Modelling and forecasting of primary healthcare utilisation, perceived quality of care and non-emergency referrals to hospitals in a national health insurance pilot district of South Africa

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Background. The first phase of the National Health Insurance (NHI) pilot programme focusing on primary healthcare has been implemented in Tshwane and 10 other districts of South Africa since 2012. This was envisaged to improve the quality of healthcare at primary healthcare level, and offset the burden of non-emergency healthcare at hospital outpatient level. However, there are no population-level studies that have been done to determine the relationship and interdependence of primary healthcare and hospital outpatient-level indicators that are needed to forecast utilisation of health services. This information is key to plan for roll-out of NHI, in setting benchmarks to guide health policy and allocation of resources.

Objectives. To determine the interdependence and relationships between primary healthcare and hospital outpatient-level indicators in a NHI pilot district, and forecast the utilisation of services to 2030.

Methods. This was a quasi-experimental ecological study design, making use of selected primary healthcare and outpatient department indicators in the District Health Information System monthly reports between January 2010 and December 2019 for Tshwane district. We used the vector error correction model to determine the interdependence and relationships between these indicators, and used these to forecast utilisation of services to 2030.

Results. The study found that most non-emergency care is provided at primary healthcare level by professional nurses. It confirmed the influence of selected primary healthcare and outpatient department headcounts on each other by finding the existence of four co-integration relationships between the variables. Both long-run and short-run causality exists between them. Based on these relationships, we forecasted that by the end of 2030, the outpatient department follow-up headcounts would have doubled, but both primary healthcare total and clients seen by a professional nurse will marginally decline.

Conclusion. Our findings confirm that there is a relationship between primary healthcare and outpatient department indicators, which can be used to plan for provision of services in the future. Based on this relationship and current trends, we found that implementation of the NHI pilot programme will not attain the envisaged goal by 2030.

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The World Health Organization (WHO) set 2030 as the year by which member countries should have attained universal health coverage (UHC) by addressing challenges facing public healthcare,[1,2] including strengthening of health systems. This is critical for sub-Saharan Africa, which has the worst access to health services, despite accounting for 25% of the global burden of disease.[3] In 2012, the South African government (SAG), through the National Department of Health (NDoH), introduced the National Health Insurance (NHI) pilot programme in 10 districts, including Tshwane, as a strategy towards this goal.[4,5] Envisaged to be implemented over 5 years, the first phase focused on strategies to improve primary healthcare (PHC) services.[6] These include the ideal clinic realisation and maintenance (ICRM) model incorporated into the district health system (DHS) with a strong bi-directional referral system,[7] ward-based PHC outreach teams (WBPHCOTs), an integrated school health programme (ISHP), district clinical specialist teams (DCST), contracting of private non-specialised medical practitioners (MPs),[5,8,9] a centralised chronic medicines dispensing and distribution programme (CCMDD),[10] a health patient registration system (HPRS)[11] and a stock visibility system (SVS).[12] Implementation of these strategies was anticipated to improve access to appropriate and efficient quality of care at PHC level, and offset the burden on outpatient departments (OPDs).[6]

Almost 9 years after the launch of the NHI pilot programme, no studies have been done to assess the interdependence and relationship between PHC and OPD indicators and project toward the 2030 goal. This information is crucial because in public healthcare, PHC is the entry point for non-emergency patients, who are then referred to OPDs for higher levels of care as per identified need.[13] However, previous studies found that owing to perceived poor quality of PHC services, some patients enter the health system at higher levels of care.[14-18] Similarly, adherence to referral guidelines has been poor from both PHC and OPDs.[19,20] In the immediate post-NHI pilot implementation in Tshwane district, some studies have shown a decrease in utilisation of PHC services and improvement in perception of quality of PHC services, as evidenced by reduction in self-referral headcounts in OPD,[21,22] but the long-term impact is not known. Despite successes noted in the NHI pilot evaluation report,[23] several gaps in provision of PHC still exist, such as lack of medical equipment, inadequate monitoring of contracted MPs, lack of critical medical specialists, lack of integration of different aspects of the project and inability to adequately monitor effectiveness of the referral system.[23] Notably, NHI pilot implementation coincides with the changing epidemiological profile in SA from HIV/AIDS to a convergence with and possible shift to non-communicable diseases (NCDs).[24,25] However, PHC services have predominantly been capacitated for and provided HIV/AIDS services and related conditions for the past few years,[26] hence the rationale to contract private MPs at PHC level as part of NHI.[27]

Understanding the interdependence and relationship between PHC and OPD indicators is key to forecasting for utilisation of services. Utilisation as an important health outcome indicator is needed to measure and plan for roll-out,[28] understand consumer satisfaction and determine access to care, and can be used as a benchmark to guide health policy and allocation of resources.[29] Given the above, it is important to determine how implementation of the NHI pilot programme has affected the relationship between PHC and OPD services, given the different categories of staffing providing these services. This information is important in determining the capacity of PHC facilities that will be needed in the long term as the epidemiological profile evolves.[30] The focus of this study was to empirically analyse the existing relationship between selected PHC and OPD indicators of utilisation in a pilot NHI district, and then forecast to 2030.

Methods

Research design

This was a quasi-experimental ecological study design, making use of secondary data routinely collected into the District Health Information System (DHIS) monthly by the Gauteng Department of Health (GDoH) between January 2010 and December 2019.

Study setting

The study was done in the Tshwane district of Gauteng Province, which is one of the NHI pilot districts in SA. It has a population of 2 921 488 people,[31] receiving PHC services from 68 public facilities (PHC facility ratio of 1:36 980),[32] and referral services from 12 hospitals (5 district, 1 regional, 1 provincial tertiary, 2 national central, 3 specialised).[33]

Study population

We studied the population of adults and children ≥5 years, utilising non-emergency public PHC and OPD services in Tshwane district from January 2010 to May 2019. The population represents people being targeted for UHC in the district. OPD clients utilising specialised and emergency services at hospitals were excluded, as they do not have a direct interaction with PHC facilities.

Data collation and management

We made use of routinely collected secondary data from the DHIS monthly reports.[34] The selection of variables (Table 1) and time points was based on several considerations. We made use of quarterly data by combining 3-monthly reports into quarters of a year. PHC data elements and indicators were selected owing to the focus of the implementation of the first phase of the NHI pilot programme. We also included HIV/AIDS, diabetes mellitus (DM) and hypertension (HTN) data elements and indicators at PHC level owing to the prevailing epidemiological profile in SA.[25]

Ethics

Ethics approval for this study was obtained from the University of the Witwatersrand Human Research Ethics Committee (ref. no. M180956). The DHMIS data are aggregated at district level, and therefore do not contain any identifiers.

Statistical analysis

The study data were continuous; therefore, they were initially evaluated descriptively using means (standard deviations) and medians (interquartile ranges), and the range evaluated using minimum and maximum values.

We employed a special case of vector auto regression (VAR) of multivariate time series regression analysis called the vector error correction model (VECM) to determine interdependence and the dynamic relationship between indicators of PHC and OPD services. We conducted a natural log transformation of all the time series data to enhance additivity, linearity and validity.[35] The model combines levels and differences of non-stationary multiple time series data without differencing, ensuring long-run relationships among the integrated variables by adding an error correction term (ECT) to the VAR system.[36,37] The significance of the *t*-statistic on the parameter of ECT indicates that there is evidence of the existence of the long-run relationship and long-run causality between the variables.[38] Therefore, unlike VAR, VECM allows for analysis of both stationary and non-stationary variables. It can also be used as a dynamic system that forecasts the impact of one variable on another by directly indicating the speed of adjustments of one variable to restore equilibrium after the change in another variable.[39] The general model equation is shown below:[40]

$$Yt = \alpha + \beta T + \gamma Yt - 1 + \sum_{i=1}^{n} \delta t Yt - i + \epsilon t$$

where α = intercept, t = trend.

We first determined the level of lags at which variables are interconnected or endogenously obtained owing to the sensitivity of causality and number of lags. Lags were selected using Akaike's information criterion (AIC), Hannan-Quinn information criterion (HQIC) and Schwarz Bayesian information criterion (SBIC), with the lowest being the best.[38] Stationarity was assessed using both graphical means and the augmented Dick Fuller (ADF) test, used to confirm the stability of each time series.[37] The Johansen co-integration test was conducted to evaluate co-integration, defined as a statistical method used to test the correlation between two or more non-stationary time series in the long run or for a specified time period.[41] We then developed the VECM model for error correction.[36] Additionally, an error correction bias was conducted using the Granger causality test to determine whether one time series is useful for forecasting another. If the probability value is less than any α level, then the hypothesis would be rejected at that level.[36] If a causal relationship exists between each time series, future variables can be predicted. We therefore employed the VECM relationship between variables in the model to forecast data to 2030.[42]

All statistical analysis assumed a two-sided hypothesis with a 10% and 5% significance level. Analysis was conducted using STATA 16.1 (StataCorp, USA).[43]

Results

Basic statistics of the time series data for the selected PHC and OPD indicators are shown in Table 2. Approximately 1.4% of PHC clients self-referred themselves to OPD centres in a quarter. In comparing PHC and OPD follow-up, there were 6.7 times more patients being seen at the PHC than OPD. A comparison of categories of staff who

Table 1. Definitions and short formats of selected PHC and OPD indicators

Variable	Variable definition	Short format
OPD headcount not referred new	New clients attending a general or specialist outpatient clinic without a referral letter from a PHC facility or a doctor	OPD_not_ref
OPD headcount referred new	New client attending a general or specialist outpatient clinic with a referral letter from a PHC facility or a doctor	OPD_ref
OPD headcount follow-up	Client attending a general or specialist outpatient clinic for follow-up care	OPD_follow_up
PHC headcounts total	Clients of all ages attending the facility for PHC. Each client is counted once a day regardless of the number of services provided on that day	PHC_total
PHC, diabetes client treatment new	Newly diagnosed clients with a fasting blood glucose >7 mmol/L or random blood glucose >11.1 mol/L	PHC_DM_new_clients
PHC client seen by public doctor	A PHC client of any age consulted and/or treated by a doctor employed in the public sector for a PHC curative and preventative service	PHC_public_MP
PHC client seen by professional nurse	A PHC client of any age consulted and/or treated by a professional nurse for a PHC service	PHC_PN
PHC ART adult remaining on ART at end of period	Total adults remaining on ART at the end of the reporting month are the sum of the following: any adult who has a current regimen in the column designating the month being reported on; any adult who is not yet considered lost to follow-up in the column designating the month being reported on; clients remaining on ART = [naive (including post exposure prophylaxis and prevention of mother to child transmission) + experienced (exp) + transfer in (TFI) + restart] – [died (RIP) + loss to follow-up (LTF) + transfer out (TFO)]	PHC_ART_remain

PHC = primary healthcare; OPD = outpatient department; ART = antiretroviral therapy.

Table 2. Basic statistics of the data

Variable	Observations, *n*	Mean	Median	Minimum	Maximum	SD
OPD_not_ref	39	17 194	15 348	117	28 664	8 494
OPD_ref	39	27 512	27 880	637	54 153	17 233
OPD_follow_up	39	178 036	147 211	3 598	339 884	119 022
PHC_total	39	1 186 272	1 168 541	1 058 886	1 345 360	77 458
PHC_DM_new_clients	39	2 483	2 526	464	4 883	1 285
PHC_public_MP	39	82 171	82 105	57 128	101 327	10 314
PHC_PN	39	964 517	958 106	862 137	1 102 281	58 980
PHC_ART_remain	39	378 515	408 437	57 979	683 222	183 089

SD = standard deviation; OPD = outpatient department; PHC = primary healthcare.

see patients at PHC level showed that 91% of the clients were seen by professional nurses, compared with 7% by public MPs, meaning that only 2% were seen by private MPs.

Fig. 1A - F shows that, since the implementation of the NHI private GP contracting pilot programme, there has been a gradual increase in the selected OPD indicators: OPD_not_ref (1A), OPD_ref (1B), OPD_follow_up (1C) and in PHC_ART_remain (1H). There were also marginal declines in PHC_public_MP (1D), PHC_PN (1E) and PHC_total (1G) The PHC_DM_new_clients (1F) remained relatively unchanged.

A unit root test (in appendix Table 1; https://www.samedical.org/file/1992) to confirm the stability of each time series variable showed that the null hypothesis could not be rejected for all the selected variables as they had a lesser negative number and a non-significant *p*-value at 5% level, except for PHC_public_MP, which had a significant ***p***-value. These findings are confirmed by the graphs in Fig. 1, which show that all variables show a downward or upward trend. Therefore time series of all the variables cannot have a constant mean and variance. As such, we used the VECM.

Lag selection (in appendix Table 2) using AIC, HQIC and SBIC[41] showed a selection of three lags. However, in conducting model diagnostics in testing for autocorrelation, it was found that it did not exist only for lag 1 (p=0.16765) and lag 2 (p=0.35686).

Johannsen's co-integration test (in appendix Table 3) confirms that that at 5% significance level, there were four co-integration relationships between the variables, as both the trace and maximum eigenvalue statistic were smaller than the critical value.

Table 3 shows the results of the estimation of the VEC model, which was statistically significant at 10%, as evidenced by the χ^2 and R-squared values. To ascertain long-term causality, four ECTs were derived for each variable in the co-integrating relationships. The speed of adjustment coefficients, which indicate how quickly the unbalanced error deviating from the long-term balance return to the balanced state were derived. These was significant in all variables except for OPD_ref and PHC_DM_new_clients. The ECTs generally showed that there is a balanced relationship between the selected PHC and OPD indicators.

Long-term equilibrium relationships

If the four ECTs in the long-term equilibrium relationship were 0, the derived co-integration equations and interpretations are shown in appendix Table 4.

Table 3. VECM model results for short- and long-term equilibrium relationship

Error correction	OPD_ not_ ref	OPD_ref	OPD_follow_up	PHC_total	PHC_DM_new_ clients	PHC_public_MP	PHC_ PN	PHC_ ART remain
Co-integrating equation 1	−0.10	0.29*	0.35*	0.01	0.02	0.02	0.02	−0.06
Co-integrating equation 2	−0.01	−0.04	−0.04	0.02*	−0.05	0.03	0.02	0.17***
Co-integrating equation 3	0.14	−1.04*	−1.09*	−0.02	−0.08	0.01	−0.02	0.05
Co-integrating equation 4	0.72	4.46†	2.43	−1.02*	−3.8	0.66	−0.33	−0.98
Constant	0.02	−0.004	0.0151	−0.0145	−0.0022	0.0163	0.0009	−0.0005
D_OPD_not_ ref	LD = 0.04	LD = −0.09	LD = −0.51	LD = 1.39	LD = −0.26	LD = −1.88	LD = −0.99	LD = −0.09
D_OPD_ref	LD = 0.08	LD = −0.62*	LD = 0.63*	LD = −3.08	LD = −0.27	LD = −0.51	LD = 2.67	LD = −1.91***
D_OPD_follow-up	LD = −0.28‡	LD = 0.37‡	LD = 0.15	LD = 0.25	LD = 0.16	LD = 0.63	LD = 3.57	LD = −0.72*
D_PHC_total	LD = 0.01	LD = 0.01	LD = 0.02	LD = 0.63†	LD = 0.02	LD = −0.06	LD = −0.10	LD = 0.10*
D_PHC_DM_ new_ clients	LD = 0.06	LD = −0.02	LD = −0.03	LD = −0.62	LD = 0.15	LD = 0.70	LD = −0.83	LD = −0.17
D_PHC_public_MP	LD = −0.01	LD = 0.03	LD = −0.03	LD = −0.06	LD =−0.07	LD = −0.44	LD = 0.47	LD = 0.09
D_PHC_PN	LD = 0.01	LD = −0.01	LD = 0.01	LD = 0.23	LD = 0.03	LD = −0.04	LD = 0.23	LD = 0.08
D_PHC_ART_ remain	LD = 0.04	LD = −0.13‡	LD = −0.26*	LD = 0.11	LD = 0.06	LD = −0.09	LD = −0.12	LD =−0.16
RMSE	0.797576	0.324298	0.315851	0.041041	0.322786	0.097718	0.04048	0.116393
R-squared	0.2687	0.6835	0.6929	0.6538	0.4596	0.6631	0.5948	0.7433
χ^2	8.083792	47.50118	49.64236	41.54355	18.70898	43.30266	32.29446	63.71525
p-value	0.8381	<0.0001	<0.0001	<0.0001	0.1324	<0.0001	0.0022	<0.0001

AIC =−9.242231 , HQIC = −7.400315 , SBIC = −4.017632.
VECM = vector error correction model; OPD = outpatient department; PHC = primary healthcare; DM = diabetes mellitus; ART = antiretroviral therapy; RMSE = root mean square error; AIC = Akaike's information criterion; HQIC = Hannan-Quinn information criterion; SBIC = Schwarz Bayesian information criterion.
*p<0.0001
†p<0.1
‡p<0.05

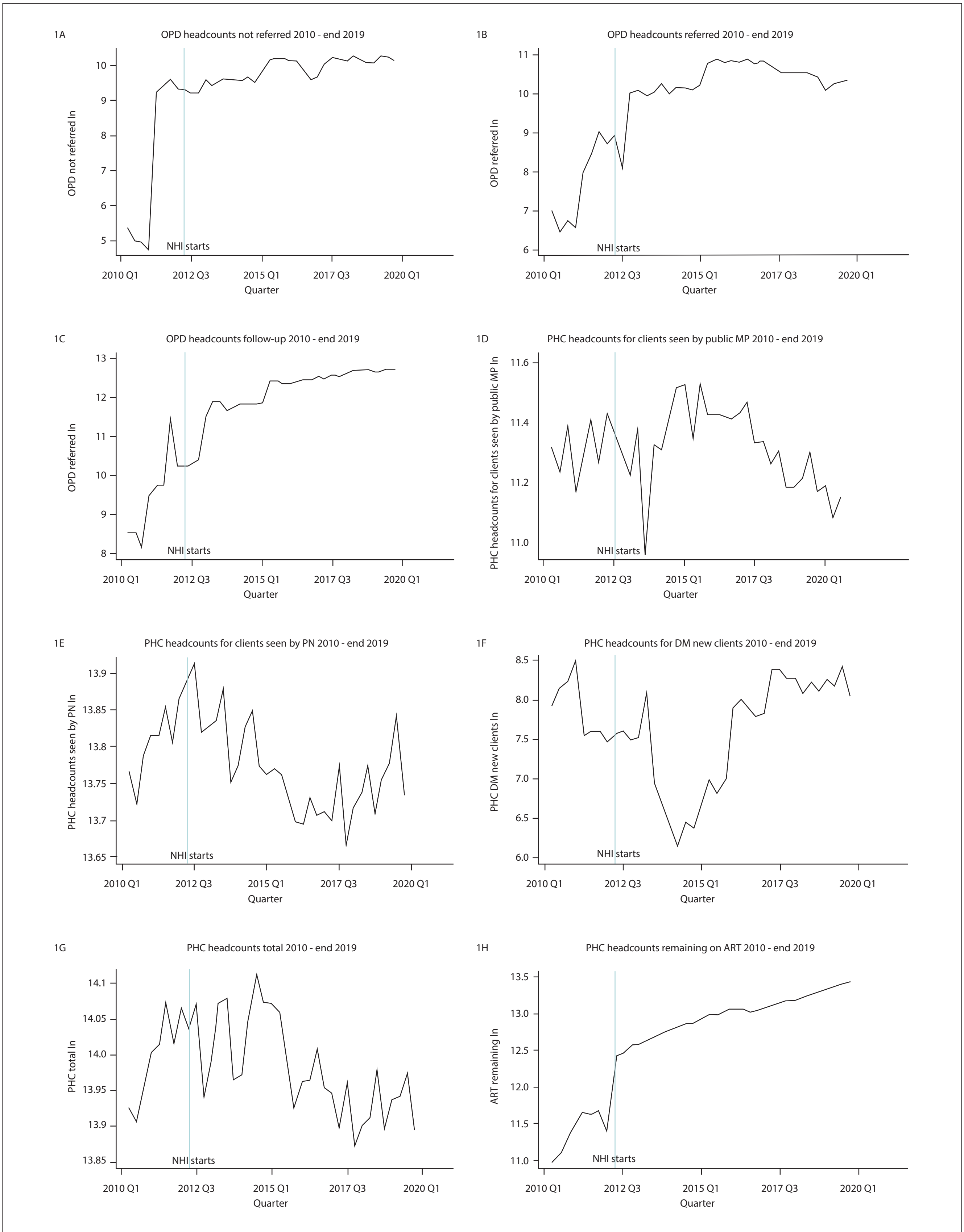

Fig. 1A - H. Trend of selected outpatient department (OPD) and primary healthcare (PHC) headcounts by time series data from 2010 to end 2019. (ln = natural logarithms; NHI = National Health Insurance; MP = medical practitioner; PN = professional nurse; DM = diabetes mellitus; ART = antiretroviral therapy.)

Table 4. Forecast of selected PHC and OPD headcounts

Variable	2019 Q4	2030 Q4	95% CI
OPD headcounts for clients not referred	24 842	44 445	–9 446 - 98 335
OPD headcounts for clients referred	31 008	37 764	–57 462 - 132 991
OPD headcounts for follow-up	337 945	704 601	437 521 - 971 681
PHC total headcounts	1 345 360	1 176 329	450 529 - 1 902 129
PHC headcounts for diabetes mellitus new clients	3 101	2 846	–10 402 - 16 095
PHC headcounts for clients seen by a public medical practitioner	68 259	43 636	–77 196 - 164 470
PHC headcounts for clients seen by a professional nurse	922 405	869 720	524 779 - 1 214 661
PHC ART adult remain on ART end of period	683 222	1 443 182	1 061 504 - 1 824 860

PHC = primary healthcare; OPD = outpatient department; Q = quarter; CI = confidence interval; DM = diabetes mellitus; ART = antiretroviral therapy.

Short-term equilibrium relationships

The short-term equilibrium relationships between the models are shown in appendix Table 5.

Since VECM showed that the independent variable affected the dependent variable but did not explicitly show the direction of causality, we did a Granger causality analysis (shown in appendix Table 6) on the variables determined to have a significant effect on the model, to determine direction, which showed its existence in all the models.

Table 4 and Fig. 2A - H show the forecast for PHC and OPD indicators for the fourth quarter of 2030. In comparing the fourth quarter of 2019 to that of 2030, there will be slightly more than twice the headcounts for OPD not referred. However, there will be a 5.4% and a 5.7% decrease in PHC total and PHC clients seen by a professional nurse (PN), respectively.

Discussion

The study found that most non-emergency care is provided at PHC level by professional nurses. It confirmed the influence of selected PHC and OPD headcounts on each other by finding the existence of four co-integration relationships between the variables. Both long-run and short-run causality exist between them. Based on these relationships, we forecasted that by the end of 2030, the OPD follow-up headcounts would have doubled, but both PHC total and PHC clients seen by a PN will marginally decline.

In the causality assessment for OPD referrals, we found that increases in PHC clients newly diagnosed with DM, remaining on antiretroviral therapy (ART), seen by a public MP and seen by a PN would lead to an increase in both OPD referred and self-referred. The increase in PHC indicators is an indication of increased workload at PHC level for both MPs and PNs, resulting in increased waiting times, and patients respond to this by seeking care at higher levels of care, leading to an increase in self-referrals.[16] The increase in referrals to OPD could be explained by MPs and PNs referring patients to higher levels of care in response to increased workload at PHC level. It is similar to findings in a UK study, which showed that general practitioners respond to an increase in workload by referring patients to specialists in the National Health Service.[44] The very high increases in PHC indicators compared with referred and self-referred patients shows that the increase in workload at the PHC facilities has a very high threshold before it affects OPD indicators. It suggests significant reduction in perception of quality of care at PHC level before affecting OPD, and therefore a critical need to improve the quality of care at PHC level with the roll-out of NHI.[22] These findings were also supported by a decrease in clients newly diagnosed with DM at a PHC level, with increases in both total volume of clients at PHC and those seen by PNs. Thus an increased volume of patients at PHC level not only led to an increased workload at OPD level, but may also compromise the quality of care at the PHC level. Hence there is a need to improve not only the clinical staffing but also the capacity of PNs in PHC facilities in the detection and management of NCDs, specifically DM.[45]

In the causality assessment for OPD follow-up, we found that increases in PHC clients newly diagnosed with DM, remaining on ART, seen by public MPs and seen by PNs, led to an increase in patients being followed up in OPD. This means that an increase in PHC indicators leads to an increase in workload at OPD level, and can be explained by suboptimal down-referral from hospitals to PHC facilities.[46] This is also supported by findings in the short-run causality assessments for PHC indicators, which show that there is an inverse proportional relationship between volume of patients at PHC level and at OPD level, which reflects the referral mechanism between the two systems. It emphasises the need for higher levels of care to not only down-refer patients but also improve the perception of care at PHC facilities. Similarly, the short-run causality assessment found that the volume of patients newly diagnosed with DM at PHC level has a positive impact on the volume of patients being followed up in OPD, which could be because of DM patients being referred to OPD for care, while the volume of those remaining on ART at PHC has a negative impact, possibly owing to retention of patients at PHC level, as ART care represents the majority of headcounts and workload for PNs.[47]

A forecast of the PHC and OPD indicators to 2030 shows that while the former would remain relatively the same and in some respects marginally reduce, the latter would significantly increase, except for patients being referred. This means that if the perception of poor quality of services at PHC facilities continues, it would lead to overutilisation of OPD services. Therefore, despite an improvement in the perception of quality of care,[22] the current levels

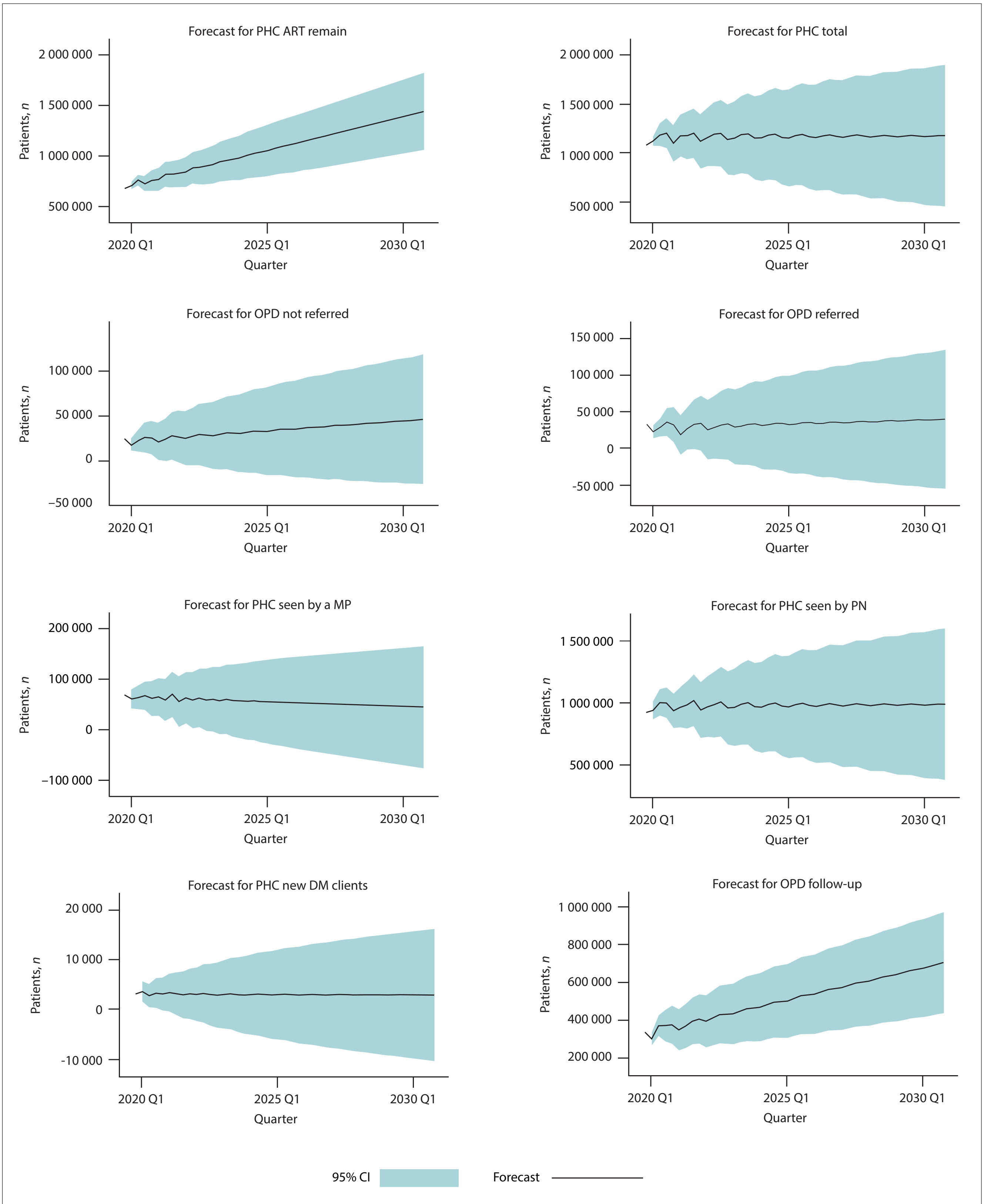

Fig. 2. Forecast of selected primary healthcare (PHC) and outpatient department (OPD) headcounts for 2030. (ART = antiretroviral therapy; MP = medical practitioner; PN = professional nurse; CI = confidence interval.)

of implementation of the NHI pilot programme in Tshwane are not sufficient to attain the 2030 goal. Therefore, addressing challenges at the PHC facilities such as staffing and capacity is critical to realisation of the goal of UHC in SA.

There are several limitations to the interpretation of our findings. Firstly, these findings are based on secondary data from the DHIS, which was not designed for research, and also has challenges that have been highlighted previously.[48] Despite this, it has been found to be useful in providing scientific insight into utilisation of healthcare services.[49] Secondly, the model diagnostics showed a problem with non-normal distribution of error residuals, which may compromise the efficiency of the model. However, this does not limit the consistency.[50] Thirdly, the selected forecast year was 2030, 9 years ahead of time, which inherent to model performance is less accurate compared with a shorter period. However, the model is still effective in forecasting for shorter periods of time. Fourthly, there is evidence for the impact that COVID-19 has had on the utilisation of both PHC and OPD.[51] However, the period covered in this study was 2010 - 2019, which was before the pandemic. Therefore, the model performance would still be valid if vaccination and other measures reduce the impact of the pandemic on the healthcare system to pre-pandemic levels.

Recommendations

We recommend that with the implementation of NHI, there is a need to improve the perception of quality of care at PHC level by appropriate staffing capacity to manage NCDs during the epidemiological transition. We also recommend strengthening of bidirectional referrals between PHC facilities and hospital OPDs.

Conclusion

Our findings confirm that there is a relationship between PHC and OPD indicators, which can be used to plan for provision of services in the future. Based on this relationship and current trends, we found that implementation of the NHI pilot programme will not attain the envisaged goal by 2030.

Declaration. This study was conducted for HM's PhD.

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Author contributions. HM and JI conceived the presented idea. HM developed the theory and performed the computations. HM and KO verified the analytical methods. JI, AF and KO reviewed the manuscript developed by HM. All authors discussed the results, contributed to and approved the final manuscript.

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