).

The second dimension is the financing of healthcare by the state through single or multiple entities. Single entities include single government schemes, such as via National Health Services (NHS) (UK, Italy, and Denmark), or single public insurer in NHI-type systems (Australia, Canada, and South Korea). Multiple entities include statutory sickness funds in SHI-type systems (Germany, France, Japan, and Switzerland), or multiple private health insurers (the Netherlands, and the US) (Table 1). Statutory sickness funds can be competitive (Germany) or non-competitive (France), being a determinant for defining the extent of consumer choice (Toth, 2016). Another distinction is based on the profit orientation of funds and insurers (Paolucci, 2011). In most countries, except the US, basic health insurance is provided by not-for-profit insurers, in contrast to supplemental services provided by for-profit insurers (Table 1).

The third dimension is the role that private health insurance plays in comparison to public health insurance schemes such as primary, complementary, supplementary or duplicative (Toth, 2016). For instance, primary PHI coverage serves as the exclusive means of obtaining health coverage when individuals do not have access to public health insurance (Colombo & Tapay, 2004), such as in the US (Table 1). Additional voluntary health insurance, present in all OECD countries to some extent, can be either complementary, where it covers all or part of the residual costs not otherwise reimbursed such as cost-sharing and co-payments, or supplementary, where it provides coverage for additional health services not at all covered by the government/compulsory scheme (OECD, 2023a). Duplicate PHI provides coverage for health services already included in public health insurance, often with the additional advantages of different service providers or levels of service, such as expedited access by queue jumping and enhanced choice of healthcare providers (Colombo & Tapay, 2004). Duplicate PHI is present in Australia and the UK (Table 1).

Table 1 Conceptual dimensions for defining and measuring the health system financing mix in OECD countries

	AUS	CAN	DEU	FRA	GBR	ITA	JPN	NLD	USA	CHE	DNK	KOR
Compulsory government schemes (% CE)*	70.7	68.1	6.6	5.3	79.3	73.6	8.1	6.5	26.3	23.4	83.7	10.1
Compulsory Social health insurance schemes (% CE)*	0	1.4	70.3	71.5	0	0.2	75.9	21.5	23.9	6.5	0	47.8
Compulsory private insurance schemes (% CE)*	1.1	0	7.1	6.8	0	0	0	54.7	32.5	36.4	0	1.5
Voluntary health care payment scheme (% CE)*	13.4	15.0	2.7	7.0	5.0	2.8	3.1	6.8	6.0	9.2	2.5	9.0
Household OOP (% CE)	14.7	15.5	13.3	9.5	15.7	23.5	12.9	10.4	11.3	23.4	13.8	31.6
Duplicate voluntary PHI coverage (% people)*	44.3	0	0	0	10.7	0	0	0	0	0	0	0
Primary voluntary PHI (% people)*	0	0	0	0	0	0	0	0	52.5	0	0	0
Complementary voluntary PHI (% people)*	0	0	24.9	96.4	10.5[5#]	10[6#]	-	0	9.5	0	36.9	70.8
Supplementary voluntary PHI (% people)*	53.6	69	-	0	0	0	-	83.7	-	-	36.9	70.8

Table 1 (continued)

	AUS	CAN	DEU	FRA	GBR	ITA	JPN	NLD	USA	CHE	DNK	KOR
Payer (basic coverage market)	Medicare: Single payer [1] Duplicate PHI: competing multiple payers [1]	Medicare: Single payer [2]	SHI: competitive non-for-profit sickness funds [3] Primary PHI: competing for-profit multiple payers [3]	SHI: non-competitive multiple payers [4]	NHS: single [5]	NHS: single [6]	SHIS: competing non-for-profit sickness funds [7]	Compulsory PHI: competing non-for-profit multiple payers [8]	Medicare, Medicaid, CHIP, Veterans Health Administration and TRICARE: single payer [9] Employer-based, individual PHI, Medicare Advantage: competing for-profit multiple payers [9]	Compulsory PHI: competing statutory non-for-profit sickness funds [10]	NHS: single [11]	SNHI: single payer [12]

Definitions

*Variables defined according to SHA Account 2011 (Table 2A) (OECD, Eurostat & WHO, 2011)

% CE = share of current expenditure on health financing schemes

References

*(OECD, 2023a) [1](Glover, 2020) [2](Allin & Peckham, 2020) [3](Blümel, 2020) [4](Durand-Zaleski, 2020) [5](Thorlby, 2020) [6](Donatini, 2020) [7](Matsuda, 2020) [8] (Wammes, 2020) [9](The Commonwealth Fund, 2020) [10](Sturny, 2020) [11](Vrangbaek, 2020) [12](WHO, 2015)

Legend

AUS = Australia, CAN = Canada, DEU = Germany, FRA = France, GBR = the UK, ITA = Italy6, JPN = Japan, NLD = the Netherlands, USA = the US, CHE = Switzerland, DNK = Denmark, KOR = South Korea—missing data

[#]Data include voluntary supplemental (supplementary and complementary) health insurance

It is clear that understanding the extent to which health systems financing in OECD countries is mixed is not straightforward. We identified ten dimensions used by previous theoretical health system frameworks to guide the selection of indicators to include in the composite measure. As multiple dimensions are relevant when defining and measuring mixed health systems, we aim to synthetize this complex phenomenon and reduce these dimensions to a single indicator to shed light on the transforming dynamics of government schemes and private health insurance across the observed waves of reform. Indeed, similar waves of reforms, in response to global challenges, might have led to a common funding structure across countries over time.

3 Methods

We operationalized a composite measure of the health system's mandatory-voluntary financing mix across 12 OECD countries between 1995 and 2022. This measure will allow policymakers to gauge the evolution of the financing mix, informed by a conceptual framework that considers various relevant dimensions (Sect. 2). We used OECD data to ensure standardization and comparability across countries (Table 1A appendix) (OECD, 2023a). We included countries that share a high-income economic profile and have different health systems defined by a diverse mix of mandatory government schemes and voluntary PHI. All countries, except the US, achieved UHC measured as breadth (share of population covered); depth (share of services covered); and height (share of users' charges in healthcare financing) (Table 1A). The percentage of people not covered by government programs or private insurance amounts to 8% in the US, and it is close to zero in the other countries of the sample (OECD, 2023a). To construct the composite indicator we follow the steps outlined in the OECD handbook on constructing composite indicators (OECD et al., 2008), including: 1) conceptual framework (Sect. 2); 2) data selection (Sect. 3.1); 3) imputation of missing data (Sect. 3.2); 4) multivariate analysis (Sect. 3.3.1); 5) normalization (Sect. 3.3.2); 6) weighting (Sect. 3.3.3); 7) aggregation (Sect. 3.3.4); 8) robustness and sensitivity (Sect. 3.3.5); and 9) links to other variables (Sect. 3.3.6).

3.1 Selection of Indicators

To represent the evolving multidimensional phenomenon of health system financing mixes, we selected seven indicators for which OECD data was accessible across the countries and time span considered. Our indicator selection was guided by both theoretical frameworks and practical considerations in health system financing. Each indicator was chosen to capture a distinct and theoretically important dimension of financing mix. Mandatory versus voluntary participation, which also reflects the public or private ownership of the financing scheme, as explained in the conceptual framework, was captured by the share of current expenditure on: (1) compulsory government schemes; (2) compulsory social health insurance schemes; (3) compulsory private insurance schemes; (4) voluntary health insurance schemes; (5) voluntary household OOP. These indicators capture the extent of risk pooling, reflecting policy choices between individual choice and collective responsibility, and indicate whether mandatory schemes—where the majority of health spending is concentrated in our sample—operate with a single or multiple-payer structure. The role that voluntary PHI plays relative to mandatory scheme, was measured by the percentage of the total population covered by (6) duplicate voluntary private health insurance and (7)

primary voluntary private health insurance, highlighting the interaction between mandatory and voluntary financing and reflecting policy choices about universal coverage strategies. Collectively, these indicators indicate the degree of system financing mix, offering an empirical means of capturing how systems balance mandatory and voluntary schemes across different funding sources. All the indicators were expressed in the same unit as percentages, ranging from 0 to 100. Thus, indicators were incorporated into the composite measure without further standardization.

3.2 Missing Data

Table 3A in the appendix provides a detailed account of the missing data by country and year. Overall, 17.6% of the data on system characteristics were missing from the OECD dataset, including data on: compulsory government schemes (5.6%); compulsory social health insurance schemes (4.5%); compulsory private insurance schemes (2.4%); voluntary health insurance schemes (3.3%); percentage of the total population covered by duplicate voluntary private health insurance (0.6%), and primary voluntary private health insurance (1.2%). Part of the data was manually imputed from various other national and international sources as reported in Table 3A (column 4). For the remaining missing data, we performed a multiple imputation procedure. This method generates multiple plausible values for each missing observation by iteratively estimating missing values from predictive distributions conditioned on the observed data. Following standard recommendations for multiple imputation (Newman, 2014), we created 40 imputed datasets to account for uncertainty in the missing values and reduce potential bias. In the pooling phase, the final estimates were obtained by combining the results across the imputed datasets. For detailed procedure, see (Newman, 2014).[1]

3.3 Estimating the Composite Measure of Health System Mandatory-Voluntary Financing Mix

3.3.1 Multivariate Analysis

We used PCA to construct a composite measure of the mandatory-voluntary financing mix. As multiple dimensions were identified as relevant to describe the financing mix in the conceptual framework, we used PCA for dimensionality reduction. Indeed, PCA reduces the dimensionality of a multivariate dataset to construct principal components as linear combinations of the selected indicators, defined by maximum variance (Mazziotta & Pareto, 2019). PCA creates new variables that are linearly uncorrelated, ensuring each principal component captures a distinct source of variation in the data, without redundancy or multicollinearity (Chan et al., 2022). Alternative methods, such as cluster analysis used in previous literature to define health system financing (Gabani et al., 2023), may not effectively address multicollinearity among variables, particularly when there are high correlations between them as is the case in our dataset (Table 4A). PCA is validated as a robust method for constructing composite measures in healthcare (Fullman et al., 2018; Havard et al., 2008; Vyas & Kumaranayake, 2006).

[1] SAS 9.4 was used for the missing value treatment step. The remaining analyses were conducted using STATA 16.

Our analysis employed a single PCA on the entire dataset, including all countries and years. The cross-sectional approach allows us to capture the overall structure of health system financing across both countries and time simultaneously. Given the study's objective of identifying country-specific patterns, this method enables us to identify consistent patterns of the mandatory-voluntary financing mix that persist across our entire sample. Moreover, to complement our original findings and provide a dynamic, long-term perspective on the evolution of health system financing mix across countries, we applied the Phillips and Sul (2007) convergence test and club clustering analysis (Phillips & Sul, 2007), using the STATA implementation described in (Du, 2017). This test examines the convergence of health system financing composite measure and its single components across countries over time, rather than the convergence of its underlying variables.

3.3.2 Normalization

We log-transformed all indicators to reduce sensitivity to variable skewness to mitigate PCA sensitivity to outliers (OECD et al., 2008; Dialga and Thi Hang Giang, 2017). Other known limitations are complexity in the theoretical interpretability of principal components and and disagreement on the criteria for component selection. Therefore, we applied Kaiser's criterion, retaining all components with eigenvalues greater than 1 (Dziuban & Shirkey, 1974). We also recalculated the composite measure using an alternative selection criterion of 80% of explained variance (OECD et al., 2008).

3.3.3 Weighting

We used the respective percentages of explained variance to weight each component (Dialga & Thi Hang Giang, 2017). This gives an indication of how much of the variability in the original data is contained within each principal component (Mazziotta & Pareto, 2019). We selected PCA because it allows for the objective weighting of the dimensions. PCA was considered against alternative methods for continuous variables that provide data-driven weighting, such as cluster analysis and factor analysis. However, cluster analysis creates typologies of health systems, a purpose widely used in previous literature (Reibling et al., 2019) and outside the scope of this study. Factor analysis was performed as a sensitivity analysis and returned similar results (Table 5A).

3.3.4 Aggregation

A simple sum of the components is used to aggregate our composite measure. Linear aggregation implies full substitutability among the components (Mazziotta & Pareto, 2016). This means that each unit increase in one component has the same impact as a unit increase in any other component, regardless of their relative importance. However, because we weight each component according to their respective explained variance, the use of weights reflects the relative importance of each component. If the first component captures a larger portion of the overall variance in the data, it will have a larger influence on the final composite measure. This approach effectively prioritizes the dimensions that contain the most information. Overall, PCA fits the purpose of our measure, which aims to systematically capture the funding mix across countries over time. The final composite measure, derived by summing scores from weighted PCA components based on explained variance is presented for each country and year, alongside the scores of individual components

between 1995–2022. Finally, the composite measure was rescaled across countries from 0 to 10. Composite measure values closer to 0 indicates that a national health system purely relies on one type of financing, either mandatory contributory-schemes or voluntary private health insurance. While a score close to 10 suggests that a national health system relies on a diversified mix of multiple financing sources, incorporating both mandatory and voluntary financing, thus resulting in a more segmented healthcare market.

3.3.5 Robustness and Sensitivity

The internal validity of our composite measure was assessed using Bartlett's Test of Sphericity (BTS), testing the null hypothesis that the selected indicators are not intercorrelated and hence unsuitable for PCA (Kaiser, 1974). We also measured internal consistency using Cronbach's alpha, which assumes suitability for measuring a single concept (Cronbach, 1951). Values closer to 1 suggest homogeneity among the indicators constituting the measure. An acceptable reliability threshold for Cronbach's alpha is 0.7 (Nunnally, 1978). Furthermore, we run sensitivity analyses calculating the Spearman rank correlation coefficients between our base composite measure and the re-computed composite measure by dropping one indicator at a time, employing alternative weight approaches, ignoring missing data, using alternative variable transformations, and employing different aggregation methods.

3.3.6 Links to Other External Indicators

Composite measurers should be correlated with existing indicators to test its explanatory power (OECD et al., 2008). In the absence of an external gold-standard measure capturing the mandatory-voluntary financing mix of a country's health system, we sought to validate our composite measure against an existing measure which also reflects health system segmentation, similarly to what has bene done in previous studies building composite measures (Bassat Orellana et al., 2018; Chung et al., 2014; Havard et al., 2008; Hogan et al., 2018). We compared the performance of our composite measure with the current expenditure on governance and financing administration as a share of the gross domestic product (Table 1A). We chose this measure because administrative health spending tends to be higher in those systems that rely on multiple payers compared to single payers (Cebul et al., 2008; Chernew & Mintz, 2021; Himmelstein et al., 2014). A higher value of our composite measure, capturing financing systems relying on a mix of mandatory government schemes and private health insurance, should positively correlate with a country's level of administrative costs.

4 Results

4.1 Descriptive Statistics

Descriptive statistics of selected untransformed indicators included in the composite measure are presented in Table 2 across the period considered (1995–2022), Government schemes and social health insurance schemes are the main sources of healthcare financing in the sample, with government schemes averaging 39.37% and social health insurance schemes 26.64% of current expenditure, while out-of-pocket payments (9.36%) are higher on average than voluntary health insurance schemes (7.04%).

Table 2 Descriptive statistics of untransformed variables between 1995–2022 (OECD, 2023a, b)

Variable	Obs	Mean	Std. Dev	Min	Max
Government schemes (% CE)	336	39.37	31.31	3.40	85.21
Social health insurance schemes (% CE)	336	26.64	29.41	0.00	76.67
Voluntary health insurance schemes (% CE	336	7.04	14.69	0.00	55.44
Household out-of-pocket (% CE)	336	9.36	8.89	0.90	40.88
Duplicate voluntary PHI (% pop)	336	4.94	15.27	0.00	63.70
Primary voluntary PHI (% pop)	336	4.52	12.06	0.00	47.30

Legend: % *CE* = percentage of current expenditure; % *pop* = percentage of population covered

4.2 Principal Component Analysis

The Kaiser criterion suggested retaining the first two components, accounting for 37% and 22% respectively of the explained variance among the seven indicators (Table 3). We define the two components that emerge by grouping the seven indicators as mandatory contributory government schemes and voluntary PHI market (Fig. 1A, Appendix). In Table 4, we show that expenditure on government schemes, social health insurance schemes load more on the first components (mandatory government scheme), whereas expenditure on voluntary health insurance, household OOP and primary voluntary private health insurance load more on the second component (voluntary PHI). While these have clear and strong weights on their respective components, compulsory private insurance schemes and duplicate voluntary PHI cross loaded between the two components. A known limitation of PCA includes the challenging interpretation of results. Cross-loadings -where an item has high loadings on more than one factor—require careful theoretical consideration when

Table 3 Principal component analysis results

	PCA	
	Mandatory contributory government schemes	Voluntary PHI market
	Component 1	Component 2
Eigenvalues	2.59	1.56
Proportion of variance explained (%)	0.37	0.22
Cumulative proportion of variance explained	0.37	0.59
Loadings		
Government schemes (% CE)	**−0.56**	0.15
Social health insurance schemes (% CE)	**0.58**	−0.08
Compulsory private insurance schemes (% CE)	**0.24**	−0.30*
Voluntary health insurance schemes (% CE)	0.19	**0.60**
Household out-of-pocket (% CE)	−0.21	**−0.42**
Duplicate voluntary PHI (% population)	−0.39*	**0.31**
Primary voluntary PHI (% population)	0.24	**0.49**

Legend: *cross loadings

Table 4 The composite measure of health system mandatory-voluntary financing mix and underlying indicators (year 2022)

Country	Year	Composite measure of health system mandatory-voluntary financing mix	Rank	Government schemes expenditure	Social health insurance schemes expenditure	Compulsory private insurance schemes expenditure	Voluntary health care payment schemes expenditure	Out-of-pocket	Duplicate voluntary health insurance coverage	Primary voluntary health insurance coverage
ITA	2022	1.3	1	75.7	0.2	0.0	2.7	21.4	0.0	0.0
GBR	2022	1.8	2	81.5	0.0	0.0	4.5	13.9	8.9	0.0
DNK	2022	1.9	3	84.8	0.0	0.0	2.3	12.9	0.0	0.0
AUS	2022	2.7	4	59.7	0.0	13.5	12.5	14.3	45.0	0.0
CAN	2022	3.9	5	70.0	1.3	0.0	13.8	14.9	0.0	0.0
KOR	2022	4.8	6	16.7	44.7	1.2	9.3	28.0	0.0	0.0
DEU	2022	4.9	7	28.2	42.1	16.2	2.5	11.0	0.0	0.0
JPN	2022	5.2	8	38.5	47.0	0.0	4.2	10.2	0.0	0.0
FRA	2022	5.3	9	34.7	35.4	14.5	4.8	10.7	0.0	0.0
NLD	2022	5.4	10	37.5	34.0	12.6	5.3	10.7	0.0	0.0
CHE	2022	5.7	11	25.3	27.3	16.3	13.9	17.2	0.0	0.0
USA	2022	8.2	12	23.7	33.6	27.5	5.4	9.9	0.0	24.5

Legend: The heatmap colors represent the relative levels of health financing indicators across countries. Red shades indicate higher values, while blue shades represent lower values

interpreting the results (Schreiber, 2021). To make the results meaningful in the context of your theory, we include compulsory PHI under mandatory contributory government schemes, considering its mandatory nature, and duplicate voluntary PHI under voluntary PHI market, considering its voluntary nature.

By using the explained variance as weights for the respective components, we are ensuring that the mandatory government schemes, which explain more variability in the original underlying indicators, are given more importance. This implies that the mandatory government schemes component has a larger influence on our final composite measure of the financing mix, reflecting its relative importance compared to the voluntary PHI market financing and coverage provisions.

4.3 Composite Measure of Health System Mandatory-Voluntary Financing Mix

Table 4 shows the composite measure of health system mandatory-voluntary financing mix and its underlying indicators. In 2022, the composite measure of health system mandatory-voluntary financing mix scores in the included countries varied between a minimum value of 1.3 and a maximum value of 8.2 (Table 4). Countries that exhibit similar scores rely on similar health system arrangements as defined form the underlying indicators. For instance, countries with low score (0–2), such as Italy, the UK and Denmark, have NHS-type systems relying mainly on taxation. Countries with low-medium score (2–5) are characterized by a universal single insurer/payer (Table 1), mainly financed through taxation such as Australia and Canada or social health insurance contributions such as Korea. Australia and Canada, with their single-insurer models, show scores more aligned with those countries that adopt a NHS model. In contrast, South Korea transitioned from a multiple-insurer system to a single-insurer model only in 2000, positioning it closer to countries where universal coverage is provided through multiple insurers (Lee et al., 2008). Indeed, countries with high medium score (5–8) are characterized by multiple payers mainly financed through taxation or social health insurance contributions such as Germany, Japan, France, the Netherlands, and Switzerland. These countries, except Japan, also rely on compulsory private health insurance. Lastly, the US exhibits a highly mixed system relying on multiple arrangements, including primary voluntary health insurance (8–10). The US is considered an outlier, as it is characterized by a unique system compared to the other countries in the sample. It is composed of a multitude of residual schemes, financed by general taxation and intended for specific population targets, such as the Veterans Health Administration, Medicare (for those 65 and older), and Medicaid (for low-income individuals) (Toth, 2016). Moreover, it is the only system that relies on voluntary PHI, covering 24.5% of the population (Table 4).

4.4 Long Term Dynamics of Financing Mix in Health Systems

We replicated the analysis for the 1995–2022 period for both the composite measure and its individual components (Tables 8A, 9A). A slight but continuous trend of convergence in the financing mix can be observed, as the range of the composite measure narrows from 0.1 (1995) to 1.3 (2022) in the lower interval and from 9.5 (1995) to 8.2 (2022) in the upper interval (Table 7A). We applied the Phillips and Sul (2007) convergence test and club clustering analysis to our health system financing composite measure. This test identifies convergence clubs, which are groups of countries that converge to similar levels or patterns over time. The convergence log t-test indicates convergence 9 (tk

> − 1.65) for both the composite measure and its components, including mandatory government schemes and voluntary PHI market (Table 10A appendix). The club clustering analysis results show that all countries in our sample belong to a single convergence club, suggesting a common long-term trend in health system financing mix across these OECD countries, despite potential short-term divergences or country-specific variations. However, this convergence does not necessarily imply that all countries are becoming identical in their financing mix, but rather that they are moving towards a similar pattern or level of financing mix over time. Two groups can be distinguished (Fig. 1). First, countries with a single insurer increase their mandatory-voluntary financing mix. Second, countries with multiple insurers tend to decrease their financing mix. However, the rate of change in the financing mix is relatively faster in the second group of countries. Exceptionally, Canada maintains a consistent score throughout the entire period. In both groups, mandatory contributory government schemes remain relatively more stable compared to the voluntary PHI component. The convergence trend in the funding mix is primarily driven by the voluntary private health insurance component (Fig. 1). The upward trend of the voluntary PHI market, driven by Korea (1997), is continuous across the two waves in countries with a single insurer. The downward trend starts in the Netherlands in 2006, before the economic crisis, and in Germany (2008), the US (2012), and France (2015), after the economic crisis.

The decline in reliance on voluntary PHI is a common factor driving reforms in multi-insurer countries, reshaping the balance between mandatory and voluntary sectors in healthcare. These shifts are captured by our composite measure (Fig. 1), though they are motivated by different policy rationales across various nations. In the Netherlands, the 2006 Health Insurance Act integrated social and private health insurance

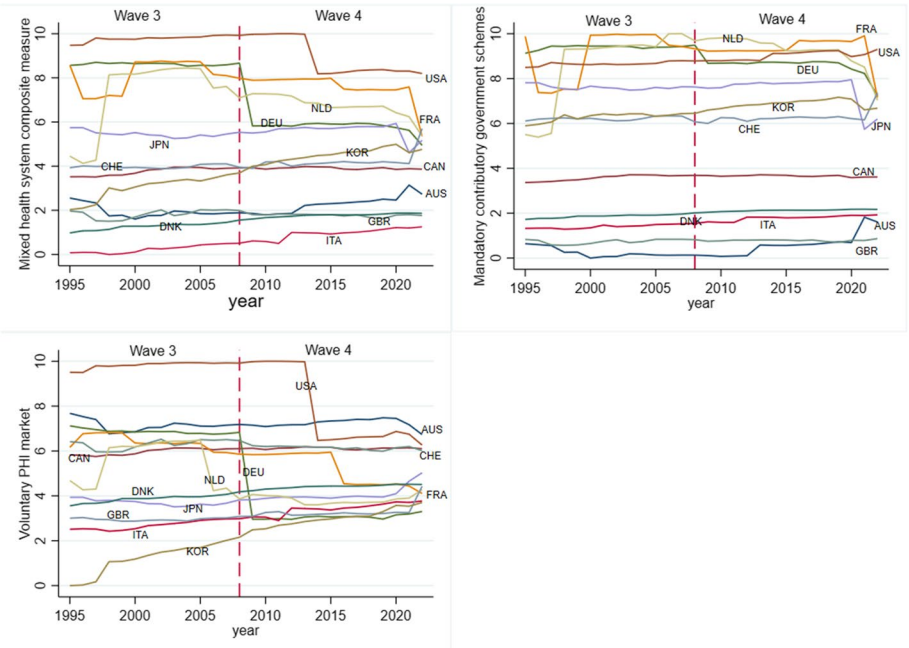

Fig. 1 Overall composite measure and its components across the third and fourth wave of reform (1995–2022)

into a single national scheme managed by private insurers, funded by income-related contributions that are pooled centrally and distributed through risk-adjusted capitation payments (Jeurissen & Maarse, 2021; van Kleef et al., 2018). This reform incentivized insurers to act as prudent buyers of care, with open enrollment allowing individuals to switch insurers annually (Schut et al., 2023). In Germany, the 2008 reform mandated coverage for all, allowing individuals with gross wages exceeding the income threshold of €68,000 and the self-employed to either remain in public insurance or opt for private coverage. 16.2% of the population is covered by compulsory PHI in 2022 (Blümel et al., 2021; OECD, 2023b). In the US, the 2012 Affordable Care Act (ACA) introduced a regulatory mandate requiring individuals to purchase health coverage (The Commonwealth Fund, 2020). After the ACA introduction, the uninsured rate for adults aged 19 to 64 reduced from 20% in 2010 to 12% in 2018 (The Commonwealth Fund, 2020). By 2023, 27.5% of the population was covered by compulsory PHI (OECD, 2023b). The law also aimed to promote equal access through individual mandates, subsidies, and the expansion of public programs like Medicaid and CHIP (Rice, 2021). However, in 2019, over one-third of Medicare beneficiaries chose private Medicare Advantage plans (The Commonwealth Fund, 2020). In France, since 2016, all employers must provide group PHI. Legal standards were introduced to address disparities in access and quality of coverage. All VHI contracts uniformly cover the gap between the reimbursement provided by SHI and the official fee (Chevreul et al., 2015). 95% of the population covered either through employers, of which 6% use means-tested vouchers and 3% receive free state-sponsored coverage (Durand-Zaleski, 2020).

4.5 Robustness Test and Sensitivity Analyses

The composite measure of health system mandatory-voluntary financing mix is the weighted sum of the scores of these two components. Test of Sphericity rejected the null hypothesis that variables are uncorrelated (p-value = 0.00). The Cronbach's alpha coefficient was calculated at 0.67. To assess the robustness of the composite measure, we recalculated the measure, retaining 4 components, accounting for an overall explained variance of 85%, which is an alternative criterion to select PCA components (Table 6A). The Pearson coefficient between the base composite measure and the measure recalculated with 4 components is 0.97 (Table 16A). Additionally, we test the sensitivity of the composite measure of mixed financing systems by calculating Spearman rank correlation coefficients between our base composite measure and the re-computed composite measure, achieved by dropping one indicator at a time (Table 11A), employing alternative weight approaches (Table 12A), ignoring missing data (Table 13A), using alternative variable transformations (Table 14A), and employing different aggregation methods (Table 15A). While all the recalculated composite measures exhibited a strong correlation with the base composite measure, the score is moderately sensitive to the inclusion of primary voluntary PHI. When primary voluntary PHI was removed, the correlation dropped below 0.7. To test the explanatory power, we correlate our composite measure to the current expenditure on governance and administration, as explained in Sect. 3.3.6. As expected, the composite measure of health system mandatory-voluntary financing mix shows a strong positive correlation with current expenditure on governance and administration as a share of gross domestic product (Spearman = 0.74) (Table 17A). The US stands out as a clear outlier (Fig. 2A).

5 Discussion

This paper explores the conceptual and methodological framework for developing a composite measure to systematically compare the evolution of health system financing across 12 OECD countries over 28 years. This measure can be used as a descriptive tool to comparatively quantify and qualify how the mandatory-voluntary financing mix is achieved. A composite index methodology was chosen for its ability to measure multidimensional phenomena, understand their development over time, and facilitate comparisons across countries (Booysen, 2002). Analytic tools such as composite measures have increasingly been used to support reforms and policies (Saltelli, 2007). For instance, the European Union has established a Center for Composite Indicators and Scoreboards (CC-COIN), applying them across various policy fields (European Commission, 2023; OECD et al., 2008). We have developed an alternative measure to previous indices to better reflect the complexity and multidimensionality of countries' health system financing mix (Barros, 2007; Gabani et al., 2023; Götze & Schmid, 2012), thereby contributing both theoretically and empirically to previous health system frameworks and classifications.

5.1 Beyond the Public–Private Dichotomy: Capturing the Complexity of Mixed Health System Financing

Over time, health systems have experienced four successive waves of reform, leading to inherently mixed financing models that challenge the traditional public–private classification (Barros & Siciliani, 2011). A composite index of health system financing mix quantifies the relative distribution of different health system funding sources (e.g., mandatory government schemes and voluntary PHI) within a health system. It provides a single metric that captures both the diversity of funding streams and their relative importance, allowing for comparison across health systems and time. The index reflects the degree of financial fragmentation, which has implications for efficiency, equity and financial protection. Our composite measure of health system financing represents and includes multiple financing dimensions that characterize the increasingly complex design of national health systems, including the ownership of the financing scheme (public, private) (Toth, 2016), its compulsoriness (mandatory, voluntary) (Barros & Siciliani, 2011; Paolucci, 2011), the nature of payer (single, multiple) (Toth, 2016), the role that voluntary PHI plays relative to the mandatory schemes (Colombo & Tapay, 2004). However, historically, health system financing has been categorized in the traditional tripartite classification, each reflecting one of the then prevalent ways of health care financing (Cuadrado et al., 2019). Following this logic, previous indices have attempted to capture the public–private funding mix by incorporating the three traditional financing sources and OOP expenditure (Barros, 2007; Götze & Schmid, 2012). Focusing solely on these financing dimensions may well ignore critical dimensions of mixed health systems such as the various dimensions of coverage, limiting the ability of a composite measure to capture the true complexity of mixed health system financing.

Therefore, in addition to the four indicators used in earlier indices, we incorporate mandatory private health insurance spending, and the percentage of the population covered by voluntary duplicate and primary private health insurance. Including the percentage of the population covered by specific financing schemes captures not only financial allocation but also the population's access to these schemes, which spending measures alone cannot fully reflect. The percentage of population covered is a crucial dimension of UHC. By expanding the scope of analysis, our measure provides a more comprehensive understanding of health system financing.

Most empirical studies on health systems have relied on static classifications based on the prevailing model (Reibling, 2010; Reibling et al., 2019). This logic can lead to the grouping of vastly different systems under the same category (Toth, 2016). This oversimplification obscures critical interactions within health systems, particularly at the intersection of mandatory government schemes and voluntary PHI markets. Given that equity and efficiency issues often emerge at the interface of multiple financing mechanisms, a reductive health system classification can limit our ability to understand how these interactions affect overall health system performance.

5.2 Advancing Methodologies for Constructing Composite Indices of Health System Financing Mix

Barros (2007) constructed a standard instability index to understand the evolution of the health system financing mix, based on absolute changes, which is appropriate for capturing variability between consecutive time periods. Götze and Schmid (2012) developed an index of hybridity using Euclidean geometry (Pythagorean Theorem) to measure the distance from a hypothetical funding mix that equally utilizes three main sources of funding, based on the Euclidean distance, which accounts for the overall magnitude of differences across multiple dimensions, providing a measure of divergence between data points. While previous methods used to measure the funding mix (Barros, 2007; Götze & Schmid, 2012) assessed similarity or dissimilarity between data points, we used PCA for dimensionality reduction and feature extraction, which is convenient for systematically comparing the evolution of the funding mix across countries over time. Considering the need to account for different dimensions when defining and measuring health systems, methods based on Euclidean geometry, lacking dimensionality reduction, may become difficult to interpret as the number of variables increases (Jolliffe, 2002).

Past studies have used cluster methodology to categorize health system organizational models, grouping countries under a prevalent type (Reibling et al., 2019; Wendt, 2014). Considering that the funding mix in health systems varies significantly across countries (Paris et al., 2010), our measure instead provides a year-country gradient of the funding mix rather than a classification of system into pre-defined categories, making the tool more versatile for use in longitudinal research. This offers greater flexibility in statistical analysis for modelling and testing, and preserves more information from the original data, enabling the quantification and qualification of differences between countries. Barros' (2007) standard instability index only measures period-to-period changes, meaning it may miss structural shifts that occur over a specific year, limiting the understanding of the underlying drivers of these trends. Instead, PCA allows for the identification and visualization of the drivers of the funding transition, capturing of long-term reform dynamics.

Furthermore, previous measures (Barros, 2007; Götze & Schmid, 2012) use equal weighting to construct composite indices, which might not account for the different importance that various financing sources play within health systems (Dialga & Thi Hang Giang, 2017). Indices that utilize equal weighting are relatively more straightforward than those that use multivariate techniques (Booysen, 2002). However, if indicators that are highly correlated are combined into a composite, an element of double counting might be introduced (OECD et al., 2008). When using explicit weights, the traditional method typically involves selecting them after consulting with experts (Booysen, 2002). However, methods based on subjective weighting might not measure the importance of each component but rather the urgency or need for political intervention (OECD et al., 2008). Instead, PCA offers a data-driven, objective, and statistically rigorous approach to weighting, ensuring more transparency and replicability.

5.3 Policy Lessons from Long Term Reform Dynamics

OECD countries are moving toward a convergent model of financing. Despite the second component weighing relatively less in the construction of the composite measure, a reduction in the reliance on the voluntary PHI market appears as a major driver of change in the funding mix. However, there are major differences among countries. The reform shifts occurred in countries with multiple insurers mainly financed through social health insurance (Fig. 1). The Netherlands (2006), Germany (2008), the US (2012) and France (2015) increased their reliance on compulsory private health insurance (OECD, 2023b). The role of the 2008 economic crisis in driving or reinforcing the trend of convergence in health financing remains ambiguous. For instance, in Korea (1997) and the Netherlands (2006), the convergence trends initiated well before the onset of the global economic crisis. Conversely, in the US (2012) and France (2015), these patterns did not manifest until well after the crisis. Only in Germany did the downward trend coincide with the economic crisis in 2008. The demand for voluntary PHI might be more elastic to the effects of economic shocks such as disposable income or employment status, altering individuals' perception of the value of insurance products. Although some of these reforms might be attributed to the lagged effects of the economic shock, other secular trends, such as aging population, chronic disease burden, political forces or path dependencies could also play significant roles.

6 Limitations

Despite the theoretical and empirical contribution in constructing a descriptive tool to monitor health system mandatory-voluntary financing mix across countries and over time, this study is not without limitations.

First, our sample size surpasses the 5:1 observation-to-variable ratio, which could impact the stability of the component solutions (Gorsuch, 1983; Johnson & Wichern, 2002; McLachlan, 1992). Although we rejected the null hypothesis of no correlation in Bartlett's Test of Sphericity, the Kaiser–Meyer–Olkin (KMO) test statistic of 0.52 fell short of the critical value of 0.6 needed for sample adequacy (Kaiser, 1970, 1974; Kaiser & Rice, 1974). However, the validity of this test has been called into question, as the Bartlett's Test of Sphericity (BTS) lacks statistical power in the context of small sample sizes (Dochtermann & Jenkins, 2011). To address this challenge, we extended the analysis across each of the 12 countries over a 28-year period, yielding 336 observations.

Second, while Cronbach's alpha and Spearman correlation coefficient with external measures are valuable tools for validating a composite measure, their limitations necessitate cautious interpretation of results. Cronbach's alpha assumes that all items in a scale measure the same underlying construct (Tavakol & Dennick, 2011). The violation of this assumption can significantly lower the estimated reliability (Tavakol & Dennick, 2011). Spearman's rank correlation coefficient measures the strength and direction of a monotonic relationship, but relationships between variables might not be linear (Sedgwick, 2014). Nonetheless, these limitations are mitigated because our composite measure is built on a strong theoretical basis for appropriate variables selection. Furthermore, a number of sensitivity analyses have been conducted to provide insights into its robustness.

Third, our composite measure does not include important variables that could significantly contribute to explaining the mix of mandatory government schemes and voluntary private health insurance due to the absence of comparable data. Complementary and supplementary

private health insurance have been recognized as important in defining health system financing mix in the conceptual framework. In NHS-type health systems, where taxation is the primary financing source, such as in Italy, the UK, and Denmark, lower scores in the composite measure might suggest a lesser reliance on a mix of mandatory and voluntary financing compared to countries with SHI-type systems, primarily relying on contributions. However, this interpretation should be approached with caution, as these countries also have a significant proportion of the population covered by voluntary private supplementary insurance markets, which are omitted form the analysis due to lack of data (Table 1).

Fourth, the dynamics of health system changes identified in this study are primarily driven by Korea in single-insurer systems and by the Netherlands, Germany, the US, and France in multi-insurer systems. While this concentration might seem to limit the generalizability of the identified trends, it also underscores how critical system-level reforms have shifted the balance between mandatory and voluntary components in a subsample of countries. Therefore, the composite measure provides a valuable policy tool for comparing reform experiences across different national health systems. Furthermore, PCA can be sensitive to the distribution of data (OECD et al., 2008). These may also limit the generalizability of the findings. Finally, although this paper adopts a system-level perspective, it is important to recognize that subnational levels can exhibit significant heterogeneity in terms of financing and coverage arrangements.

7 Conclusion

Our composite measure of mandatory-voluntary financing mix has the potential to systematically compare the dynamics of health system financing reforms across countries over time, identifying the drivers of this transition. By using PCA, we addressed the complexities of typologizing health system financing and advanced previous methodological approaches. The composite measure of the financing mix provides a system-level overview, distinguishing the pace of reform across countries, including between countries that adopt comprehensive reforms and those that follow incremental approaches. Similar to how other composite measures have been employed in previous research (Bambra, 2006; Martinussen & Rydland, 2022), this tool has the potential to assess associations with health system performance outcomes. Further research is necessary to empirically investigate whether and how this measure relates to other health system characteristics, such as provision, and to fully explain the causes and consequences of the observed changes in the financing mix, from which important policy lessons can be drawn. While our approach provides valuable insights into the overall structure of the mandatory-voluntary health system financing mix over time, particularly given the small sample size, future research could expand the sample as more data become available and explore alternative methods, such as dynamic PCA or comparing PCAs across different time periods, to offer further perspectives on the temporal dynamics of health system financing.

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Data Availability The data used for this study are publicly available.

Declarations

Ethics Approval and Consent Not applicable.

Competing interest The authors have no competing interests to declare.

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