ORIGINAL RESEARCH

Mapping Regional Well-Being in the Universal Health Coverage System in Taiwan

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Purpose: Regarding the universal health coverage (UHC) goal of eliminating health disparity, this study seeks to examine whether this objective has actually been achieved and whether residence affects health and well-being inequality.

Methods: Based on Taiwan's experience with its UHC system, this research quantifies health and well-being indicators, including quality-adjusted life expectancy (QALE), consumption, and utility-adjusted life expectancy (UALE), and uses the geographic information system (GIS) to map regional well-being throughout Taiwan. Using spatial lag regressions, this study estimates how residence and socio-economic factors affect population's well-being.

Results: Estimation results indicate a 1‰ increase in the mortality rate reduces the population's UALE by 0.4131 utility-adjusted life-years (UALYs). The differences in health and well-being indicators between urban and rural residents were 6.49 quality-adjusted life-years (QALYs) and 3.84 UALYs. Residents living in Taipei City had the highest level of QALE, consumption, and well-being, and those in Taitung County had the lowest level of QALE and well-being. The regional spatial autocorrelation results show that a population's health status and well-being are connected to residence.

Conclusion: Our estimation results show that risk of higher mortality rates in disadvantaged areas appears to be associated with well-being inequality, even with universal healthcare coverage. We suspect that related health intervention efforts, such as preventive and curative medical devotion, in Taiwan might not have effectively reached more rural residents, and thus recommend more work be undertaken to reduce mortality rates in these communities.

Keywords: quality of life, utility-adjusted life expectancy, universal health coverage

Introduction

Lack of health insurance is viewed as one of the main reasons for health inequalities around the world.[1,2] Consequently, the World Health Organization (WHO) has supported the introduction of universal health coverage (UHC) across the globe[3] to provide equal accessibility and affordability of health care to eliminate or narrow health inequality. Based on different countries' experiences, some studies have shown that the implementation of UHC could reduce health inequality,[4,5] while others indicate that such a policy could not narrow the gap of health inequality.[6–8] However, most of these studies have limited their equality measures to mortality or life expectancy without considering the influences of residence on living condition and health disparities.

The most popular and recommended utility evaluation by the National Institute of Health and Clinical Excellence (NICE) is by measuring quality-adjusted life

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expectancy (QALE) in terms of quality-adjusted life years (QALYs), which combines life years and quality of life (QoL) into one index measure.[9] The general population pursues good quality of life over life periods in terms of not only health but also consumption, reflecting income status.[10] To comprehensively assess the utilities from health status, QALE, and consumption, this research uses the indicator of utility-adjusted life expectancy (UALE) to map the regional population's satisfaction from the UHC. Regarding the UHC goal of eliminating health disparity, this study seeks to examine whether this objective has actually been achieved through mapping residents' well-being with different indicator assessments.

Taiwan launched its UHC system in 1995, providing health coverage for every citizen. Enrollees enjoy almost free access to health care, with small co-payments in most clinics and hospitals. Total health expenditures in countries such as Taiwan, Japan, and Korea, which have adopted a similar UHC system, account for around 6.58%, 10.94%, and 7.6% of the gross domestic products, respectively, and support life expectancies of around 80.4, 84.1, and 82.6 years, respectively, in 2017. Taiwan's UHC experience has become an important learning model for any country that seeks to overhaul its healthcare and medical insurance system. Although universal coverage has been offered, rural residents tend to utilize health care less than those living in urban areas do. Health disparities may still exist between rural and urban residents or low-income groups and groups with greater wealth.

Based on Taiwan's experience with its UHC system, this research quantifies well-being and accurately maps the distribution of well-being throughout Taiwan. This study offers new evidence regarding 1) income-related health and quality-of-life inequalities in the UHC program, as well as 2) possible factors affecting these disparities by investigating well-being outcomes in different regions. Our study contributes to and improves on earlier work[4,10,11] in several ways. First, our measures on regional well-being include both income and health in addition to age and geographic region. Second, this study is among the first to examine how the provision of health care linked to well-being differences. Moreover, the use of residence to represent socio-economic status has been shown to be valid in studies of health inequality.[1] Third, we offer cost-effective ways to prevent and improve well-being disparities found in various contexts of measurement.

In the following, this study specifies the different indicators of health and well-being measurement, analyses the differences in regional well-being in the UHC system, and then discusses the policy implications and concludes.

Methods
Indicator Specifications
Quality-Adjusted Life Expectancy (QALE)
The health index QoL instrument of EuroQoL-5 Dimension (EQ-5D) uses broad health domains, including mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, and can be applied in a wide range of population health. The QoL questionnaire uses an absolute scale to rate self-rated health with 0 being the worst and 100 being the best. The latest version of the EQ-5D in Taiwan was released in 2009 and has been demonstrated to be valid and reliable but has not been updated since then.[12] For this instrument, the population is classified into groups aged below 12, from 12 to 64, and above 65 years old. The age-specific data on QoL is available for each level. Individuals in each age group in a specific area are assigned the same QoL score. In this study, area boundaries were classified and data were collected according to the specifications provided by the Department of Statistics from the Ministry of the Interior in Taiwan.

Based on the life tables from Taiwan's vital statistics, this study analyzed the statistics of people aged 0–85+ years. In each area, the number of deaths was divided by the area's stationary population which yielded a conditional death ratio, and hence a survival ratio at any particular age i : p_i. The cumulated survival ratio in this study was calculated as $S_i = p_{i-1}S_{i-1}$. Combining QoL_i with the survival ratio at different ages yielded the QALE in terms of quality-adjusted life-years (QALYs):[11,13,14]

$$\text{QALE} = \sum_{i=1}^{85}(\frac{S_i + S_{i+1}}{2} + \frac{QoL_i + Qol_{i+1}}{2}) \qquad (1)$$

A specific area's QALE was calculated by adding up the QALE of all age groups. The estimated QALEs were used to evaluate the effects of UHC health services on the population's health.

Utility-Adjusted Life Expectancy (UALE)
This research used consumption to capture the utility from income,[10] collected statistics from the Survey of Family Income and Expenditure of Taiwan, and normalized the average consumption of the whole population. This paper determined the impact of income on utility from consumption with a weight of 1 as well as the impact of health on

utility from QALE with a weight of 0.48,[15] and yielded the well-being measurement UALE in terms of utility-adjusted life-years (UALYs).[11] The calculated UALYs were used to evaluate the population's well-being among different regions with universal health services.

Spatial Autocorrelations

The geographical information system (GIS) has been used for the past two decades to support the feasibility of assessments in relation to the provision of health care[16–18] and has been applied in public health for policymaking with regard to geographic differences.[19] Applying the GIS, this study examined whether the UALE in Taiwan has any spatial autocorrelations by using Global Moran's I statistics. Based on the correlation index, the relationships among nearby locations were calculated as follows:[16]

$$
\begin{aligned}
\mathrm{I} = &\frac{n}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \\
&\times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}}
\end{aligned} \tag{2}
$$

where n is the number of spatial units indexed by *i* and *j; x* is the variable of UALE; $\bar{x}$ is the mean of *x*; and w_{ij} is an element of a matrix of spatial weights with a weight of 1 if two zones are neighbors, and 0 otherwise. Using equation (2), we calculated the value of Moran's I as 0.41 and found that positive UALE spatial autocorrelation does exist in Taiwan.

Spatial Lag Estimation

If regional social well-being is also a function of residence, ordinary least square (OLS) estimates would be biased and inconsistent. The Spatial Lag Model (SLM) estimator was designed for situations with spatial autocorrelation, and has been widely applied.[20] This paper introduces SLM in GIS to represent the estimators of interest, with independent variables that are correlated with possibly regional realizations of error. This research selected explanatory variables from the literature and specified the sort of problem that were of interest to fit the model:

$$
\mathrm{UALE} = \rho Y + \beta X + \varepsilon \tag{3}
$$

Parameter ρ is the spatial lag coefficient and regarded as a weighted average of the neighbors, or as a spatial smoother; parameter β is a vector of coefficients of the vector of regressors or explanatory variables X; Y is the spatial variable; ε is the error vector. Our primary interest is how demographics, socio-economic status, and medical concerns affect the population's UALE, and whether spatial lag effects exist.

Data

The data of the following variables in 23 cities and counties were collected from the Department of Statistics, Ministry of the Interior, Executive Yuan, Taiwan. The adult mortality rate, in particular the number of deaths per 1000 population per year, is an important indicator of the impact of disease and could also be a health status indicator.[3] The mean of this variable in Taiwan was 6.94 ‰; the maximum was in Taitung County at 9.96‰; the minimum was in Taipei County at 4.66‰. Government expenditure is allocated to social security programs to raise the general state of the population's well-being. Charkhian et al indicated that an increase in expenditure on social welfare does improve the health-related quality of life of HIV-infected people in Tehran.[21] This research used the ratio of government expenditure on social security relative to total government expenditure to capture the ability of the UHC system to improve the population's well-being. The mean of this ratio was 11.62%; the maximum was in Hsinchu County at 17.37%; the minimum was in Taichung City at 8.02%. Mackenbach et al found that a decrease in persons served per physician is associated with a reduction in mortality.[22] The mean of this variable in Taiwan was 635.64; the maximum was in Hsinchu County, with 1,062.12 persons per physician; the minimum was in Taichung City, with 293.02 persons per physician.

Higher education could lead to increased health knowledge in a population, increased use of healthcare services, and better health status.[23] This research used adult literacy rate as an indicator for education. The mean adult literacy rate in Taiwan was 97.73%; the maximum was in Taichung County at 99.17%; the minimum was in Yunlin County at 95.1%. Based on the experiences in sub-Saharan Africa, an increase in health expenditure was associated with longer life expectancy.[24] Within the UHC, this research used the ratio of the government's health expenditure to the total government expenditure to represent the efforts expended on health promotion. The mean of this ratio was 1.63%; the maximum was in Penghu County at 3.31%; the minimum was in Taichung City at 0.72%. Table 1 summarizes the statistics.

Table 1 Summary Statistics

Variables	Mean	Std. Dev.	Max.	Min.	Quantiles			
					Q1	Q2	Q3	Q4
Mortality rate (‰)	6.94	1.49	9.96	4.66	5.78	6.7	7.99	9.96
The ratio of social security expenditure to government expenditure (%)	11.62	2.45	17.37	8.02	10.38	11.23	12.81	17.37
Persons/per physician	635.64	200.93	1062.12	293.02	491.28	640.01	773.44	1062.12
Literacy ratio of the population at age above 15 (%)	97.73	1.14	99.17	95.10	97.12	97.99	98.53	99.17
The ratio of health expenditure to government expenditure (%)	1.63	0.65	3.31	0.72	1.245	1.48	1.82	3.31

Notes: The data of the variables in 23 cities and counties are collected from Department of Statistics, the Ministry of Interior, Executive Yuan, Taiwan. Vital statistics, 2009, retrieved from http://www.moi.gov.tw/stat/life.aspx on March 12, 2020.[25]

Results
Background Characteristics

On the characteristics of health indicator-QALE, Figure 1 indicates the association between QALE index and residence. The population of Taipei City, the capital city located in northern Taiwan, had the highest QALE of 78.48 QALYs in contrast to that of Taitung County, which is on the southeast coast, with the lowest QALE of 71.99 QALYs. The difference in health index between urban and rural residents was 6.49 QALYs.

Regarding the characteristics of income indicator-consumption, the geographical consumption indicators are plotted in Figure 2. The population of Taipei City had the highest consumption index of 1.46 in contrast to Yunlin County, one of the least developing counties in southern Taiwan, which had the lowest consumption index of 0.73.
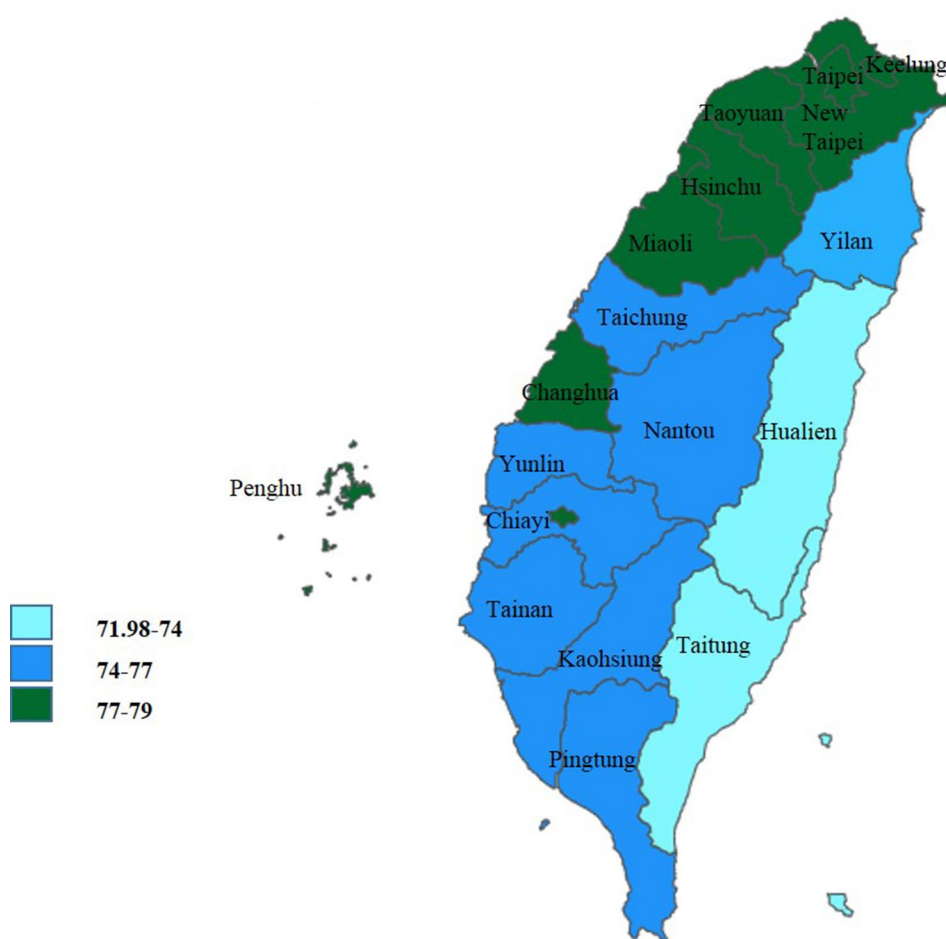
Figure 1 Health mapping in QALE in Taiwan.
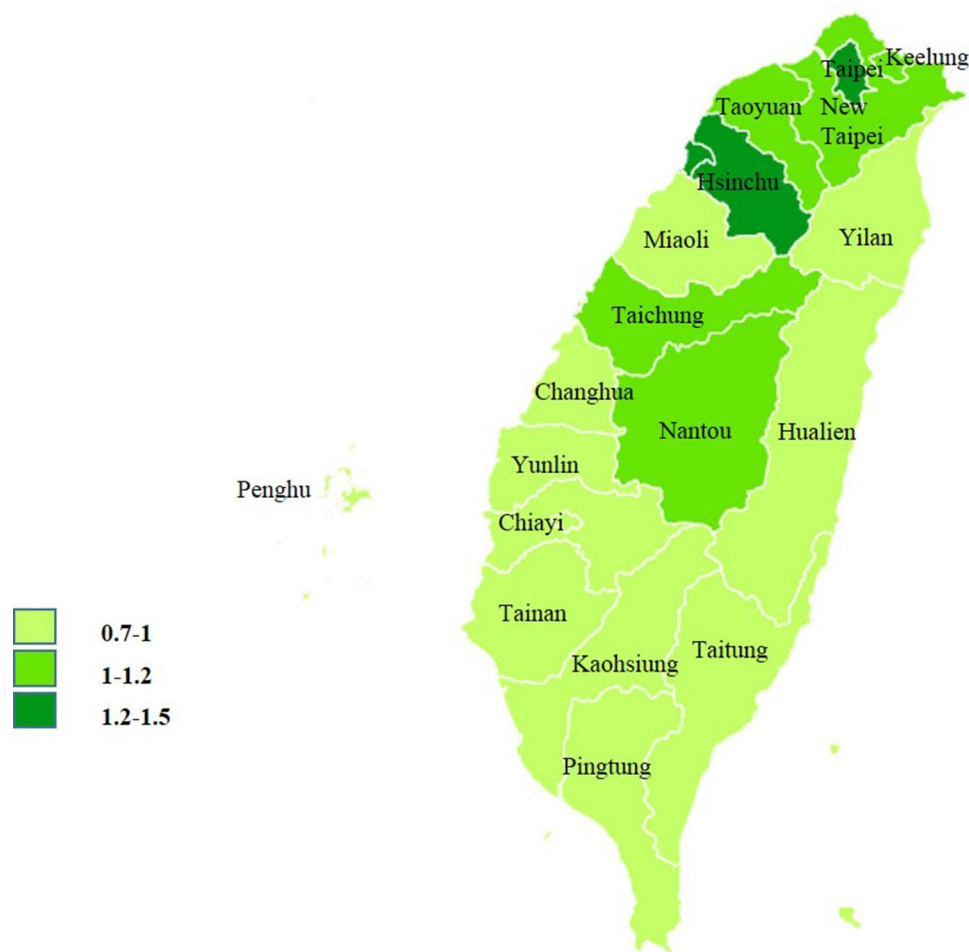
Figure 2 Consumption mapping in Taiwan.

With regard to the characteristics of well-being indicator-UALE, the association between UALE and residence was similar to the link between health and residence. The population of Taipei City had the highest UALE of 39.13 UALYs in contrast to that of Taitung County, which had the lowest UALE of 35.29 UALYs. The difference in well-being between urban and rural residents was 3.84 UALYs.

Though the weight of QALE, a health indicator for the welfare UALE evaluation was less than 1 and set at 0.48, well-being inequality mainly resulted from health inequality. The preliminary results indicate that health and well-being inequalities do matter, even with the UHC system in place. The well-being distributions in UALE are plotted in Figure 3. Based on Figures 1–3, residents living in Taipei City had the highest level of QALE, consumption, and well-being, and those in Taitung County had the lowest level of QALE and well-being.

Estimation Results

Table 2 presents the estimation results. A 1‰ increase in the mortality rate reduces the population's UALE by 0.4131 UALYs, since the population's health status worsens if more people are dying. Increases in the ratio of social security expenditure to total government expenditure, the ratio of health expenditure to total government expenditure, and the rate of adult literacy affect residents' well-being insignificantly. Spatial lag effects and well-being inequalities do exist among different geographic areas. When the spatial lag of the dependent variable is included as an explanatory variable, a multiplying effect is generated and the parameters cannot be considered as direct effects on the population's well-being.

Regional Spatial Autocorrelation in a Population's Well-Being

In Figure 4, the prussian blue-colored regions show positive spatial autocorrelations and LISA clustering
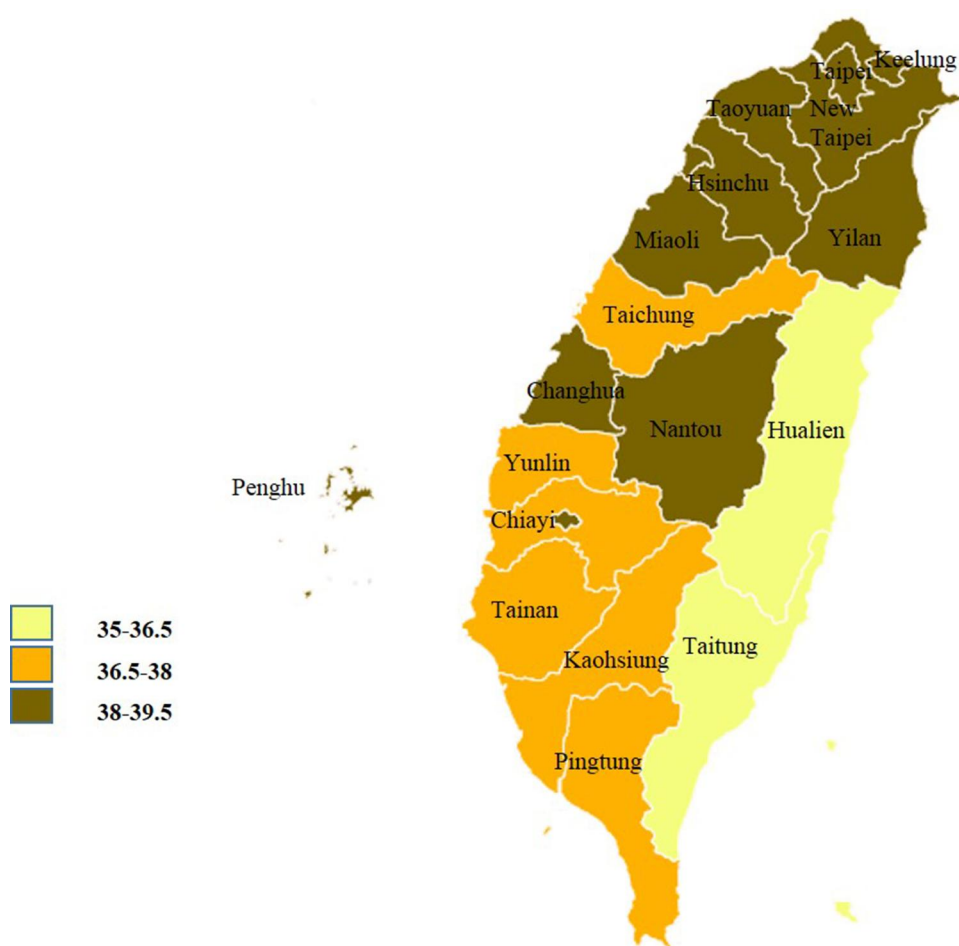
Figure 3 Well-being mapping in UALE in Taiwan.

characteristics with a high–high relationship. Both the concerned and neighboring counties had high UALE. The viridian-colored areas indicate that the focal county had a high UALE but the neighboring areas had low UALE, with a high–low spatial autocorrelation. The population's UALE in both high–high and high–low clustering areas have marked influences on the whole population's UALE. Residents living in northern Taiwan had higher UALE than those living in the other areas. The cobalt blue-colored regions show low–low spatial clustering; both the focal and the neighboring counties had low UALE. The phthalo blue-colored regions show low–high spatial clustering; the focal county had a low UALE but the neighboring counties had high UALE. The sky blue-colored regions indicate that both the population's UALE in low–low and low–high spatial clustering regions had little or no effects on the global UALE.

Positive spatial autocorrelation is the tendency to have similar values of a variable for areas that are close to one another, such as the variables are both high or both low. Health status and living standards could be similar within nearby areas and hence influence each other's UALE. Particularly, migrant domestic workers move to nearby municipalities and cities for health care. Therefore, a population's health status and well-being are connected to residence. The regional spatial autocorrelation results in Figure 4 indicate that residents living in eastern Taiwan have lower UALE than those living in the other areas.

Discussion and Policy Implications

This research examines the hypothesis that the introduction of UHC health care could eliminate health and well-being inequalities. Although we found a consistent positive correlation between health and income even under the UHC system, it does not necessarily indicate that UHC does not reduce health inequality. We have, however, the following

Table 2 Spatial Lag Regression Estimates of UALE on Selected Variables

UALE	Coef.	Std. Err.	95% Conf. Interval	
Spatial lag effects	0.9154***	0.0587	0.8003	1.0305
Constant	1.6791	8.3155	−14.6193	17.9775
Mortality rate (‰)	−0.4131***	0.0784	−0.2594	−0.5668
The ratio of social security expenditure to government expenditure (%)	0.0046	0.0406	−0.0750	0.0842
Persons/per physician	−0.0041	0.0022	−0.0085	0.0003
Literacy ratio of the population at age above 15 (%)	0.0382	0.0770	−0.1128	0.1892
The ratio of health expenditure to government expenditure (%)	0.2248	0.1753	−0.1188	0.5684

Notes: ***Significant at 1%; observed year: 2009; number of areas: 23; R-squared: 0.8866; AIC: 31.772; SC: 39.720.

arguments to corroborate the above hypothesis: First, our measures of inequality include both income and health, in addition to age and geographic region. Since medical resources are distributed unevenly across Taiwan, the characteristic of equal accessibility under UHC did not solve the problem of unequal distribution. We are confident that mapping population well-being can reflect the influence of residence on inequality without bias. Second, the introduction of the universal coverage of health insurance aims to provide equal affordability of health care, irrespective of geographical location or economic resources. We understand that the UHC system could not distribute wealth evenly
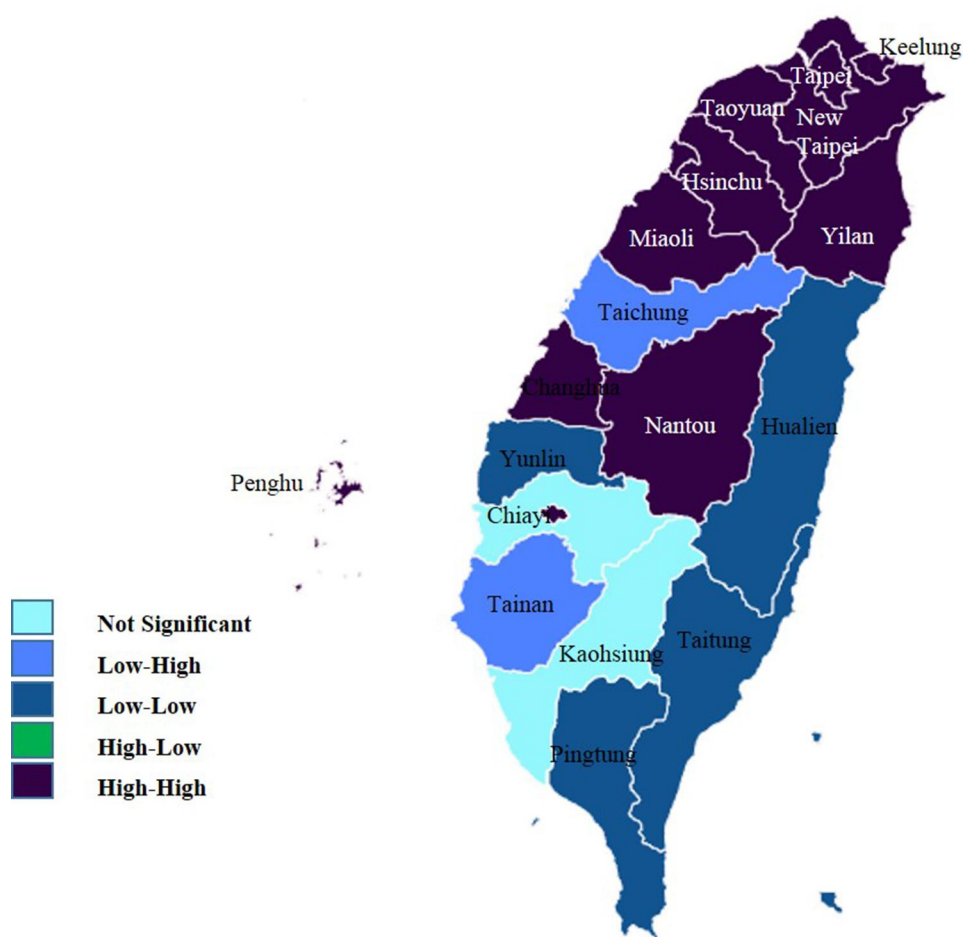
Figure 4 Local indicators of spatial association of UALE in Taiwan.
Abbreviations: High–High, both the concerned and neighboring counties have high UALE; High–Low, the focal county has a high UALE, but the neighboring ones have low UALE; Low–Low, both the focal and the neighboring counties have low UALE; Low–High, the focal county has a low UALE, but the neighboring counties have high UALE; not significant, other spatial clustering regions have little or no effects on the global UALE.

among the population but is designed to improve the health and the quality of life of residents, especially for the low-income groups. We then examined how the provision of UHC links health with income and whether the residents' living standards are equally improved. Third, we compared the inequalities in UALE with those in other measures of well-being, such as health, consumption and income, which still corroborates our hypothesis. Therefore, we tentatively conclude that UHC could not reduce health and well-being inequality, as shown in Figures 1–4, and it deserves further attention.

Our findings suggest that increased accessibility may not be executed optimally across different areas, and the UHC in Taiwan has achieved limited success with regard to eliminating health and well-being inequalities, as verified above. Our research findings are in line with those of Von dem Knesebeck et al and Wen et al[7,8] but in contrast to those of Currie and Decker and Remler,[4,5] although the socio-economic indicators and health measurements in previous studies were different to ours. Based on the experiences of the United States and Germany, health inequalities were observed among the elderly, covered by health insurance, in both countries.[7] A UALE-based policy, which allocates more resources to poorer regions, could be used to reduce mortality rates, as is assured in most of the health-policy issues demonstrated in Table 2.

Conclusions

Though welfare indicators may differ, well-being inequalities still appear to exist among different geographic and economic groups in both developed and developing economies.[26] Our estimation results show that risk of higher mortality rates in disadvantaged areas appears to be associated with well-being inequality, even with universal healthcare coverage. We suspect that related health intervention efforts, such as preventive and curative medical devotion, in Taiwan might not have effectively reached more rural residents, and thus recommend more work be undertaken to reduce mortality rates in these communities. Our findings are specific to an economy with universal health services, ie Taiwan. Nevertheless, the implications of these findings could be applicable to other countries that have or are developing a system of UHC.

Ethical Declaration

The data underlying the results presented in the study are from third party web resources and are open and available for individuals or institutes from the URL: https://www. hpa.gov.tw/Pages/Detail.aspx?nodeid=234andpid=1280. As well as https://www.moi.gov.tw/stat/node.aspx?cate_sn=andbelong_sn=6028andsn=6585. The macroeconomic statistics are open for the public without medical experimentation and human or animal subjects, human cell lines or human tissues.

Acknowledgment

Disclosure

The authors have declared that they have no conflicts of interest for this work.

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