Analyzing the Impact of Travel costs on COVID-19 Vaccination Coverage: A Focus on Subsequent Doses and Boosters in Taiwan

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Introduction

Owing to Taiwan's stringent border management, the nation remained free of COVID-19 outbreaks until the spring of 2021. While this policy provided an extended period of respite, it concurrently diminished awareness of the pandemic among the Taiwanese populace, resulting in low COVID-19 vaccination coverage during that period. Empirical investigations, as conducted by Lee et al. (2022) and Tsai et al. (2022), underscore the pivotal role of risk perception in shaping individuals' decision-making processes.

In February 2022, the Central Epidemic Command Center (CECC) of Taiwan declared the cancellation of the level three alert for the COVID-19 pandemic. Despite the decreased urgency, the government continues to import boosters to combat variant viruses. In this relatively eased circumstance, this study explores whether travel costs impact people's willingness to get vaccinated, potentially resulting in a lower coverage rate.

Related Works

Several studies have identified factors influencing the vaccination willingness among the Taiwanese population. Lee et al. (2022) conducted a comprehensive survey elucidating the determinants of vaccine acceptance in Taiwan. Notably, individuals prioritizing the quality of life in the physical health domain and exhibiting positive health behaviors demonstrated reduced vaccination hesitancy. Furthermore, a sociopolitical dimension emerged, indicating that individuals with higher trust in the government exhibited greater willingness to receive vaccination. Nevertheless, certain demographic groups demonstrated nuanced risk perceptions; for instance, elderly individuals, typically considered at higher infection risk, exhibited a positive correlation with vaccination willingness, whereas concerns about safety among elderly Taiwanese were associated with a negative inclination toward COVID-19 vaccination (Huang 2022).

While extant studies shed light on cognitive factors influencing vaccination willingness, geographic accessibility remains underexplored in the Taiwanese context. Citing the works of Kuehn (2022) and Ali (2021), it is posited that prevailing socioeconomic and geopolitical disparities significantly determine the current vaccination landscape. Barriers such as transportation limitations have been identified as potential contributors to diminished vaccination rates among certain

populations.

Methods

Research Questions

In light of the recognized impact of accessibility on vaccination coverage, this article endeavors to examine whether the cost associated with accessing medical agencies influences vaccination coverage in Taiwan. Given the dynamic nature of vaccination attitudes and the already high full-vaccination coverage rate exceeding 90% in Taiwan, this study specifically aims to investigate the influence on subsequent shots and booster doses.

Data

In the realm of geospatial data related to COVID-19 vaccination in Taiwan, the Taiwan Centers for Disease Control (CDC)[1] have disseminated extensive lists detailing clinics and hospitals where individuals can access vaccination services. However, as these lists exclusively contain addresses as geographical indicators, a crucial transformation into latitude and longitude coordinates is necessary. To address this, our study developed a web scraper using Python-Selenium to collect this geospatial data and saved in a csv format. Subsequently, we applied the Geocoder API developed by Google to convert addresses into precise latitude and longitude coordinates.

Table 1 provides an overview of the number of medical units offering COVID-19 vaccination services, showcasing the geographical distribution across various regions. To enhance the analysis, integration with road network data was conducted to calculate accessibility metrics related to COVID-19 vaccination within specific administrative units.

To achieve this, the study imported street data from OpenStreetMap and administrative boundaries from the Database of Global Administrative Areas (GADM)[2]. This integration with road network data allows for a more comprehensive examination of the spatial accessibility of vaccination services, providing valuable insights for public health planning and resource allocation.

In addition to the Taiwan CDC's efforts, the National Center for High-performance Computing (NCHC)[3] has introduced a COVID-19 Global Pandemic Map dashboard. This platform serves as a valuable resource, providing statistical insights into confirmed cases and vaccination coverage not only within Taiwan but also across

[1] https://www.cdc.gov.tw/Category/List/hlrN4cZsF2Pe4C6DFhggqQ
[2] https://gadm.org
[3] https://covid-19.nchc.org.tw/2023_vaccination.php

various other nations. The datasets are organized by administrative units, with a particular focus on Taiwan's cities and counties treated as equivalent administrative entities. These datasets are further stratified by age groups, offering a detailed perspective on the demographics of COVID-19 cases and vaccination coverage.

Moreover, the NCHC has consistently published vaccination coverage statistics every week since November 7, 2022. This regular and longitudinal dataset enables us to conduct comprehensive studies, particularly in assessing whether the impact of cost distance on vaccination coverage changes over time. The ability to perform longitudinal analyses enhances our understanding of the evolving dynamics of vaccination efforts and their correlation with spatial factors.

Table 1. Number of Medical Units in Each Administration

Administration	Number of Medical Units	Administration	Number of Medical Units
Changhua	100	Nantou	58
Chiayi City	3	New Taipei	234
Chiayi County	49	Penghu	21
Hsinchu City	29	Pingtung	21
Hsinchu County	33	Taichung	30
Hualien	55	Tainan	310
Kaohsiung	209	Taipei	108
Keelung	20	Taitung	35
Kinmen	14	Taoyuan	81
Lienkiang	5	Yilan	62
Miaoli	17	Yulin	14

Spatial Data Processing

To analyze the accessibility of COVID-19 vaccination services, a series of spatial data processing steps were employed. First, the roads data from OpenStreetMap was rasterized, and the resulting dataset was resampled with values of 1 and 0, representing whether the grid cells corresponded to roads or not.

Prior to calculating the cost distance, the dataset of medical units offering COVID-19 vaccination services was projected to EPSG: 4236, utilizing the WGS84 Coordinate System. This step ensures consistency in the spatial reference system for accurate analysis.

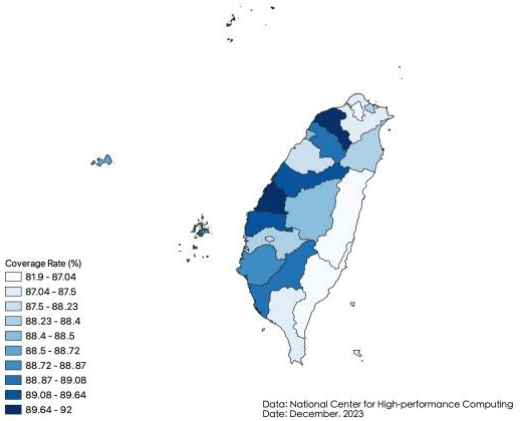
The r.cost tool in QGIS was then applied to compute the cost distance from the medical units to every grid cell. Subsequently, descriptive statistics within cities and counties were obtained by utilizing the zonal statistic function. This process allows for a detailed examination of the spatial accessibility of COVID-19 vaccination

services, providing valuable insights into the distribution of vaccination resources and potential areas of improvement.

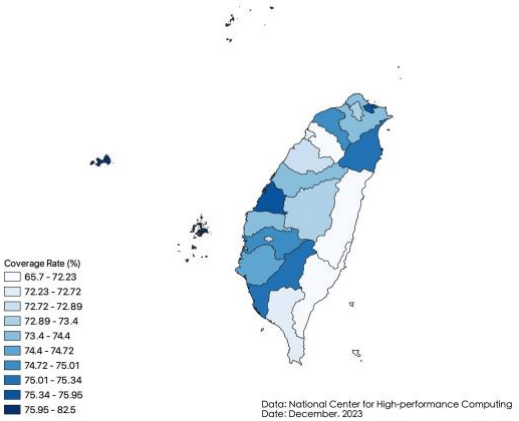
Results

Given that the coverage of the initial dose in Taiwan has surpassed 90%, our attention shifts to subsequent shots, particularly comparing differences between the secondary dose and the first booster. In the spring of 2022, the Taiwanese government inaugurated the COVID-19 booster vaccination initiative, with the culmination of the year witnessing a 74.0% coverage rate for the first booster dose, juxtaposed against rates of 93.9% for the initial dose and 88.4% for the secondary dose.

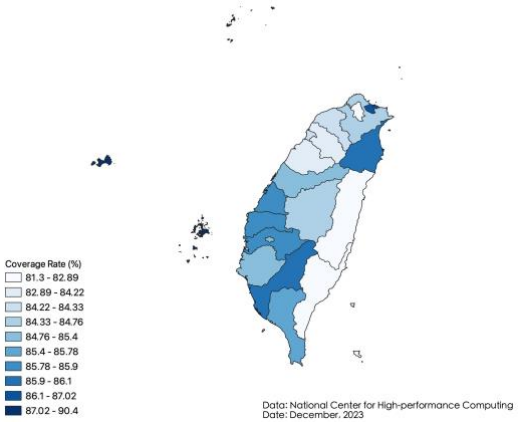
a. Coverage of 2nd shot by Nov. 07, 2022



b. Coverage of 1st by Nov. 07, 2022



c. Coverage of 2nd shot by Sep. 17, 2023



d. Coverage of 1st by Sep. 17, 2023

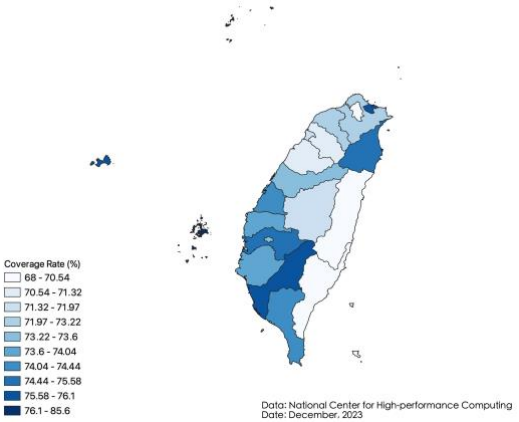


Figure 1.[4]

[4] The anticipated slight decrease in vaccination coverage rates in 2023 relative to 2022 is likely influenced by factors such as natural population loss or domestic migration.

Figure 1 delineates the coverage rates of the secondary dose and the first booster across administrative units in Taiwan, stratified into 10 quantiles. The varying shades of blue in the figure correspond to the coverage rates, with lighter hues indicating lower rates. Notably, eastern Taiwan, encompassing Hualien County and Taitung County, exhibits consistently lower coverage rates for each dose. In 2022, Changhua County manifests the highest coverage rates; however, by 2023, mid and southern Taiwan exhibit comparatively higher average coverages than other regions.

Regarding the cost distance to COVID-19 vaccination services (Table 2.), Hualien County represents the highest cost of accessibility, with a median of 410.92 units, followed by Yilan County (375.93) and Taitung County (344.97). One the other hand, Taipei City, Chiayi City, Hsinchu City exhibit the lowest cost distance to COVID-19 vaccination services.

Table 2. Descriptive Statistic of Cost Distance in Each Administration

Administration	Mean	Median	Standard Deviation
Changhua County	77.99956336	65.35533906	52.9253384
Chiayi City	40.68623314	37.89949494	21.01209917
Chiayi County	188.0888008	126.0243866	156.1077597
Hsinchu City	54.81517012	45.45584412	36.90263761
Hsinchu County	303.5333603	181.3797257	274.4674919
Hualien County	461.1932991	410.9188309	304.8857651
Kaohsiung City	308.9676684	174.5807358	303.431253
Keelung City	69.07042814	60.9411255	45.90503713
Kinmen County	66.10900311	66.84062043	31.76425539
Lienkiang County	174.3358107	54.69848481	559.9017993
Miaoli County	263.8653802	144.9238816	254.3172834
Nantou County	392.8209563	330.8183259	278.2957275
New Taipei City	148.7262633	123.1248917	220.0718944
Penghu County	177.6396471	58.35533906	451.3231494
Pingtung County	317.3237721	260.492424	249.1208682
Taichung City	244.4548863	152.5807358	216.742022
Tainan City	100.1690839	78.11269837	78.12892436
Taipei City	48.83556679	32.97056275	45.82211583
Taitung County	423.0805063	344.9655121	308.6678385
Taoyuan City	136.7721645	82.42640687	149.2094655
Yilan County	427.2304375	375.9310242	312.6961035
Yulin County	146.5242454	136.9116882	83.29337373

This observed distribution aligns with our hypothesized expectation that vaccination coverage would inversely correlate with the cost distance. Consequently, we employed linear regression analysis (Table 3.) to scrutinize this hypothesis, opting for the median instead of the mean to mitigate the influence of outlier data points.

As of November 7, 2022, with a 95% confidence level, the median cost distance significantly influences both the coverage rate of the secondary dose and the first booster. A unit increase in the median cost distance corresponds to a 0.99% reduction in the coverage of the secondary dose, with an R-squared value of 0.3038. Similarly, the coverage of the first booster shows a decrease of 1.59% for each unit increase in the median cost distance, accompanied by an R-squared value of 0.3066. Notably, the significance of the effect of median cost distance on the coverage of the first booster persists until January 16, 2023, with a unit increase correlating to a 1.30% reduction. Meanwhile, the median cost distance has ceased to have an effect on the coverage of the secondary dose.

Despite the statistical significance observed, it is noteworthy that both the coefficients and R-squared values pertaining to the secondary dose and the first booster have exhibited a decreasing trend over time. The diminishing coefficients indicate a waning impact of cost distance on vaccination coverage, suggesting a weakening relationship between the two variables. Furthermore, as of November 7, 2022, the explanatory power of cost distance was maintained at a moderate level; however, subsequent to this date, it gradually declined to a lower level, reaching a diminished level of influence by January 2023.

Table 3. Linear Regression Result

Published Date	Predictor	Secondary Dose		First Booster	
		b	R^2	*b*	R^2
2022-11-07	(Intercept)	89.705249***		76.301699***	
	Median	-0.009898**	0.3038	-0.015882**	0.3066
2023-01-16	(Intercept)	86.395573***		75.137304***	
	Median	-0.006726.	0.1219	-0.012978*	0.1691
2023-04-10	(Intercept)	86.405887***		75.766507***	
	Median	-0.006286.	0.09789	-0.012811.	0.1352
2023-07-09	(Intercept)	86.252545***		75.809114***	
	Median	-0.006084.	0.08961	-0.012643.	0.1346
2023-09-17	(Intercept)	86.093031***		75.666171	
	Median	-0.006022.	0.08123	-0.012451.	0.1252

Note: . indicates p<0.1; * indicates p<0.05; ** indicates p<0.01; *** indicates p<0.001. R^2 represents the adjusted R^2. N = 22.

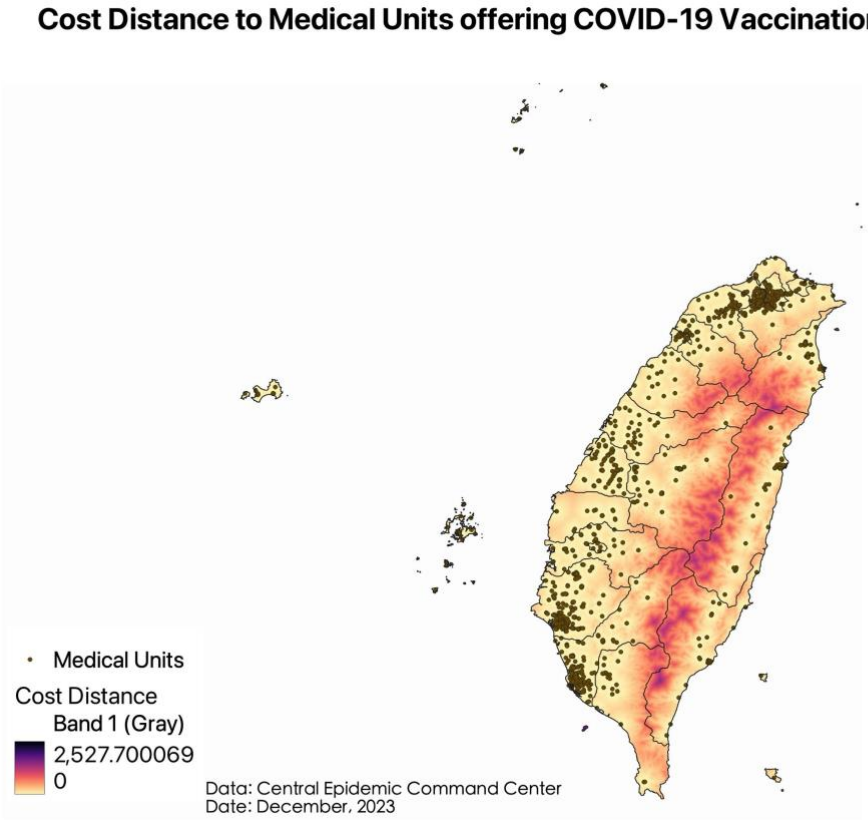


Figure 2.

Discussion

The findings from the linear regression analysis reveal that, in the initial phase of the COVID-19 vaccination campaign, cost distance exhibited a discernible impact on vaccination coverage across diverse administrative regions. While the observed influence is modest, it substantiates the notion that in areas characterized by a scarcity of medical resources, the associated travel costs may pose a noteworthy challenge to be addressed. Nonetheless, it is noteworthy that the influence and potency of this effect are expected to diminish over time. This trend is attributed, at least in part, to the cumulative increase in vaccine supply over time, suggesting a potential resolution to the challenge of low coverage rates.

Conclusion

While the impact of travel cost on COVID-19 vaccination coverage is anticipated to diminish over time, this study underscores the significance of considering this factor, particularly during the initial phase of the vaccination campaign. From a policy-making standpoint, the findings suggest that, in the case of serious and urgent infectious diseases, governments should prioritize the assessment of medical accessibility, recognizing the potential impediment posed by travel costs to

vaccination efforts.

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