Associations between physician supply levels and amenable mortality rates: A descriptive and panel data analysis of Taiwan over nearly four decades

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Abstract

Background. Access to health care is an important determinant of health, but despite years of research, it remains unclear whether having more physicians reduces mortality. In this study, we investigate whether a greater supply of physicians in given administrative areas is associated with lowers rates of amenable mortality, defined as deaths that can be delayed with appropriate and timely medical treatment or public health measures.

Methods. We use Taiwan's population-level National Death Certification Registry data spanning nearly four decades to study the trend in age-standardized amenable mortality rates by area physician supply quartiles. We also conducted multivariate panel data regression analyses of the association between age-standardized amenable mortality rates and physician supply, controlling for mean household income, education attainment, urbanization levels, decade fixed effects, and the implementation of universal health care.

Results. The trend analyses (adjusted for age and sex only) show that Taiwanese townships in the top quartile of physician supply consistently had the lowest age-standardized amenable mortality rates. However, in the panel data regression analyses, after controlling for at least mean household income, the negative association between physician supply and overall amenable mortality loses statistical significance, although it remains statistically significant for ischemic heart disease.

Conclusions. These findings suggest that physician supply, while important, is but one input that contributes to population health and is likely confounded with other socioeconomic factors correlated with better health. Physician supply levels are not randomly distributed, and doctors likely choose to practice in higher income areas and areas with demonstrated medical need. More research is needed, but policy makers should consider broader social policies, not just healthcare resources, as means to promote population health once a critical mass of physicians is achieved.

Background

Is greater physician supply associated with better health and lower mortality? Evidence shows that timely and appropriate primary care can help prevent disease, whether such care is measured in terms of primary care physician supply, an established relationship with the primary care system, or the receipt of a defined and important aspect of primary care.[1] More physicians, ceteris paribus, should theoretically increase access to timely primary care, prevent disease, and ultimately lower mortality rates, particularly from causes of death amenable to medical care.[2] Yet debates still remain whether empirically, having more physicians improves health reduces amenable deaths. Some argue that, with advances in medical technology, health care is making an increasingly important contribution to overall health.[3, 4] Others, however, believe that the marginal return from healthcare services is eclipsed by broader social policies such as education, housing, and transportation.[3, 5, 6]

Existing literature, derived primarily from data before 2000 in Western nations, shows considerable variations in conclusions. The literature overall, however, suggests no consistent relationship between physician supply and amenable mortality.[7] On the one hand, two studies from England concluded that mortality is negatively associated with physician partnership size but not with the supply of available general practitioners.[8, 9] A German study found a negative association between physician supply and avoidable deaths due to cancer of the female breast, as well as colorectal cancer in both sexes.[10] However, a study using OECD data for 19 countries did not find any association between overall physician supply and amenable mortality.[7] In Asia, a single study from Korea determined that a higher number of primary care physicians was associated with lower cancer and cardiovascular mortality.[11] The authors, however, also noted that socioeconomic and population factors seemed to have a greater impact on avoidable mortality rates than physician supply.[11] Other studies that investigate amenable mortality in Asia focused on the relationship between amenable mortality and factors other than healthcare resources, such as income or urbanization.[12, 13]

We examined whether greater physician supply is associated with lower amenable mortality rates using population-level data of all deaths in Taiwan from 1971 to 2008. Our study contributes to the literature by being, to our knowledge, only the second to explore this question in Asia, which has significant structural and cultural differences in healthcare delivery compared to Western countries. Most East Asian countries, including China, Japan, Korea, and Taiwan, lacked or continue to lack a gatekeeping system for referrals to specialists.[14–16] This may make results on the relationship between primary care physician supply and amenable mortality from Western countries less generalizable to East Asia, since patients can and often do self-refer to specialists directly.[15] Different cultural attitudes to medicine, in particular an emphasis on pharmacotherapy in Asian countries,[17] may also alter the effect of physician supply on mortality rates. In addition, our nearly four-decade-long study period spans significant changes in medical technology and the health policy landscape in Taiwan, and affords a long-term, longitudinal analysis of the association between physician supply and amenable mortality.

Taiwan is a particularly interesting case to study in our selected time period. Between 1971 and 2008, Taiwan experienced rapid economic development, and by many measures reached the status of developed economy by the end of the twentieth century. In 1970, Taiwan's life expectancy was 67.88 years, which grew to 78.19 by 2008.[18] The number of physicians per 1,000 grew from 0.4 in 1970 to 1.8 in 2008.[19] In 1970, per capita GDP was $396 United States Dollars, and increased nearly 100-fold to $34,936 in terms of purchasing power parity by 2008.[20, 21] Before 1995, only half of Taiwan's population had health insurance coverage, but the implementation of its National Health Insurance (NHI) in 1996 extended coverage to nearly the entire population virtually overnight.[22] A government-sponsored single-payer system with a mix of private and public providers, NHI has been credited with reducing disparities in access to care and health outcomes in Taiwan.[23] It remains to be seen, however, whether the increasing numbers of physicians reduced disparities in amenable mortality over the nearly four-decade long period of our study.

As healthcare systems around the world face the twin challenges of health disparities and resource constraints, it is important to understand whether increasing scarce healthcare resources, such as the supply of physicians, will mitigate disparities and improve health outcomes. If so, better policies to recruit additional physicians to under-resourced areas should be a top health policy priority. If not, policymakers should consider pursuing evidence-based policies to improve health in disadvantaged areas, such as education and health literacy campaigns, better housing and other improvements to the built environment, and/or infrastructure to improve access to needed healthcare and other social resources.

Methods

Aim, design, and setting

The objective of this study was to assess whether greater physician supply is associated with lower mortality rates from causes of death amenable to medical care. We assessed associations between physician supply and amenable deaths using trend and multivariate analyses, drawing our data from all deaths in Taiwan between 1971 and 2008.

Data

Our primary data source consists of Taiwan's National Death Certification Registry from 1971 to 2008. The data include information on age, sex, location of death, and cause of death for ***all*** deaths of Taiwanese nationals. Because Taiwan law requires a death certificate to be issued by a trained medical registrar within 30 days of death, cause-of-death coding is considered complete and accurate.[24] We collected data on the number of physicians per 1,000 residents by township from Taiwan's Ministry of Health and Welfare's statistics on the current status of healthcare institutions and healthcare utilization,[25] and township-level information on mean household income, population, and education attainment from Taiwan's National Statistics Bureau. We obtained data on township urbanization levels from Tzeng and Wu,[26] who created a composite score of urbanization for each township in Taiwan.

Variables

Amenable Mortality. The death certification data include, for each death, the primary cause of death coded according to the International Classification of Disease, Ninth Revision (ICD9). We followed the definition created by Concerted Action of the European Community on Avoidable Mortality (CAEC) to identify each death as either an "amenable death" or "non-amenable death."[27] Amenable deaths include those causes of death that can be delayed with appropriate and timely medical treatment and/or public health measures. For example, lung cancer death is considered amenable both to public health policy measures (smoking prevention and cessation initiatives) and to medical care (chemotherapy). We present the CAEC classification of amenable mortality in Table 1.

Trends in age-standardized mortality rates by sex. To account for differing age structures between townships, mortality rates were age-standardized in 5-year intervals by physician supply quartile and by sex, except for years 2006-2008, which only has three years because of insufficient number of years in the final period. We disaggregated age-standardized mortality rates by sex because some diseases are specific to women (e.g., breast and cervical cancer), and some may have mortality differences based on sex.[See, e.g., 28, 29, 30] We used the direct method, as listed below, to calculate age-standardized mortality rates (ASMRs) per 100,000 residents for each sex and physician supply quartile:[31]

See Formula 1 in the supporting information.

In the formula above, Wi is the population in the ith age class of the reference population (world population) in 2000, and Ai is the age-specific mortality rate in the ith age class in Taiwan. In our age-standardized and sex-stratified trend analyses of the association between ASMRs and physician supply quartiles, we simply present the trend in all ASMRs (in the aggregate and by specific amenable causes of death) by physician supply quartiles over time.

Physician supply levels. We obtained the number of physicians per 1,000 residents in each of Taiwan's 357 townships[1] or city districts (hereinafter 'townships') from Taiwan's Ministry of Health and Welfare. In our study, we counted all physicians, not just primary care physicians, to reflect the lack of gatekeeping in Taiwan, where most physicians serve roles similar to primary care physicians in the West. For the trend analyses of ASMRs, we categorized the townships into quartiles based on the number of physicians per 1,000 residents, with the first quartile having £0.277 physicians; the second quartile, >0.277 and £0.483 physicians; the third quartile, > 0.483 and £0.984 physicians; and the fourth quartile, >0.984 physicians per 1,000 respectively.

Control variables. Mean household income at the township level was obtained directly from the National Statistics Bureau of the Ministry of the Interior and measured in New Taiwan Dollars. We also obtained education attainment data from the National Statistics Bureau, and calculated the percentage of the population with at least a junior high school education as the number of individuals who completed junior high school divided by the total number of individuals in a given township. We focused on education attainment at the junior high school level (defined as completing nine years of education), as Taiwan implemented the nine-year mandatory educational system in 1968, three years prior to the beginning of our study period. We collapsed Tzeng and Wu's[26] eight levels of urbanization into four levels by combing levels 1-2, 3-4, 5-6, and 7-8, and created three of the four levels as a series of dummy variables to be used in our statistical analyses, with level 4 (the most urbanized townships) as the omitted reference level. Finally, given the long study period and the evolution of medical technology over time, we also constructed decade dummy variables to control for decade fixed effects. Using 1971-1980 as the reference decade, we created three separate dichotomous variables, decade1, decade2, and decade3 respectively representing the years 1981-1990, 1991-2000, and 2001-2008.

Multivariate regression analysis. In addition to the simple analyses of trends, we also conducted several multivariate regressions using age-adjusted ASMR (for all amenable deaths, and key individual amenable causes of death) as the dependent variable, with the following independent variables: the number of physicians per 1,000 residents, dummy variables for urbanization levels, average household income, percentage of junior high school graduates, a post-national health insurance (NHI) dummy variable, and linear time trends variables both before and after NHI. Our unit of observation in the panel was the township-year, and we ran the following regression for each sex separately, where *i* represents township and *t* represents year:

See Formula 2 in the supporting information.

In an alternative specification, we excluded the pre- and post-NHI linear trend variables, and included instead the decade dummy variables (with decade0, 1971-1980 as the reference decade).

The key coefficient of interest is b_0, which denotes the relationship between number of physicians per 1,000 residents and age-standardized mortality rates for amenable causes. We ran a baseline model with physicians per 1,000 residents as the only covariate, then added mean household income, as well as the three rurality, education, pre-NHI year counter, post-NHI dummy and post-NHI year counter variables, or replaced the linear trend variables with decade fixed effects. We clustered our Huber-White robust standard errors at the township level to account for correlations between observations within the same township over time. In addition, because our unit of observation (the township) varied widely in population, we used the township-level population as probability weights in our regressions.

[1] The official number of townships fluctuated because several smaller townships were consolidated over the years.

Results

Overall results. Our findings differ depending on the statistical approach taken, but overall the results do not show that more physicians are associated with lower amenable mortality rates. In our simple trend analyses, the results initially suggest that townships with more physicians have lower amenable mortality rates. In our multivariate regressions, however, the negative association between physician supply and amenable mortality lost statistical significance in almost all specifications after adjusting for our control variables. Below, we provide further detail on these overall results by presenting our descriptive statistics and describing our findings under our trend and multivariate analyses.

Descriptive Statistics. In Table 2, we present the descriptive statistics of our analytical sample. Throughout the nearly four-decade long study period, Taiwanese townships had an average of approximately 0.956 physician per 1,000, ranging from 0 to 17.537 physicians per 1,000 population. Average annual household income in 2001 New Taiwan Dollars (NTD) was approximately $362,502 NTD ($12,083 United States Dollars) over all years, with a minimum of $10,453 NTD ($348 U.S. Dollars) and a maximum of $2,007,955 NTD ($66,931 U.S. Dollars). Around 73.4% of all townships were in the two most rural categories (rural1 and rural2), and the average junior high school graduation rate across townships over the years was approximately 73.1%. Average all-cause ASMR was about 336.23 per 100,000, and 77.57 per 100,000 for amenable mortality rates. Injuries (81.22 per 100,000), followed by hypertension / cerebrovascular disease (36.64 per 100,000), lung cancer (8.92 per 100,000), ischemic heart disease (IHD) (7.45 per 100,000), and asthma (3.47 per 100,000) rounded up the top five amenable causes of death in terms of age-standardized mortality rates.

Trend Analysis Results. Aggregate amenable mortality rates fell during our study period for all physician supply quartiles, and the highest quartile enjoyed the lowest rates over the entire study period. (See Figure 1 and Appendix Table A, top portion in each quartile). However, for the remaining quartiles, the ranking of mortality rates was not strictly monotonic based on physician supply quartiles. On the other hand, all-cause mortality rates and *non-amenable* mortality rates (which are not modifiable by medical intervention) were the lowest in townships in the highest quartile of physician supply, suggesting that non-physician factors also contribute to better health in wealthier areas.

In addition, the aggregate amenable mortality rates masked heterogeneity in the mortality rates of individual amenable causes of death. (See Figure 2 and Appendix Table A, bottom portion in each quartile). For all causes of death other than injuries for both sexes and breast cancer for females, the townships with the greatest physician supply initially had the highest mortality rates but had the lowest mortality rates by the end of the study period. For deaths from injuries, the townships with the greatest physician supply consistently had the lowest mortality rates from 1971 to 2008. Deaths from breast cancer among females show a unique pattern: townships with the highest physician supply had the highest mortality rates in every period of our study. The overall pattern for the trend and descriptive analyses suggests that townships with more doctors eventually had lower mortality rates.

Multivariate panel data regression results. The baseline regression results using only physician supply as the explanatory variable in Table 3 are consistent with the trend and descriptive results. A unit increase in the number of physicians per 1,000 is associated with a reduction of 1.703 ($p < 0.01$) and 0.965 ($p < 0.01$) in ASMR for males and females, respectively (Table 3, columns (1) and (6)). However, when we also controlled for at least income, the negative and significant association between physician supply levels and amenable mortality disappeared. This association between more doctors and fewer amenable deaths also lost statistical significance in all subsequent specifications with additional covariates such as education attainment, urbanization levels, NHI implementation or decade fixed effects. See Table 3, specification (2) to (5) and (7) to (10).

On the other hand, the coefficients on mean household income are negative and significant for both males and females respectively regardless of the specification (See Table 3, specifications (2) to (5) and (7) to (10)). For each additional dollar in mean household income, our results show that amenable mortality rates fall by 0.0234 ($p < 0.05$) to 0.0395 ($p < 0.01$) per 100,000 for men, and 0.0157 ($p < 0.05$) to 0.0233 ($p < 0.01$) per 100,000 for women. The education variable is associated with lower amenable mortality rates among men (ranging from -29.28 (not statistically significant) to -64.34 ($p < 0.01$)). Among women, however, education attainment is significant in none of the specifications.

The negative and significant coefficients on pre-NHI slope (-2.727 ($p < 0.01$) and -2.291 ($p < 0.01$) for men and women, respectively) show that amenable mortality rates fell even before universal health insurance was implemented, and the positive and significant coefficients on post-NHI year counter indicate that the falling trend slowed in the post-NHI years, but remain negative (-2.727 + 2.223 = -0.504 for males and -2.291 + 1.767 = -0.524 for females) until 2008. (See Table 3, specifications (4) and (9) respectively for men and women). In the specification with decade fixed effects, the results demonstrate that independent of other covariates, amenable mortality rates fell relative to the first decade of our study period, 1971-1980. See Table 3, specifications (5) and (10).

In Table 4, we present the results of our preferred specification with NHI implementation rather than decade fixed effects, using as dependent variables five of the most important individual causes of death (ischemic heart disease (IHD), injuries, cerebrovascular disease (CVD) / hypertension, lung cancer, and for women only, breast cancer). The coefficients on physicians per 1,000 are generally non-significant, except for IHD (-0.127 ($p < 0.05$) for men, and -0.0655 ($p < 0.05$) for women).

The coefficients on mean household income are generally negative, except for lung cancer (0.000490 (not significant) and breast cancer for women (0.000920 (not significant)). The coefficients on urbanization levels vary considerably but for many of these leading causes of mortality, the most rural townships actually had lower age-standardized mortality rates. The only noteworthy exception is deaths from injuries, where the most rural townships had higher mortality rates (42.59 ($p < 0.01$) for men and 16.53 ($p < 0.01$) for women). Education attainment, as before, is generally negatively associated with these five amenable causes of death among men, but not among women. (See Table 4, all specifications). As in the main regressions using all amenable deaths as the dependent variable (Table 3), NHI implementation is associated with a reduction in individual amenable deaths, except for breast cancer among women. (See Table 4, specification (9)).

Discussion

Overall, our results show that physician supply was not statistically associated with amenable mortality rates once we controlled for income. Rather than physician supply, greater income was almost always linked to lower mortality, with the notable exception of deaths from breast cancer among females. Our results are consistent with those of Gulliford and colleagues, who concluded that a strong negative univariate association between supply of general practitioners and mortality disappears when adjusted for health status and sociodemographic factors.[8]

It may not be surprising that we found little statistically significant relationship between physician supply and amenable mortality once socioeconomic factors are accounted for. It is essential to recall that physicians do not choose practice locations randomly. In Taiwan until 1983, for example, physician location was determined solely by market forces, and physicians heavily favored rich, urban areas.[32] Post-1983, Taiwan mandated the assignment of certain government-subsidized physicians to relocate to underserved rural areas, but physician supply remained largely concentrated in urbanized centers.[32] Physician supply level is therefore likely confounded with areas with higher income. In our data, for example, physician supply is positively and statistically significantly associated with township mean annual income (every additional $1 in mean income is associate with 0.00452 ($p < 0.01$) additional physician per 1,000), and negatively and significantly associated with rurality. In turn, these wealthy urban areas are likely to have better overall health outcomes due to a combination of sociodemographic and structural factors. Analyses not accounting for wealth/income when exploring the association between physician supply and health outcomes, would therefore be highly likely to suffer from omitted variable bias and biased downward to show a negative relationship.

Our findings that greater mean household income often predicts reduced mortality are consistent with existing studies.[33-37] Income and wealth, at the individual level, are often proxies for a host of sociodemographic, environmental and behavioral constructs that are associated with better health. [35, 38-44] As such, it is not surprising that richer townships have lower rates of amenable mortality.

We note also that in our descriptive analyses (Appendix Table A1), even causes of death *not amenable to medical care* are the lowest in townships with the greatest number of physicians. In areas with the highest number of physicians per 1,000 residents, *non-amenable* mortality was consistently lower than any other townships in Taiwan during the entire 38-year study period. This pattern further supports the argument that physician supply is not the sole contributor to population health. It appears that factors other than access to physicians contributed to such geographical disparities in mortality outcomes across Taiwan.

This is not to say that health care does not contribute to population health. Physician supply is but one type of healthcare resource and is not the only determinant of better population health. In our analyses of individual major causes of death, our results show that certain diseases may benefit from additional physician supply. In particular, age-standardized mortality rates for IHD for both males (-0.127 ($p < 0.05$)) and females (-0.0655 ($p < 0.05$)) decreased with increasing physician supply even when controlling for income (Table 4, specifications (1) and (5)).

Additional evidence of the importance of medical care is provided by the negative coefficients related to the introduction of National Health Insurance in 1995 for certain medical conditions. This significant change in social policy increased health insurance, and therefore access to physician care, from 57% to virtually the entire population within a year.[14] There were especially large reductions in deaths for injuries (-11.84 ($p < 0.01$) and -3.813 ($p < 0.01$) for men and women respectively in all following statistics), IHD (-1.269 ($p < 0.01$) and -1.119 ($p < 0.01$)) and CVD/hypertension (-2.901 ($p < 0.01$), -3.585 ($p < 0.01$)) around the introduction of NHI, with continued acceleration in reductions amenable deaths from injuries (-2.573 ($p < 0.01$), -1.061 ($p < 0.01$)) and IHD (-0.140 ($p < 0.01$), -0.0798 ($p < 0.01$)) for both men and women in the years following NHI adoption. (See Table 4). Removing cost barriers for a large number of individuals through increased health insurance coverage may explain some of the reductions in amenable mortality around 1995-2000 and thereafter.

Conclusion

Our study, which investigated the relationship between physician supply and amenable mortality for the entire population of Taiwan over nearly four decades, found that areas with more physicians did not have lower amenable mortality rates after controlling for socioeconomic factors. Instead of physician supply, higher income emerged as one of the most consistent predictors of lower amenable morality. The importance of income suggests that a host of income/wealth-related sociodemographic factors, including environmental contexts, health behavior and literacy, may play a larger role than medical treatment in reducing mortality once a critical mass of physicians is available. However, physician supply may still be important for some diseases such as heart disease. Given growing health disparities and healthcare resource constraints around the world, future studies should consider investigating diseases and disease characteristics that benefit from greater physician supply. Policy makers should pinpoint scarce physician labor resources in areas with such need, and effective broader social policies may be required to reduce disparities and improve health outcomes in areas where a minimum sufficient number of physicians already exists.

Limitations

There are several limitations to this study. First, miscoding of the ICD-9 cause of death codes may exist, although Taiwan's household death registry data are generally considered accurate and complete. A review of Taiwan's death registry data conducted in 2000 showed 80.9–83.90% agreement rates between the original coding and the reviewer's coding of patients' cause of death.[24] Even if these agreement rates are not considered high enough, our results should remain valid as long as no systematic coding errors exist.

Second, an independent variable used in our study - urbanization levels - was defined in one single year. We were unable to control for changing urbanization over the years in our regressions, but it is likely that relative urbanization levels between townships did not change much during out study period. Indeed, the major loci of urbanization in Taiwan – Taipei, Taichung, and Tainan-Kaohsiung – and their surrounding communities have retained their dominance for over a century.[45, 46] Moreover, our main results related to physician supply and mortality were unchanged whether or not the urbanization variables were included.

Finally, despite the availability of newer definitions of amenable mortality, we chose the 1997 CAEC definition given that it is located near the midpoint of our long 38-year study period. Newer definitions of amenable mortality, which include diseases now considered to be amenable to medical care in modern medicine,[47] may not be applicable to the older years of our long study period. For example, HIV/AIDS, Hepatitis C, and a number of cancers (e.g., bone cancer, testis cancer, thyroid cancer) and some cardiovascular diseases (valvular heart disease, atrial fibrillation and flutter) may not have been as readily treatable in the past as they are today in a then developing economy, or may not be relevant in Taiwan's population (e.g., HIV/AIDS). In addition, to be consistent with prior studies in the literature and given that we assessed past rather than future trends, we restricted our sample to deaths occurring at age 65 or younger.

Declarations

- **Ethics approval and consent to participate**

Not Applicable - This study has been determined by the University of South Carolina Institutional Review Board not to involve human subjects because it does not involve living individuals about whom an investigator conducting research obtains information or biospecimens through intervention or interaction with the individual, and uses, studies, or analyzes the information or biospecimens; or obtains, uses, studies, analyzes, or generates identifiable private information or identifiable biospecimens.

- **Consent for publication**

Not applicable

- **Availability of data and materials**

The datasets generated and analyzed during the current study are available in the National Taiwan University Health Data Research Center repository upon approval of application at https://hdrc.ntu.edu.tw/health_data/data.

- **Competing interests**

The authors declare that they have no competing interests

- **Funding**

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- **Authors' contributions**

Brian Chen conducted initial analysis of the data and completed the first and final draft of the manuscript. Dakshu Jindal conducted additional regression analyses of the data. Y. Tony Yang and Nicole Hair provided critical feedback and revisions for the manuscript. Chun-Yuh Yang initiated the research question and prepared the data as well as conducted the initial descriptive analyses.

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Abbreviations

ASMR – Age-Standardized Mortality Rate

CAEC – Concerted Action of the European Community

HIV/AIDS – Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome

ICD9 – International Classification of Diseases, 9th Revision

IHD – Ischemic Heart Disease

NHI – National Health Insurance

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Tables

Table 1: CAEC Classification of Avoidable Deaths

Cause of death	Intervention	ICD9 code	Age-groups (years)
Deaths amenable to both medical care/public health		001-999	0-64
Ischemic heart disease	Public health	410-414, 429.2	35-64
	Smoking cessation, lifestyle modification		
	Medical care		
	Pharmacotherapy, angioplasty, surgery		
Deaths amenable to medical care			
Tuberculosis	Immunization, contact tracing, pharmacotherapy	010-018, 137	5-64
Malignant neoplasm of the breast [breast cancer]	Screening, surgery, radiation therapy, chemotherapy	174	25-64
Malignant neoplasm of the cervix uteri [cervical cancer]	Screening, surgery, radiation therapy, chemotherapy	180	15-64
Malignant neoplasm of the uterus [uterine cancer]	Screening, surgery, radiation therapy, chemotherapy	179, 182	15-64
Hodgkin's disease	Chemotherapy, radiation therapy,	201	15-64
Hypertension and cerebrovascular disease	Pharmacotherapy, carotid endarterectomy	401-405, 430-438	35-64
Asthma	Pharmacotherapy	493	5-44
Gastric and duodenal ulcer [ulcers]	Pharmacotherapy, surgery	531-534	25-64
Appendicitis	Surgery	540-543	5-64
Hernia	Surgery	550-553	5-64
Cholelithiasis, cholecystitis and cholangitis [Gallbladder diseases]	Pharmacotherapy, surgery	575-476	5-64
Complications of pregnancy [Maternal mortality]	Pharmacotherapy, surgery	630-676	0-64
Perinatal conditions	Screening, pharmacotherapy, surgery	760-779	> 28 weeks, gestation < 1 week and stillbirths

Adapted from the European Community Working Group on Health Services and Avoidable Deaths, 1997

Table 2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
	N=27,028*			
Physicians per 1,000	0.956	1.635	0.000	17.537
Mean annual household income**	362.502	295.135	10.453	2007.955
% Junior high	0.731	0.110	0.455	0.949
Rural level 1 (%)	0.385			
Rural level 2 (%)	0.349			
Rural level 3 (%)	0.139			
Age std mortality rates***				
All cause	336.231	210.019	0	3222.235
Amenable	77.565	60.320	0	1500.901
IHD	7.450	11.993	0	368.418
Injuries	81.222	74.921	0	1293.328
Hypertension/CVD	36.640	36.254	0	1005.838
Lung cancer	8.924	12.109	0	313.595
Breast cancer	2.882	6.906	0	155.019
Cervical cancer	2.656	7.540	0	313.181
Uterine cancer	1.486	5.639	0	175.355
Hodgkin's lymphoma	0.105	1.543	0	150.525
Asthma	3.474	10.826	0	588.235
Ulcers	2.491	8.480	0	395.174
Appendicitis	0.123	1.757	0	106.066
Hernia	0.040	0.849	0	84.335
Gall bladder	0.482	3.079	0	120.048
Maternal mortality	0.543	4.163	0	141.785

*% junior high only has 26,886 observations

** Mean annual household income in 1,000 New Taiwan Dollars

***ASMR in number of deaths per 100,000

Table 3: Associations between age-standardized amenable deaths and physician supply

Dep Var:	Men					Women				
Amenable SMR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Physicians per 1000	-1.703**	0.391	0.565	0.200	0.226	-0.965**	0.0834	0.122	-0.166	-0.146
	(0.489)	(0.569)	(0.473)	(0.440)	(0.440)	(0.295)	(0.346)	(0.299)	(0.288)	(0.287)
Mean income		-0.0395**	-0.0234*	-0.0326**	-0.0321**		-0.0198**	-0.0157*	-0.0233**	-0.0229**
		(0.00793)	(0.0108)	(0.0110)	(0.0109)		(0.00480)	(0.00705)	(0.00699)	(0.00699)
Rural1			-1.014	-1.386	-1.265			-0.824	-1.111	-1.003
			(5.173)	(4.937)	(4.953)			(3.302)	(3.122)	(3.132)
Rural1			-4.862	-5.994*	-5.845*			-2.371	-3.388	-3.257
			(2.964)	(2.760)	(2.775)			(1.897)	(1.752)	(1.759)
Rural3			0.968	1.282	1.315			1.347	1.627	1.672
			(3.568)	(3.392)	(3.404)			(2.306)	(2.160)	(2.168)
Percent > junior high			-64.34**	-29.28	-31.44			-20.42	13.86	11.92
			(19.53)	(18.86)	(18.89)			(12.89)	(12.26)	(12.30)
Post NHI				2.138**	-9.121**				0.118	-7.052**
				(0.779)	(0.742)				(0.648)	(0.610)
Pre-NHI trend				-2.727**					-2.291**	
				(0.0864)					(0.0565)	
Change trend post-NHI				2.223**					1.767**	
				(0.143)					(0.0921)	
Decade1					-31.10**					-23.88**
					(1.229)					(0.917)
Decade2					-43.03**					-38.24**
					(1.372)					(0.991)
Decade3					-44.28**					-39.87**
					(1.619)					(1.120)
Constant	78.62**	106.0**	146.3**	174.7**	161.7**	57.94**	71.79**	85.36**	106.6**	95.18**
	(1.251)	(5.217)	(14.65)	(14.00)	(13.99)	(0.763)	(3.187)	(9.475)	(8.938)	(8.931)
Observations	13,514	13,514	13,443	13,443	13,443	13,514	13,514	13,443	13,443	13,443
R-squared	0.006	0.042	0.056	0.357	0.337	0.003	0.018	0.02	0.375	0.353

Robust standard errors in parentheses

** p<0.01, * p<0.05

Table 4: Associations between select causes of death amenable to medical care and physician supply

	Men				Women				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	IHD	Injuries	Hypertension/ CVD	Lung Cancer	IHD	Injuries	Hypertension/ CVD	Lung Cancer	Breast Cancer
Physicians per 1000	-0.127*	0.290	0.166	-0.0333	-0.0655*	0.246	-0.0728	-0.0529	-0.00443
	(0.0499)	(0.154)	(0.100)	(0.0468)	(0.0371)	(0.190)	(0.151)	(0.0455)	(0.0414)
Mean income	-0.000924	-0.0418**	-0.0202**	-0.00107	-0.00133**	-0.0136**	-0.0155**	0.000490	0.000920
	(0.000860)	(0.00323)	(0.00180)	(0.000719)	(0.000475)	(0.00402)	(0.00363)	(0.000729)	(0.000764)
Rural1	-2.210**	42.59**	-3.361**	-2.065**	0.108	16.53**	-0.0503	-1.432**	-1.583**
	(0.388)	(1.726)	(0.878)	(0.387)	(0.368)	(2.320)	(1.613)	(0.453)	(0.342)
Rural2	-1.980**	31.06**	-3.384**	-1.787**	-0.211	10.85**	0.0670	-1.301**	-1.164**
	(0.284)	(1.022)	(0.585)	(0.267)	(0.239)	(1.209)	(0.968)	(0.245)	(0.241)
Rural3	-0.0131	16.48**	1.152	-0.532*	0.281	5.610**	1.433	-0.256	-0.101
	(0.294)	(1.068)	(0.605)	(0.246)	(0.219)	(1.374)	(1.153)	(0.230)	(0.249)
Percent > junior high	-4.759**	-19.67**	-0.521	-8.017**	1.218	4.987	19.02**	-2.930	1.962
	(1.503)	(6.891)	(3.439)	(1.573)	(1.518)	(8.860)	(6.170)	(2.146)	(1.277)
Post NHI	-1.269**	-11.84**	-2.901**	-0.810**	-1.119**	-3.813**	-3.585**	-0.0107	0.819**
	(0.343)	(1.207)	(0.553)	(0.302)	(0.182)	(0.561)	(0.471)	(0.202)	(0.246)
Pre-NHI trend	0.260**	0.453**	-1.378**	0.194**	0.0267*	0.183**	-1.346**	0.0778**	0.152**
	(0.0139)	(0.0570)	(0.0348)	(0.0129)	(0.0120)	(0.0330)	(0.0412)	(0.0109)	(0.00914)
Change in trend post-NHI	-0.140**	-2.573**	0.852**	0.0412	-0.0798**	-1.061**	0.809**	0.0456*	0.0924**
	(0.0377)	(0.121)	(0.0629)	(0.0343)	(0.0196)	(0.0791)	(0.0548)	(0.0226)	(0.0280)
Constant	11.59**	122.6**	82.59**	16.37**	4.413**	33.36**	47.66**	7.532**	1.389
	(1.146)	(5.211)	(2.692)	(1.231)	(1.193)	(6.520)	(4.635)	(1.654)	(0.986)
Observations	13,443	13,443	13,443	13,443	13,443	13,443	13,443	13,443	13,443
R-squared	0.062	0.345	0.336	0.059	0.019	0.179	0.43	0.035	0.185

Robust standard errors in parentheses
** p<0.01, * p<0.05

Figures

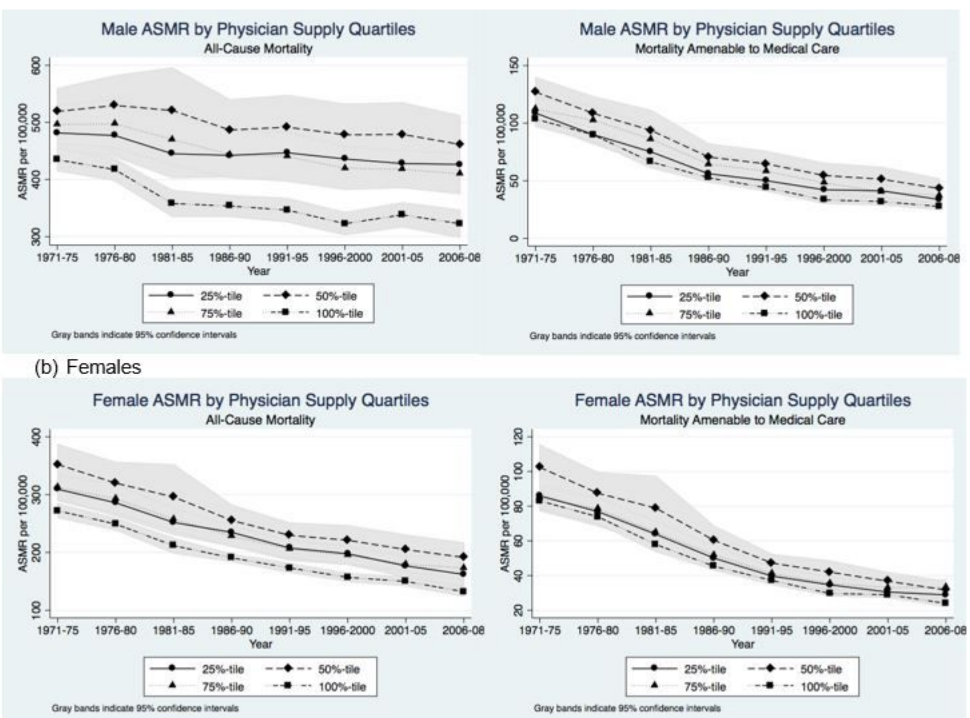

Figure 1

Age-standardized mortality by physician supply quartiles

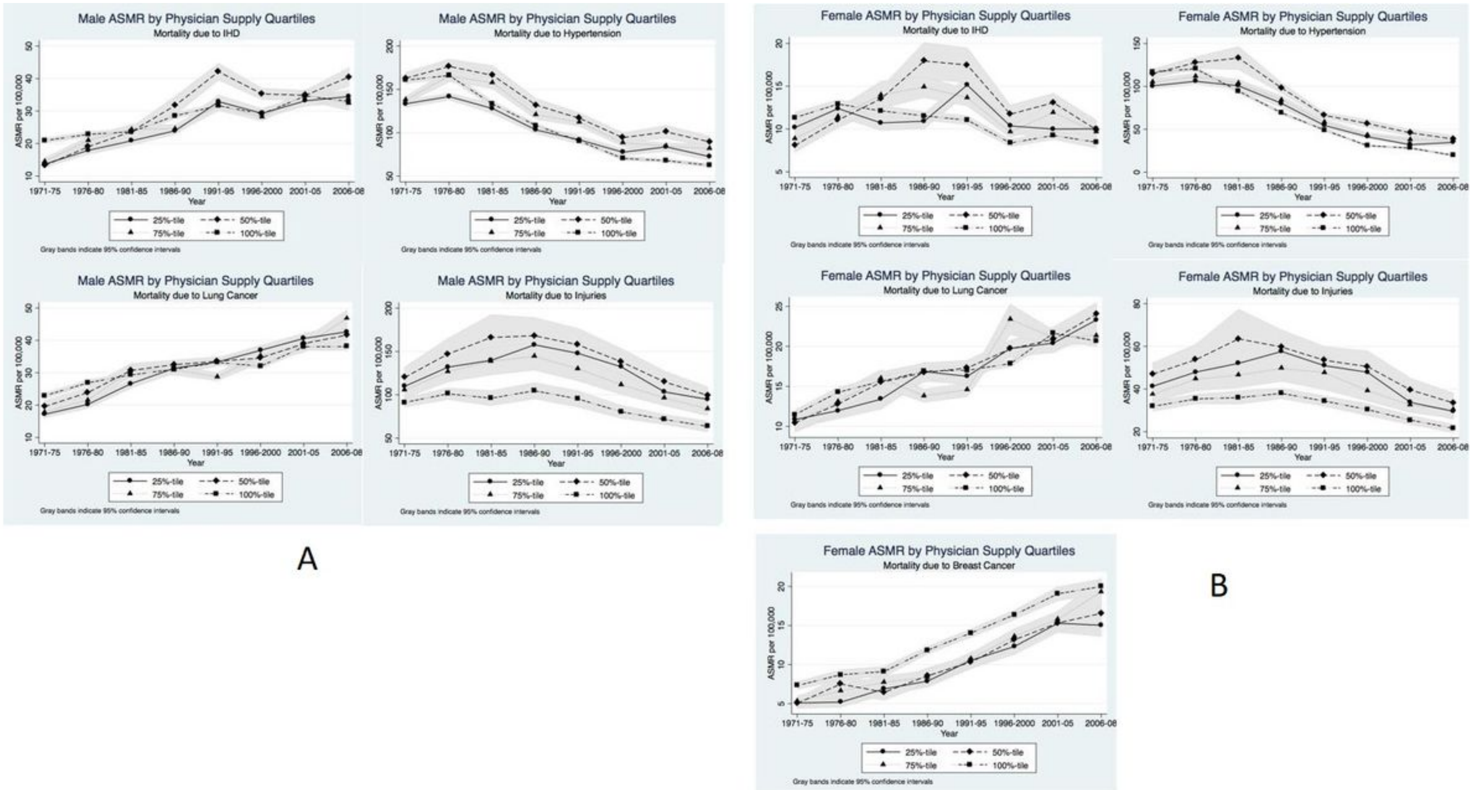

Figure 2

Age-standardized mortality of select causes of death by physician supply quartiles. (A) Males (B) Females

Supplementary Files

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- AppendixTableA1.docx
- Formula2.JPG
- Formula1.JPG