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Who should bear the cost of COVID-19 non-vaccination? An equity analysis using a luck egalitarian framework in a South African insured population

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TITLE PAGE

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ABSTRACT

Background

Personal choice in health behaviours raises difficult questions of equity: when individuals freely decline effective health interventions, who should bear the resulting costs? This question sits at the heart of debates about personal responsibility in health financing, yet it has rarely been examined empirically. Luck egalitarianism offers a framework for assessing these questions: inequalities arising from brute luck (circumstance) should be compensated, while those from option luck (genuine choice) may legitimately be borne by individuals. Applying this framework requires distinguishing empirically between non-vaccination due to choice and non-vaccination due to constrained circumstance — a distinction that has rarely been operationalised in real-world health financing contexts. COVID-19 vaccination in South Africa's privately insured population, where vaccines were freely available and access barriers minimal, offers a favourable setting for such an inquiry.

Methods

Using de-identified claims data for approximately 550,000 members of two South African medical schemes (March 2020–December 2022), we estimated each individual's predicted probability of

vaccination based on demographic and clinical characteristics using logistic regression. We compared observed and predicted uptake across probability strata to infer whether non-vaccination reflected personal choice or constrained circumstance. We then modelled excess costs attributable to non-vaccination using a zero-inflated negative binomial model, comparing observed expenditure with a counterfactual in which all members were vaccinated. Excess costs were calculated across predicted probability strata.

Results

Predicted and observed vaccination rates aligned closely, suggesting that residual non-vaccination in higher-probability groups reflected personal choice rather than constrained circumstance. Observed costs exceeded predicted costs by an average of 22% under a universal vaccination scenario, with the excess concentrated among older adults and those with comorbidities. Among younger, low-risk members, predicted costs slightly exceeded observed expenditure, as the fixed cost of vaccination was not offset by avoided hospitalisation.

Conclusions

The study empirically distinguished choice-based from circumstance-based non-vaccination and quantified the financial consequences of that distinction in the pseudo-laboratory setting of the study. This offers an empirical basis for assessing the equity of responsibility-based financing arrangements, and for deliberating when personal responsibility should inform health financing design.

Keywords

COVID-19 vaccination, Cross-subsidisation, Equity, Fairness, Health financing, Luck egalitarianism, Personal responsibility, Risk pooling, Solidarity, South Africa

Title: Who should bear the cost of COVID-19 non-vaccination? An equity analysis using a luck egalitarian framework in a South African insured population

Background

Personal choice in health behaviours raises difficult questions: when individuals make poor health choices or elect to decline effective health interventions, who should bear the resulting costs? This question has become increasingly pressing as behavioural risk factors drive a growing share of the global disease burden [1, 2], and as scarce medical resources are consumed by conditions that could be avoided through individual behaviour rather than directed at suffering for which no individual is responsible [3]. At stake are fundamental questions of equity: how responsibility for health should be distributed between individuals and the collective, and whether inequalities in health outcomes and costs reflect unfair disadvantage or legitimate consequences of personal choice.

Personal responsibility in health policy refers to approaches that link an individual's contributions, coverage, or access to care to factors under their control, through mechanisms such as premiums, co-payments, benefit limitations, or exclusions. The underlying logic is that those who make personal choices that increase their risk of illness or injury should bear a greater share of the associated costs or face limitations on the care they receive [4, 5]. Such approaches remain deeply contested [6]. Proponents argue that individuals should bear some consequences for avoidable ill health arising from their choices, as this promotes fairness and efficient use of limited resources [5]. Critics counter that health behaviours often reflect structural constraints, social determinants, and access barriers rather than genuine choice, undermining the fairness of assigning responsibility [7, 8]. This impasse has been long standing, in part because the debate has remained largely abstract.

Underlying this impasse are different views of what constitutes justice, the morally proper distribution of benefits and burdens within society [9] and, more specifically, distributive justice: how the benefits of health care (access, treatment, resources) and the burdens of paying for them should be allocated among individuals with competing needs and claims[9, 10]. What counts as fair or equitable depends on which theory of distributive justice is valued. Libertarianism holds individuals responsible for the consequences of their choices, and regards market allocation as the fairest mechanism [11]. Classical egalitarianism disregards choice entirely, arguing that access to care should be based on need rather than behaviour [12]. Communitarianism prioritises collective welfare [13-15], while utilitarianism is indifferent to responsibility except insofar as it affects aggregate welfare [14, 16]. Each theory therefore yields a different criterion for what counts as a fair distribution, and each would assess the equity of responsibility-based policies differently. This divergence helps explain why the debate has remained unresolved, and why empirical evidence alone cannot settle it.

Luck egalitarianism occupies a middle position between these extremes and offers a particularly relevant lens for assessing the equity of responsibility-based health policies. It reconciles a commitment to equality with recognition that genuine personal choices matter[5, 17]. It distinguishes between inequalities arising from factors beyond individual control — brute luck — and those arising from genuine personal choices — option luck [5, 10, 18]. Under this framework, inequalities from brute luck are unjust and should be compensated, while inequalities from option luck may legitimately be borne by individuals. This distinction is central to equitable health financing: it provides a principled basis for determining which health care costs should be pooled and which may fairly be attributed to individual choice. A key challenge of this framework is an empirical one: how can we determine whether a given health outcome reflects choice or circumstance? Roemer operationalised this distinction by separating outcomes due to "circumstances" from those due to "effort"[19, 20]. Yet applications of this approach to real-world health financing decisions remain rare.

South Africa, with among the highest levels of income inequality globally and a dual health system comprising a public sector serving approximately 84% of the population and a private sector covering the remaining 16% [21], offers a particularly salient setting for this inquiry. Within the privately insured population, community-rated premiums mean that costs are pooled across members, raising directly distributional questions about who bears the burden of avoidable health care expenditure.

COVID-19 vaccination is a favourable case for such an inquiry. It is a clearly defined preventive action, and in South Africa's privately insured population, vaccines were freely available and financial and physical access barriers were minimal [22, 23]. This creates conditions in which non-vaccination can more plausibly be attributed to personal choice rather than constrained access, allowing the luck egalitarian distinction between choice and circumstance to be operationalised in a real-world health financing context. COVID-19 vaccination in the insured population thus serves as a useful "pseudo-laboratory" for operationalising luck egalitarian principles in a real-world context.

This setting allows us to ask: when individuals chose not to vaccinate despite free and widespread availability, should they bear the resulting health care costs? We pursue two aims. First, we assess whether non-vaccination reflected genuine personal choice rather than constrained circumstance. Second, we quantify the distribution of COVID-19-related costs between vaccinated and unvaccinated members of the insurance pool. In doing so, the study empirically applies luck egalitarian principles to a real-world health financing question, offering an empirical approach to assessing the equity of responsibility-based health financing arrangements.

METHODS

Overview

This study draws on secondary insurance claims data to operationalise a luck egalitarian framework in the context of COVID-19 vaccination within a South African insured population. The framework distinguishes between inequalities arising from choice and those arising from circumstance, a distinction central to assessing the equity of responsibility-based health financing arrangements.

The analytical approach is informed by the work of John Roemer [19, 20], who developed a formal framework for distinguishing outcomes due to "circumstances" (factors beyond individual control) from those due to "effort" (matters of personal responsibility). Roemer's method involves dividing the population into "types" sharing the same circumstances and comparing effort within types. While the available data limited us to a regression-based approach rather than Roemer's full "type" methodology, the underlying logic is the same: individuals with a high predicted probability of vaccination (given their circumstances) who nevertheless remain unvaccinated are inferred to have made a genuine personal choice.

Following the principles of the STROBE guidelines[24] for observational studies and the CHEERS 2022 guidelines[25] for economic evaluations, we sought to ensure transparent reporting of study design, data, and analysis, while recognising that the hybrid normative–empirical nature of this study does not map perfectly onto standard reporting checklists.

The study comprised two components, corresponding to the two research aims: The first assessed whether non-vaccination could reasonably be attributed to personal choice rather than constrained circumstance, where circumstance is understood broadly to include factors beyond individual control, such as access barriers. This step is foundational: only if non-vaccination reflects choice can the resulting costs be fairly attributed to individual behaviour. The second component quantified the extent to which non-vaccinated members generated excess costs borne by the insurance risk pool as a whole. An overview of the data, the analytic approach, the outputs and interpretation are summarised in Figure 1.

Figure 1. Overview of data inputs, analytic approach, and outputs and interpretation.

Setting, Context, and Study Population

The study population consisted of 550,327 individuals who were enrolled in one of two large medical schemes between 1 March 2020 and 31 December 2022. This period corresponds to the first confirmed COVID-19 case in South Africa (5 March 2020) and the end of the fourth wave with the lifting of restrictions (30 December 2022). The sample represents approximately 5% of the South African insured population and is broadly comparable to the national insured population in terms of household structure, contributions, and health expenditure patterns [26].

Vaccination coverage was determined by national rollout policy. Two vaccines were primarily used in South Africa during the study period: the Johnson & Johnson (J&J) adenoviral vector vaccine and the Pfizer-BioNTech mRNA vaccine [27, 28]. Vaccination status was defined dynamically over time, following definitions established in the literature [29] and consistent with South African practice [30]. For the analyses in this paper, individuals who received at least one dose of either vaccine were classified as vaccinated; those with no recorded doses were classified as non-vaccinated. While earlier research on this cohort distinguished between partial and full vaccination [26], this paper's analytical requirements, particularly the need to generate stable predicted probabilities and counterfactual cost estimates, favoured a binary classification. This also allowed for clearer interpretation of the choice-versus-circumstance distinction.

Data Sources

De-identified individual-level claims data were extracted from the data warehouse of NMG Consultants and Actuaries, an independent actuarial firm managing the schemes included. Three linked datasets were constructed:

- Demographic dataset which consisted of a record per enrolled member, including unique study identifier, sex, age, province of residence, enrolment dates, and comorbidity indicators. Comorbidities considered were those identified as clinically relevant for COVID-19 outcomes (cancer, chronic renal disease, congestive cardiac failure, COPD, diabetes, HIV, hypercholesterolemia, hypertension, hypothyroidism, ischemic heart disease, pregnancy, tuberculosis). These were identified following Council for Medical Schemes (CMS) claims-based algorithms[31].
- Vaccination dataset which consisted of a record for each COVID-19 vaccination event, including vaccine type, date, provider, and amount reimbursed. Vaccination status was defined dynamically over time and collapsed into an end-of-period measure: vaccinated (≥1 dose) vs. non-vaccinated.

- A hospital and related expenditure dataset which consisted of a record for each COVID-19 hospital admission, including admission/discharge dates, length of stay, ICD-10 diagnosis codes, procedure codes, and total reimbursed hospital expenditure. Individuals with multiple admissions contributed multiple records.

Total hospital and vaccination related expenditures took an insurer perspective and reflected the amounts paid by the health insurance funds to cover the claims submitted by health care providers for services rendered to the hospitalised individuals. These direct costs included health care providers, hospital bed days, as well as any pharmaceuticals, medical or surgical consumables dispensed, and vaccinations provided. All expenditures in South African Rands (ZAR) were converted to United States Dollar ($) values using the December $/ZAR exchange rate for the given year and then inflated/deflated to be expressed in 2022 values using the South African Consumer Price Index[32].

Part 1: Assessing Non-vaccination as Choice versus Circumstance

We distinguished between non-vaccination due to personal choice (voluntary refusal despite available opportunity) and due to constrained circumstance where circumstance is understood broadly to include factors beyond individual control, such as access barriers.

For the contextual assessment, following established frameworks in the health care access literature [33, 34], we conceptualised access barriers across three dimensions: availability, financial risk protection, and acceptability. The barriers across the three dimensions were assessed by a contextual review of the policy environment, vaccination coverage and communication strategies. We reviewed scheme-level benefit coverage, Council for Medical Scheme circulars mandating COVID-19 vaccination as a prescribed minimum benefit [22, 23], and publicly available scheme communication strategies during the rollout[30].

Empirically, we estimated each member's probability of vaccination using logistic regression with vaccination status (vaccinated vs. non-vaccinated) as the dependent variable. Independent variables included sex, age group (<18, 18–25, 25–40, 40–65, ≥65), presence of COVID-19 comorbidity (yes/no), and province of residence. The model produced a predicted probability of vaccination for each individual, reflecting the predicted uptake given their demographic and clinical profile.

To infer the relative role of choice versus circumstance, we then grouped individuals into strata based on their predicted probability of vaccination (0–10% to 70–80%), allowing comparison of actual and predicted vaccination rates across groups with similar predicted probability of vaccination. The underlying logic, informed by Roemer's framework[19, 20], is that individuals with a high predicted

probability of vaccination (given their circumstances) who nevertheless remain unvaccinated can reasonably be inferred to have made a genuine personal choice. Conversely, those in low-probability strata may have faced unmeasured access barriers or other circumstances beyond their control. We did not set any arbitrary cut-offs, but persistent non-vaccination in higher-probability strata (e.g., ≥50%) is more plausibly attributable to personal choice, while non-vaccination in lower strata (<30%) could reflect “constrained circumstance" or "access barriers”.

Part 2: Assessing Excess Costs and Cross-subsidisation

To quantify the excess costs associated with non-vaccination, we conducted a three-step analysis. In the first step, we restricted the dataset to vaccinated members and used their information to build a benchmark model to estimate the predicted COVID-19–related costs had the individual vaccinated. Because most individuals incurred no COVID-19 hospital expenditure while a smaller proportion incurred very high costs, we applied a zero-inflated negative binomial (ZINB) regression model. This model accommodates both the probability of zero costs and the over-dispersed distribution of positive costs. Predictor variables included sex, age group, comorbidity status, and province. The model generated a predicted cost for each member, representing the average expenditure anticipated for an individual with their risk profile if they had vaccinated.

In the second step, we applied this benchmark model to the entire study population, both vaccinated and unvaccinated, to generate a counterfactual scenario estimating what each individual’s costs would have been if they had been vaccinated, given their demographic and clinical characteristics. This produced predicted expenditure under a universal vaccination scenario.

In the third step, we compared observed and predicted costs across the predicted probability bands generated in Part 1, allowing direct comparison between actual expenditure and the counterfactual for each individual.

Two indicators were derived to quantify the additional costs associated with remaining unvaccinated. The excess cost was calculated as the absolute difference between observed and modelled (predicted) expenditure, while the excess cost percentage was calculated as ((Observed/Predicted)-1)*100, representing the proportional deviation from predicted expenditure. Positive values indicate higher costs than would be predicted under the universal vaccination scenario, denoting greater costs attributable to non-vaccination. Together, these indicators quantify both the absolute and relative extent to which higher costs among unvaccinated members increased the collective costs borne by the insured risk pool. Finally, we examined observed versus predicted expenditure and excess cost across strata defined by predicted vaccination probability bands (from Part 1 of the analysis).

RESULTS

Study Population

The study included 550,327 individuals enrolled between March 2020 and December 2022. Of all the individuals, 53.6% were female, 34.4% were less than 18 years old, 23.3% had one or more comorbidity, and the highest proportion (45.4%) of individuals resided in Gauteng province (Table 1).

Table 1. Characteristics of study population

Variable	Number of individuals	
	N	% of total
Sex		
Female	295 112	53.6%
Male	255 216	46.4%
Age		
Less than 18	189 402	34.4%
Between 18-25	40 190	7.3%
Between 25-40	145 003	26.3%
Between 40-65	140 255	25.5%
Greater than 65	35 477	6.4%
COVID-19 Comorbidities		
No	422 116	76.7%
Yes	128 215	23.3%
Province		
Eastern Cape	40 877	7.4%
Free State	22 347	4.1%
Gauteng	249 646	45.4%
KwaZulu-Natal	85 572	15.5%
Limpopo	19 410	3.5%
Mpumalanga	18 514	3.4%
North-West	19 064	3.5%
Northern Cape	10 002	1.8%
Western Cape	84 895	15.5%
Total	550 327	100.0%

Part 1: Non-vaccination by Choice versus Circumstance

A contextual review of policy environment, vaccination coverage and communication strategies was undertaken to assess access barriers in terms of availability, financial risk protection and acceptability. In terms of financial risk protection, vaccines were provided free of charge to all eligible individuals, with costs of administration covered by medical schemes and vaccine procurement covered by the

state [22, 35]. Access was supported through a network of public and private vaccination sites, and major schemes, including those analysed here, implemented extensive member communication campaigns via digital portals, SMS prompts, and call-centre support [30]. These features substantially reduced barriers linked to financial risk protection (no out-of-pocket costs) and availability (widespread vaccination sites). Extensive communication campaigns by schemes and public authorities further addressed information-related barriers, though unmeasured dimensions of acceptability, such as vaccine hesitancy and trust, may have persisted.

In terms of the empirical analysis, an overall 37.2% of the study population received at least one dose of a COVID-19 vaccine by the end of study period (Table 2).

Table 2. Univariate and multivariate analysis of vaccination probability

Variable	**Number of individuals**			
	N	**Number Vaccinated**	**% Vaccinated**	**Adjusted OR (95 CI)**
Sex				
Female	295 112	116 328	39.4% (39.2%-39.6%)	Reference
Male	255 216	88 288	34.6% (34.4%-34.8%)	0.89 (0.88-0.90)
Age				
Less than 18	189 402	13 547	7.2% (7.0%-7.3%)	Reference
Between 18-25	40 190	16 161	40.2% (39.7%-40.7%)	8.69 (8.46-8.92)
Between 25-40	145 003	63 835	44.0% (43.8%-44.3%)	9.69 (9.49-9.89)
Between 40-65	140 255	85 037	60.6% (60.4%-60.9%)	17.11 (16.75-17.48)
Greater than 65	35 477	26 036	73.4% (72.9%-73.8%)	24.24 (23.49-25.02)
COVID-19 Comorbidities				
No	422 116	125 996	29.8% (29.7%-30.0%)	Reference
Yes	128 215	78 620	61.3% (61.1%-61.6%)	1.55 (1.52-1.57)
Province				
Eastern Cape	40 877	15 837	38.7% (38.3%-39.2%)	Reference
Free State	22 347	8 363	37.4% (36.8%-38.1%)	1.04 (1.00-1.08)
Gauteng	249 646	96 709	38.7% (38.5%-38.9%)	1.18 (1.15-1.21)
KwaZulu-Natal	85 572	27 698	32.4% (32.1%-32.7%)	0.79 (0.77-0.81)
Limpopo	19 410	5 981	30.8% (30.2%-31.5%)	0.91 (0.87-0.94)
Mpumalanga	18 514	5 084	27.5% (26.8%-28.1%)	0.69 (0.66-0.72)
North-West	19 064	6 129	32.1% (31.5%-32.8%)	0.86 (0.82-0.89)
Northern Cape	10 002	3 358	33.6% (32.6%-34.5%)	0.84 (0.80-0.88)
Western Cape	84 895	35 457	41.8% (41.4%-42.1%)	1.08 (1.06-1.12)
Total	**550 327**	**204 616**	**37.2% (37.1%-37.3%)**	

Across the predictor variables, females (39.45%, 95%CI 39.2%, 39.6%), individuals aged 65 and above (73.4%, 95%CI 72.9%, 73.8%), those with one or more comorbidity (61.3%, 95%CI 61.1%, 61.6%) and those from the Western Cape (41.8%, 95%CI 41.4%, 42.1%) had higher vaccination rates. In multivariate analysis, after adjustment for all other factors, males were less likely to be vaccinated than females (AOR 0.89, 95%CI 0.88, 0.90), while individuals aged 65 and above (AOR 24.24, 95%CI 23.49, 25.02), those with COVID-19 comorbidities (AOR 1.55, 95%CI 1.52, 1.57) and those from Gauteng (AOR 1.18, 95%CI 1.15, 1.21) were more likely to be vaccinated [Table 2].

Table 3 presents the distribution of the study population by predicted probability of vaccination and compares the observed proportion vaccinated with the model-predicted proportion in each stratum. The predicted probability of vaccination was estimated using logistic regression. Individuals were then grouped into strata based on their predicted probability (e.g., 0–10%, 10–20%, etc.), allowing comparison of actual and predicted vaccination rates across groups with similar predicted likelihoods. The table shows, for each predicted probability stratum, the number of individuals in that stratum, the proportion of the total population they represent, the observed vaccination rate, and the model-predicted vaccination rate.

Table 3. Observed and predicted vaccination rates by predicted probability strata

Predicted strata ***	N	% of total	Observed *	Predicted **
0%-10%	182 570	33.2%	6.8%	7.0%
10%-20%	6 832	1.2%	17.2%	11.3%
20%-30%	697	0.1%	23.4%	29.1%
30%-40%	49 000	8.9%	35.7%	36.0%
40%-50%	126 233	22.9%	44.7%	44.6%
50%-60%	77 360	14.1%	56.6%	56.0%
60%-70%	67 375	12.2%	65.3%	64.9%
70%-80%	40 260	7.3%	72.4%	74.1%
Grand Total	550 327	100.0%	37.2%	37.2%

*Observed: Actual percentage of individuals in each stratum who received at least one COVID-19 vaccine dose during the study period.
**Predicted: Average predicted probability of vaccination for individuals in each stratum, as estimated by the logistic regression model.
***Predicted Strata: Individuals are grouped into strata based on their predicted probability of vaccination (estimated from logistic regression using sex, age, comorbidity status, and province). The stratum "0–10%" contains individuals with a predicted probability of 0% to 10%; "10–20%" contains those with predicted probability of 10% to 20%; and so on.

One-third of members (33.2%) fell into the lowest vaccination probability band (0–10%), within which 6.8% were vaccinated, closely aligning with the model's predicted 7.0%. At the opposite end of the spectrum, among those with a predicted probability of 70–80% (7.3% of the sample), 72.4% were vaccinated, again consistent with the predicted 74.1%. Overall, at the population level, the model

performed well, with the observed vaccination proportion of 37.2% exactly matching the predicted 37.2%. This alignment across strata provides confidence in the predictive validity of the model and suggests that the logistic regression adequately captured the main demographic and clinical determinants of vaccination uptake in this insured population. The two smallest strata (10–20% and 20–30%), comprising approximately 1.3% of the sample, showed less precise alignment, likely reflecting small cell sizes. Given the absence of financial or physical access barriers to vaccination during the study period, the close alignment between predicted and observed uptake suggests that persistent non-vaccination among higher-probability groups was primarily due to personal choice rather than constrained circumstance or access barriers.

Part 2: Excess Costs and Cross-subsidisation

Table 4 compares the observed annual per capita COVID-19–related expenditure for vaccinated and non-vaccinated members with the predicted expenditure if all members had been vaccinated under the universal vaccination scenario, stratified by sex, age, comorbidity status, and province. For all groups, the "Observed" columns show the actual costs recorded in the claims data for members in that category. The "Predicted" columns have different interpretations depending on the group. For non-vaccinated members, the "Predicted" column shows the modelled cost if these individuals had been vaccinated (counterfactual). For vaccinated members, the "Predicted" column shows model-predicted costs based on the vaccinated cohort, serving as a validation check. The "All members" columns present the weighted average expenditure across the entire population, with the predicted column showing the counterfactual scenario where all members are vaccinated.

Table 4. Observed and predicted annual per capita COVID-19 expenditure (US$) by vaccination status and population subgroup.

Expenditure: US$/Individual/year	Non-vaccinated members		Vaccinated Members		All members	
	Observed*	Predicted**	Observed*	Predicted***	Observed*	Predicted****
Sex						
Female	17.47 (16.13-18.82)	12.74 (12.72-12.76)	16.94 (16.61-17.28)	17.10 (17.06-17.14)	17.26 (16.44-18.09)	14.46 (14.44-14.48)
Male	18.23 (16.82-19.65)	12.98 (12.96-13.00)	18.05 (17.46-18.65)	17.79 (17.75-17.84)	18.17 (17.22-19.12)	14.65 (14.62-14.67)
Age						
Less than 18	0.92 (0.74-1.09)	10.25 (10.24-10.25)	10.41 (10.18-10.64)	10.47 (10.45-10.49)	1.60 (1.43-1.76)	10.26 (10.26-10.27)
Between 18-25	2.92 (1.57-4.26)	12.29 (12.27-12.31)	12.58 (12.29-12.88)	12.65 (12.62-12.68)	6.80 (5.99-7.62)	12.43 (12.42-12.45)
Between 25-40	12.35 (10.90-13.80)	13.36 (13.35-13.37)	13.50 (13.27-13.73)	13.58 (13.56-13.59)	12.86 (12.04-13.68)	13.46 (13.45-13.47)
Between 40-65	66.13 (61.22-71.03)	17.26 (17.24-17.29)	17.69 (17.18-18.21)	17.64 (17.62-17.66)	36.76 (34.80-38.72)	17.49 (17.48-17.51)
Greater than 65	135.85 (120.00-151.70)	32.81 (32.73-32.89)	32.79 (31.05-34.54)	32.53 (32.48-32.57)	60.22 (55.74-64.70)	32.60 (32.57-32.64)

Expenditure: US$/Individual/year	Non-vaccinated members		Vaccinated Members		All members	
	Observed*	Predicted**	Observed*	Predicted***	Observed*	Predicted****
COVID-19 Comorbidities						
No	6.49 (5.94-7.04)	11.55 (11.54-11.55)	13.56 (13.40-13.71)	13.64 (13.62-13.65)	8.60 (8.21-8.99)	12.17 (12.16-12.18)
Yes	85.61 (79.72-91.51)	20.68 (20.62-20.73)	23.61 (22.82-24.40)	23.43 (23.38-23.48)	47.60 (45.25-49.94)	22.37 (22.33-22.40)
Province						
Eastern Cape	13.67 (11.36-15.99)	11.93 (11.87-11.99)	16.25 (15.35-17.16)	16.50 (16.40-16.60)	14.67 (13.21-16.13)	13.70 (13.65-13.76)
Free State	16.51 (12.30-20.72)	11.93 (11.86-11.99)	15.92 (14.53-17.32)	15.57 (15.45-15.68)	16.29 (13.60-18.98)	13.29 (13.22-13.35)
Gauteng	16.75 (15.25-18.25)	13.03 (13.01-13.05)	17.17 (16.73-17.61)	17.07 (17.03-17.11)	16.91 (15.98-17.85)	14.59 (14.57-14.61)
KwaZulu-Natal	21.76 (19.01-24.51)	13.39 (13.36-13.42)	18.19 (17.30-19.09)	18.20 (18.12-18.27)	20.61 (18.73-22.49)	14.95 (14.91-14.98)
Limpopo	5.70 (3.83-7.57)	10.57 (10.52-10.62)	13.64 (10.85-16.44)	13.61 (13.49-13.73)	8.15 (6.59-9.71)	11.51 (11.45-11.56)
Mpumalanga	10.17 (7.02-13.32)	10.53 (10.47-10.58)	13.56 (12.32-14.81)	13.62 (13.50-13.74)	11.10 (8.79-13.41)	11.38 (11.32-11.43)
North West	15.61 (12.49-18.73)	10.87 (10.82-10.93)	13.78 (12.89-14.67)	13.92 (13.80-14.03)	15.02 (12.89-17.16)	11.85 (11.80-11.91)
Northern Cape	22.00 (13.74-30.25)	11.06 (10.98-11.15)	14.63 (13.47-15.78)	14.85 (14.66-15.03)	19.52 (14.02-25.02)	12.33 (12.24-12.43)
Western Cape	24.51 (21.51-27.52)	14.45 (14.40-14.50)	20.47 (19.51-21.42)	20.53 (20.45-20.62)	22.82 (21.03-24.62)	16.99 (16.94-17.04)
Total	**17.84 (16.87-18.82)**	**12.86 (12.84-12.87)**	**17.42 (17.10-17.74)**	**17.40 (17.37-17.43)**	**17.69 (17.06-18.31)**	**14.55 (14.53-14.56)**

Notes:

All figures are annual per capita averages.

* Actual expenditure recorded in the claims data for members in that category.
** Model predicted cost if non-vaccinated members had been vaccinated (counterfactual scenario).
*** Model-predicted costs based on the vaccinated cohort (model validation).
****Model predicated cost if all members had been vaccinated (universal vaccination counterfactual).
Note: For younger, low-risk groups, predicted costs under universal vaccination may exceed observed costs because the fixed cost of vaccination is not fully offset by avoided hospitalisation in groups with very low baseline risk.

The results show that observed and predicted expenditures were closely aligned among vaccinated members (US$17.42 vs. US$17.40), confirming good model calibration. Among non-vaccinated members, observed expenditure exceeded predicted costs overall (US$17.84 vs. US$12.86), particularly in older adults (≥65 years: US$135.85 vs. US$32.81) and those with comorbidities (US$85.61 vs. US$20.68), indicating substantial excess costs attributable to non-vaccination in higher-risk groups. In contrast, among younger members (<40 years), predicted costs under a universal vaccination scenario were slightly higher than observed costs, reflecting that vaccination added a modest direct cost in groups with very low hospitalisation risk. These dynamics are further considered in the discussion section.

Table 5 presents the comparison between observed and predicted annual COVID-19–related expenditure per individual, stratified by predicted probability of vaccination. All figures are annual per capita averages. The excess cost column shows the difference between observed and predicted expenditure (observed minus predicted) for all members in each stratum. Although the calculation includes all members, the excess cost essentially reflects the difference attributable to non-vaccinated

members, as observed and predicted costs for vaccinated members were very close (US$17.43 vs. US$17.41 overall). Positive values indicate that observed costs exceeded predicted costs under universal vaccination, as seen among non-vaccinated members in higher-probability strata. Negative values indicate that predicted costs exceeded observed spending.

Table 5. Observed and predicted expenditure (US$) by predicted probability of vaccination strata

Predicted Probability of vaccination strata***	Expenditure: US$/Individual/year							
	Non-vaccinated		Vaccinated		All members		Excess Cost	
	Observed*	Predicted**	Observed*	Predicted**	Observed*	Predicted**	Excess Cost (US$/Individual/year)	Excess Cost %
0%-10%	0.81	10.13	10.20	10.14	1.45	10.13	-8.68	-85.7%
10%-20%	4.25	13.94	12.57	13.90	5.68	13.93	-8.25	-59.2%
20%-30%	0.97	10.36	10.05	10.36	3.09	10.36	-7.27	-70.2%
30%-40%	5.53	12.03	12.16	12.05	7.90	12.04	-4.14	-34.4%
40%-50%	10.87	13.29	13.46	13.28	12.03	13.29	-1.26	-9.4%
50%-60%	42.76	16.25	15.60	16.28	27.40	16.27	11.13	68.4%
60%-70%	93.78	19.79	20.41	20.34	45.87	20.15	25.71	127.6%
70%-80%	129.48	28.76	29.84	29.16	57.43	29.07	28.37	97.6%
Total	**17.83**	**12.85**	**17.43**	**17.41**	**17.69**	**14.55**	**3.14**	**21.6%**

* Observed: Actual expenditure recorded in the claims data for members in that category.
**Predicted: Modelled expenditure if all individuals had been vaccinated (counterfactual scenario).
**Excess Cost: Difference between observed and predicted expenditure (Observed – Predicted). Positive values indicate higher costs than would have been expected under universal vaccination; negative values indicate lower costs.
***Predicted Probability of Vaccination Strata: Individuals are grouped into strata based on their predicted probability of vaccination (estimated from logistic regression using sex, age, comorbidity status, and province). The stratum "0–10%" contains individuals with a predicted probability of 0% to 10%; "10–20%" contains those with predicted probability of 10% to 20%; and so on.
Note: Negative excess cost values in lower predicted-probability strata indicate that predicted costs under universal vaccination exceeded observed expenditure, reflecting that the fixed cost of vaccination was not offset by reduced hospitalisation in these low-risk groups.

Among members with low predicted vaccination probability (<30%), observed expenditure was minimal, ranging from US$0.81 to US$4.25 across strata, and substantially below predicted costs under a universal vaccination scenario (US$10.13– US$13.94). This resulted in negative excess cost values (–US$7.27 to –US$8.68) and corresponding excess cost percentages of –70.2% to –85.7%. This indicates that in low-predicted probability of vaccination strata; comprising largely younger, low-risk members; the direct costs of vaccination would have exceeded the limited costs associated with hospitalisation.

From the 30–40% predicted vaccination probability band upward, however, the relationship reversed. Observed expenditure among non-vaccinated members rose steeply relative to predicted costs, with excess costs increasing progressively across higher predicted vaccination probability strata. In the 50–60% band, non-vaccinated members incurred mean costs of US$42.76 versus a predicted US$16.30 (excess cost = US$11.13; +68.4%). The disparity widened further in the 60–70% and 70–80% bands,

where observed costs were four to five times higher than predicted (US$93.78 vs. US$19.79 and US$129.48 vs. US$28.76, respectively), corresponding to excess costs of +127.6% and +97.6%.

At the population level, non-vaccinated members had observed average costs of US$17.83 compared to a predicted average of US$12.85, yielding an overall excess costs of US$3.14 per individual per year (+21.6%). For vaccinated members, observed and predicted expenditures were nearly identical (US$17.43 vs. US$17.41), confirming the validity of the cost model. Collectively, these results show that excess costs from non-vaccination were concentrated among individuals with a high predicted likelihood of vaccination, those for whom non-vaccination was more likely a matter of personal choice rather than constrained circumstance.

DISCUSSION

This study applied a luck egalitarian framework to examine COVID-19 vaccination uptake and associated costs within a large South African insured population. By combining a contextual review of the policy environment and communications and regulatory requirements with empirical predictive modelling, the study sought to distinguish non-vaccination due to personal choice from non-uptake due to constrained circumstance, including potential access barriers, and to quantify the financial implications of these behavioural differences for the insurance risk pool. In doing so, it offers an empirical approach to assessing the equity of responsibility-based financing arrangements in insurance, responding to the broader debate about whether, and under what conditions, personal responsibility should inform health financing decisions in systems pursuing Universal Health Coverage.

Two main findings emerge from the study. First, non-vaccination in this insured population was unlikely to result from financial or physical access barriers, given the absence of user fees for vaccination, widespread availability of vaccination sites, and the extent of public and insurer-level communication. Predictive modelling, validated by the close alignment between predicted and actual uptake, provided a basis for inferring that non-vaccination in higher-probability groups plausibly reflected personal choice.

Second, unvaccinated members generated measurable excess costs relative to modelled expectations. When expenditure patterns from vaccinated members were applied across the entire population, observed costs exceeded predicted costs by an average of 22%. These excess costs were concentrated among individuals with high predicted vaccination probabilities, those who had the highest risk factors for severe COVID-19 and for whom non-vaccination is most plausibly due to personal choice. In the 50–60% probability band, observed costs exceeded predicted costs by 68.4%. The disparity widened further in the 60–70% and 70–80% bands, where observed costs exceeded predicted costs by 127.6% and 97.6%, respectively.

Among younger, low-risk members in the lowest probability strata (<30%), however, predicted costs under universal vaccination exceeded observed expenditure. For example, in the 0–10% band, observed costs were 92% lower than predicted costs. This reflects that the fixed cost of vaccination was not fully offset by avoided hospitalisation in groups with very low baseline risk. This reversal illustrates the efficiency–equity trade-off inherent in preventive interventions: vaccination yields modest direct financial benefits for low-risk individuals but substantially reduces costs and severe outcomes among higher-risk groups, strengthening the equity and sustainability of the collective risk pool. Taken together, these findings highlight the tensions between responsibility-sensitive fairness and financial solidarity in private health insurance arrangements.

Much of the existing literature on luck egalitarianism in health care is normative and conceptual. This study provides an empirical demonstration of how these principles can be operationalised in a real-world context. The central luck egalitarian claim that inequalities traceable to "brute luck" should be compensated, while those resulting from option luck may legitimately be left for individuals to bear has been influential in health ethics [36-38]. Scholars such as Segall [10] and Knight [39] have examined the implications of responsibility-sensitive allocation in health systems, while Albertsen and Knight[17] explored practical limits.

Our analysis contributes by showing that in this insured South African cohort, it was possible to contextually establish that access barriers were minimal, to identify individuals for whom non-vaccination could reasonably be attributed to personal choice, and to quantify the excess costs imposed on the risk pool by these individuals. These findings align with arguments that personal responsibility may be a legitimate distributive principle when genuine personal choice exists [15, 40]. At the same time, we recognize the critiques of responsibility-based approaches. Social determinants, misinformation, and systemic distrust may have influenced vaccine hesitancy in ways not fully observable in claims data [41, 42]. Other empirical and theoretical studies have highlighted how such unmeasured contextual factors complicate straightforward attribution of responsibility [43, 44] and risk reinforcing disadvantage if overlooked.

The observed cross-subsidisation has direct implications for equity in health financing in this study population. In a context where premiums are community-rated, vaccinated members effectively cross-subsidised the higher costs incurred by unvaccinated members, raising a normative question about whether such pooling fairly distributes the costs of voluntary risk-taking.

Luck egalitarianism suggests that while inequalities from brute luck warrant collective compensation, those from option luck may legitimately be borne by individuals. Our analysis operationalised this

distinction, providing an evidence base for assessing whether responsibility-based financing arrangements would be more equitable than unconditional pooling in this study population.

At the same time, the finding that excess costs are concentrated among those with high predicted probability of vaccination, those for whom non-vaccination is most plausibly a matter of choice, suggests that concerns about regressive effects may be less pronounced than critics of responsibility-based policies fear. However, implementing responsibility-sensitive policies requires caution to avoid penalising individuals whose non-vaccination may still reflect unmeasured barriers. More broadly, the findings highlight the tension between solidarity, efficiency, and responsibility in health financing arrangements [17]. While we do not argue for punitive policies against the unvaccinated, our results highlight the need for transparent debate about the fairness of cross-subsidies when risks are voluntarily assumed, and the conditions under which responsibility may legitimately be invoked.

This study has several limitations. First, the findings are specific to COVID-19 vaccination in an insured South African population and cannot be generalised to uninsured populations or different health system contexts. Second, the analysis uses routine "real world" demographic and claims data collected by the health insurance funds as part of their business, not data collected for research purposes per se. Only services and vaccines for which claims were submitted were analysed. The implications are that both COVID-19 vaccination events and hospitalisation for COVID-19 infection could be over or underreported. While it is difficult to predict the impact of these biases, it seems plausible that they would not negate the findings entirely, given the magnitude of the impact. Third, the counterfactual cost model assumes that the relationship between covariates and costs is the same for vaccinated and unvaccinated individuals. If unvaccinated members differed systematically in unobserved ways, for instance, in health-seeking behaviour or adherence to other preventive measures, the predicted costs under universal vaccination may be biased. Fourth, the binary end-of-period vaccination classification does not capture variation in the timing of vaccination relative to COVID-19 waves, which may affect both the choice inference and the cost estimates. Fifth, we lacked individual-level data on geographic availability (distance to vaccination sites, waiting times) and acceptability (vaccine hesitancy, trust, misinformation). These unmeasured factors may have influenced vaccination decisions in ways not captured by our analysis, and caution is warranted in interpreting residual non-vaccination as solely a matter of personal choice.

Despite these limitations, the study demonstrates that the choice–circumstance distinction central to luck egalitarianism can be operationalised using routinely collected data, offering a replicable approach for assessing the equity of responsibility-based financing arrangements

CONCLUSION

This study set out to examine whether non-vaccination for COVID-19 in a South African insured population reflected personal choice or constrained circumstance, and to quantify the resulting financial implications for the insurance risk pool. Within a context of comprehensive vaccine availability, minimal access barriers, and extensive communication, non-vaccination was more plausibly attributable to personal choice than to constrained circumstance.

Using predictive and expenditure modelling, we found that observed costs exceeded predicted costs by an average of 22% under a universal vaccination scenario, with the excess concentrated among those whose non-vaccination most plausibly reflected personal choice. Among younger, low-risk members, the fixed cost of vaccination was not fully offset by avoided hospitalisation.

The study empirically distinguished choice-based from circumstance-based non-vaccination and quantified the financial consequences of that distinction in the pseudo-laboratory setting of the study. This offers an empirical basis for assessing the equity of responsibility-based financing arrangements, and for deliberating when personal responsibility should inform health financing design.

Abbreviations

Abbreviation	Full term
AOR	Adjusted odds ratio
CHEERS	Consolidated Health Economic Evaluation Reporting Standards
CI	Confidence interval
CMS	Council for Medical Schemes
COVID-19	Coronavirus disease 2019
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th Revision
J&J	Johnson & Johnson
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
ZAR	South African Rand
ZINB	Zero-inflated negative binomial

DECLARATIONS

ETHICS APPROVAL

The data for the study on which a large part of this evaluation is based were accessed in terms of and under the conditions set out in the agreement between NMG and the client insurance funds and between NMG and the researcher. The terms set out in these agreements ensured that the access and use of the data is in full compliance with the requirements of the Protection of Personal Information (PoPI) Act in South Africa. Ethics approval for the use of the database to conduct this study was granted by the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town (reference number 606/2023).

CONSENT TO PARTICIPATE

This study used de-identified administrative claims data. The requirement for individual informed consent was waived by the University of Cape Town Human Research Ethics Committee (HREC Ref: 606/2023), as the research involved no more than minimal risk and obtaining consent from all insured members would have been impracticable. The underlying use of the NMG database was granted a waiver of ethics review by the Ethics Committee of the South African Medical Research Council (project registration number EC001-1/2019).

CONSENT FOR PUBLICATION

Not applicable

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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AUTHORS' CONTRIBUTIONS

GS: Conception and design of the study; data collection (dataset preparation); data analysis (prepared and ran the analytical models with input from FL); drafting the article (wrote the first draft of the manuscript).

FL: Data analysis (provided input and guidance on the analytical models); critical revision of the article (critically reviewed and revised the manuscript).

SC: Conception and design of the study; data interpretation (contributed to interpretation of the findings); critical revision of the article (critically reviewed and revised the manuscript).

All authors: Reviewed and approved the final version for submission.

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Figures

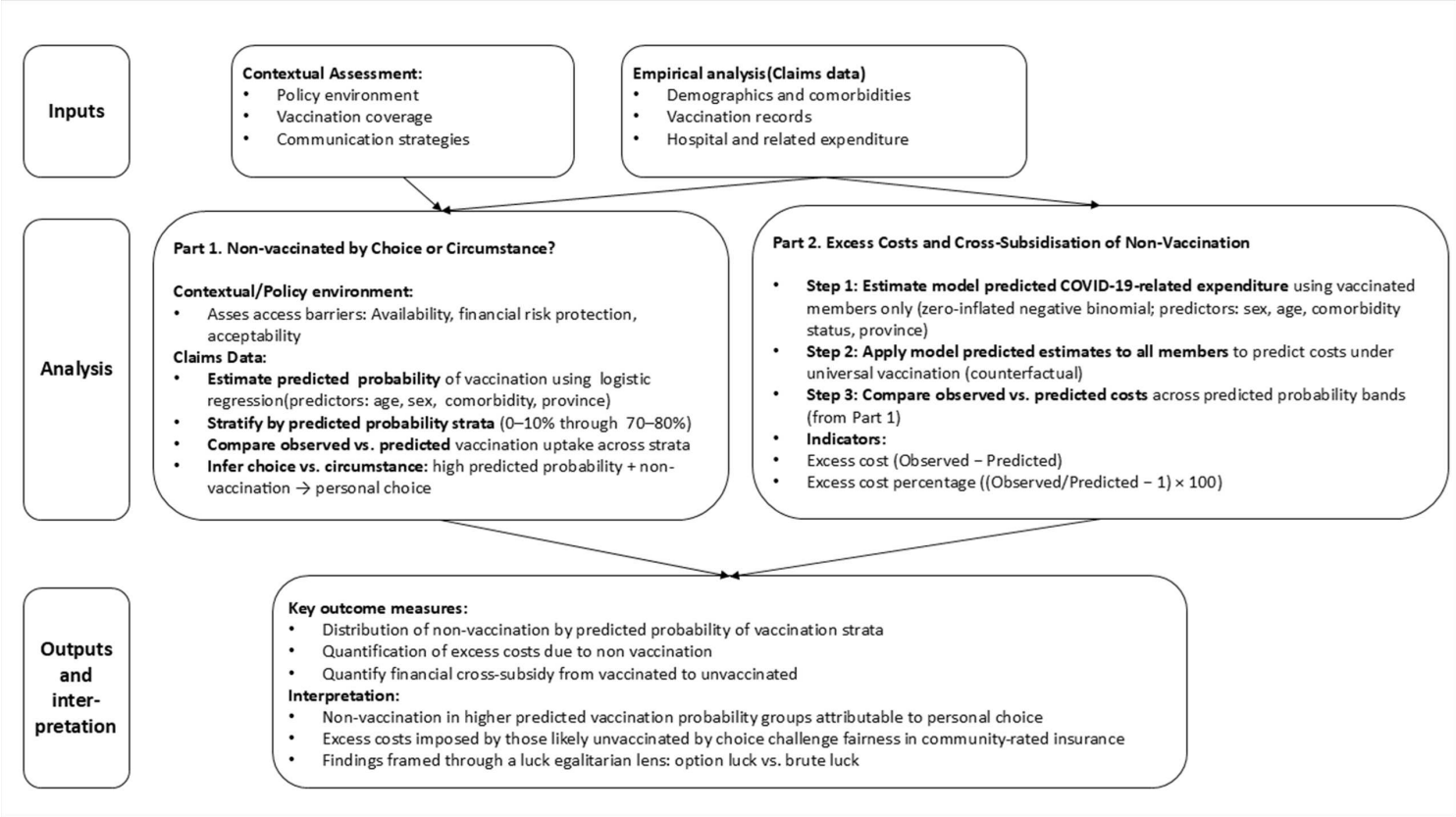


Figure 1

Overview of data inputs, analytic approach, and outputs and interpretation.