

HEALTH WORKER DENSITIES AND IMMUNIZATION COVERAGE IN TURKEY: A PANEL DATA ANALYSIS

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ABSTRACT

Background: Increased immunization coverage is an important step towards fulfilling the Millennium Development Goal of reducing childhood mortality. Recent cross-sectional and national research has indicated that physician, nurse and midwife densities may positively influence immunization coverage. However, little is known about relationships between densities of human resources for health (HRH) and vaccination coverage within developing countries and over time. The present study examines HRH densities and coverage of the Expanded Program on Immunization (EPI) in Turkey during the period 2000 to 2005.

Methods: The study is based on provincial-level data on HRH densities, vaccination coverage and provincial socio-economic and demographic characteristics published by the Turkish government. Panel data regression methodologies are used to analyze the data

Results: Three main findings emerge: 1) combined doctor, nurse and midwife density is positively and significantly associated with vaccination rates — independent of provincial female illiteracy, GDP per capita and land area — although the positive association diminished over time; 2) HRH-vaccination rate relationships differ by cadre of health worker, with nurse/midwife densities exhibiting positive associations over time while initially positive physician densities turn negative; 3) HRH densities bear stronger relationships with vaccination coverage among Turkey's lower-income provinces compared to higher-income provinces. These patterns of associations are robust to model specification as random or fixed effects.

Conclusions: We draw four main policy conclusions. First, positive nurse-midwife density relationship with EPI vaccination coverage over time suggests that investing in nurses and midwives may be a cost-effective way to increase immunization coverage. Second, the positive relationship between combined physician/nurse/midwife density and EPI vaccination rate —

even with differing relationships when disaggregated — suggests that a focus on shared provision of immunizations may be important for Turkey to achieve its immunization coverage goals. Third, the stronger HRH density-vaccination coverage among lower-income provinces provides empirical justification for encouraging HRH services in relatively disadvantaged areas of the country. Finally, dividends from adequate densities of health personnel can be felt at a level of development well-above that of the world's poorest countries.

BACKGROUND

Increasing vaccination coverage is an important step towards reducing under-5 mortality by two-thirds by 2015, the fourth Millennium Development Goal (MDG). While there have been large reductions in childhood mortality since the second half of the 20th century, over 10 million children still die before the age of five [1]. Vaccine-preventable diseases continue to contribute greatly to this mortality burden, accounting for an estimated 14% of those deaths. Measles alone accounts for around one-third of those deaths while pertussis and tetanus combine for another one-third [2]. Since 1974, the World Health Organization's (WHO) Expanded Program on Immunization (EPI) has been a key tool used by nations to reduce child mortality.

Immunizations against measles, diphtheria, pertussis, and tetanus (DPT), and polio form the core of all countries' basic EPI package, with other antigens included as a country's level of development and financial resources permit. The importance of a strong EPI framework in reducing child mortality is reflected in one of the indicators of the fourth MDG — the proportion of children vaccinated against measles has been selected as one of the indicators of the fourth MDG. Rate of measles immunization is indicative of the coverage and quality of national health care systems since most basic health packages in low- and middle-income countries finance vaccinations against measles and DPT [3].

In Turkey, where levels of childhood mortality and morbidity remain above those in many of its neighboring countries, achieving higher vaccination coverage remains an unmet goal. Turkey is a middle-income country that has experienced substantial economic growth over the past 50 years. As in many other countries with similar development trajectories (e.g., Mexico), it now faces a dual burden of disease wherein communicable diseases continue weigh down the health

of the Turkish people even while the chronic disease burden grows. Infectious diseases account for around 10% of the country's overall disease burden and 80% of childhood deaths [4]. As many children under five die each year (29 per 1,000 live births) as those in middle age (45-59) and it experiences the eighth highest child mortality rate in the WHO European region [2].

Since the 1980s, the Turkish Ministry of Health (MOH) has made significant efforts to reduce childhood mortality through increased immunization coverage. Under Turkey's Expanded Program of Immunizations, vaccinations for BCG, polio, DPT, measles, Hepatitis B and tetanus toxoid are provided free of charge by MOH facilities at the primary health care level. This delivery system accounts for almost all childhood vaccinations administered in Turkey.

Vaccination services are provided primarily by nurses and midwives under the supervision of primary care facility physicians. In theory, nurses provide vaccinations only in health facilities while midwives administer vaccinations both in facilities and in the field. In practice, however, their roles are more interchangeable especially when there are staffing shortages. National Immunization Days (NIDs) launched since the mid-1990s have helped to significantly increase immunization rates over the past decade. Indeed, the drop in post-neonatal death rates since the 1990s may in part be reflective of successes surrounding the EPI program [4]. Nevertheless, improving vaccination coverage remains an important component to reducing the burden of disease of Turkey's children. Turkey's target of 90% complete EPI coverage remains unfulfilled and wide regional differences in vaccination rates persist. Further, findings from the most recent Demographic and Health Survey (DHS) indicate that in 2003, fewer than 50% of children under five received a full complement of the EPI vaccinations before their first birthday [5]. Indeed, incomplete and uneven coverage may be a contributory factor to cyclical outbreaks of measles

which seem to occur every three to four years [6] and persistently elevated levels of childhood mortality more generally.

Recent international research suggests that the size of countries' health workforces can be important in increasing vaccination coverage. The 2004 Joint Learning Initiative's Human Resources for Health report and the 2006 World Health Report focused attention on the many important roles that human resources for health (HRH) play in the functioning of health systems. Findings from the World Health Report were based in part on recent cross-country research examining density of HRH (i.e., number of health workers per population) and health outcomes and service provision, including vaccination coverage. Using 63 country-years of data from 49 countries, Anand and Baernighausen (2007) examine associations between coverage of three types of vaccines — measles-containing vaccine, DPT and polio — and health worker density. Controlling for GNI per capita, land area and female adult literacy, they find that the combined density of doctors and nurses to population is positively and significantly related to coverage of the three vaccines. When densities are disaggregated by type of health worker, they find that nurse density in particular is positively associated with vaccination coverage while physician density is not. The authors hypothesize that the opportunity cost for physicians of administering vaccinations is sufficiently high such that an increase in density does not lead to increased vaccination coverage [7].

A second cross-national study finds similar positive relationships. Expanding on a dataset as used by Anand and Baernighausen (2004), Speybroeck et al (2006) find a positive relationship between aggregate HRH density and measles coverage [8, 9]. Findings from their disaggregated

analysis, however, differ from those of Anand and Baernighausen (2007). Speybroeck et al. find that physician density remains statistically significant with vaccination coverage while nurse/midwife density does not. The authors hypothesize a number of reasons for differences in findings. Opposite results pertaining to physician density may be due to the generally low levels of physician densities in Anand and Baernighausen's sample (the implication being that lack of variation inhibited finding of statistical relationships). Non-significance relating to nurses/midwives may be due to greater cross-country heterogeneity in defining these categories of HRH than for physicians (implying greater measurement error undermining true relationships).

While such cross-national studies have begun to construct an evidence base surrounding deployment of health workers and coverage of health services/health outcomes, two major gaps in our knowledge remain. First, little within-country research has been conducted on levels of health workers and health outcomes. As Speybroeck et al. note, the qualifications, training, classification and roles of health workers vary widely from country to country. Nurses in some countries, for example, may undertake many of the same activities as junior doctors in others. Examining relationships between types of health workers and health service provision at the cross-national level is therefore prone to error. A within-country analysis avoids such limitations and can therefore provide somewhat stronger evidence on these associations.

Second, while previous studies have generated valuable hypotheses on causal relationships between HRH and health outcomes [10], their cross-sectional design inhibits deeper investigation. Just as vaccination coverage may be a function of health worker density, so both

vaccination coverage and HRH density may be affected by other unobserved characteristics which enter into the HRH-health relationship. The quality of a country's infrastructure, logistics system, or citizen trust in health institutions and workers, for example, may be associated with vaccination coverage. Should those unmeasured factors be related to health worker density, the previous studies' empirical estimates may be capturing much more than just the role of health workers on vaccination coverage. Additionally, the previous cross-sectional studies provide little insight on how relationships may evolve over time. Such knowledge could be useful to policymakers seeking to undertake long-term strategies of heightening their country's vaccination coverage.

The present study seeks to answer the question: have HRH densities contributed to increasing vaccination rates in Turkey and what implications do findings hold for raising future vaccination coverage? The analysis takes advantage of a panel dataset to extend prior research on this subject. It not only offers insights into immunization rate variation at any particular point in time but changes in immunization rates over time. Panel data analysis also makes it possible to distinguish health worker densities from unobserved (and relatively static) country characteristics which may impact vaccination coverage; this feature addresses the second major limitation of previous research. While it does not purport to make firm declarations on chains of causality between health workers and vaccination coverage, it does provide evidence which goes beyond that provided by cross-sectional studies to date.

DATA AND METHODS

The analysis draws upon three sources of provincial-level data from Turkey that span the period 2000 to 2005. Turkey is composed of 81 administrative provinces within seven broader

geographical regions. Provincial-level data on vaccination coverage and deployment levels of public sector human resource densities are drawn from Primary Health Care statistics published by the Turkish Ministry of Health [11]. Data on provincial population levels, per capita GDP, land area and female adult illiteracy are published by the Turkish Statistical Institute [12].

Dependent variable

Data on immunizations are collected by the Turkish Ministry of Health based on the national registry system which records the number of doses administered by the government for a variety of types of vaccinations. Vaccination rates are calculated according to standard administrative methods in which the number of doses of each vaccination is divided by the number of eligible-aged children living in each respective province. The dependent variable is constructed as the mean vaccination rate of the six component immunizations of all vaccinations provided by the national EPI program (i.e., measles, BCG, Hepatitis B, polio (3 doses), DPT (3 doses), and tetanus typhoid (2 doses)). While previous research has focused on relationships between HRH and individual antigens, a composite EPI indicator is justified and more informative in the context of Turkey. As indicated in Table 1, correlations among the five antigens aimed at communicable diseases are particularly high — ranging from 82% to 99% — while tetanus typhoid exhibits yearly correlations from 60% to 76%¹. A composite EPI indicator therefore adds greater variability and information to the outcome in a way that does not fundamentally alter relationships between individual vaccinations and HRH densities. Indeed, we find empirically that results from EPI analyses do not differ qualitatively from those examining HRH densities and individual vaccination rates (results available from authors upon request).

¹ Despite its lower degree of correlation, tetanus typhoid is included in analysis because it a) is nonetheless part of Turkey's EPI program and b) exclusion of this EPI component from analysis does not substantively affect empirical results (results available from authors upon request).

Independent Variables

Choice of independent variables is informed by previous studies and the nature of our dataset. HRH density is measured in two ways: aggregate density of doctors, nurses and midwives working in public sector primary care facilities; and density of doctors and aggregate density of nurses/midwives. Nurses and midwives are combined into one category given their primary roles in vaccination services. Following previous studies, variables on GDP per capita, female adult illiteracy and land area are also included. Data on per capita GDP and female adult illiteracy are limited to the year 2000 — the last year that both variables were calculated as part of Turkey's year 2000 census. Provincial land area is measured in kilometers (squared). Finally, a linear time trend variable (range 0 – 5) is constructed given the panel nature of our dataset.

Estimation Strategy

Previous research leads us to hypothesize the following provincial-level model:

Vaccination Rate = $f(\text{HRH density, time, provincial socio-economic characteristics, provincial demographic characteristics})$.

Our theoretical model results in the following estimating equation:

$$\ln\left(\frac{Y}{1-Y}\right)_{it} = \beta_0 + \beta_1 \ln(\text{HRH} / \text{pop})_{it} + \beta_2 \text{TimeTrend} + \beta_3 \ln(\text{GDP} / \text{capita})_i + \beta_4 (\text{FemaleIlliteracy})_i + \beta_5 \ln(\text{LandArea})_i + a_i + \varepsilon_{it} \quad (1)$$

where Y is either rate of measles vaccination or rate of our composite EPI indicator, and HRH/pop is specified in two different ways: 1) aggregate density of primary care doctors, nurses and midwives, and 2) density of doctors and aggregate density of nurses/midwives. We employ

a logistic-log functional form to be consistent with — and for the same reasons as — previous research. As described in Anand and Baernighausen, the logistic functional form of the dependent variables addresses both upper and lower boundedness between 0 and 1 [7].

Our empirical analysis expands upon the base model in equation (1) in three main ways. First, to explore the relationships between both our time-varying HRH explanatory variables (i.e. health worker densities) and time-invariant provincial characteristics (i.e., GDP per capita, female adult illiteracy, and land area) we estimate both random and fixed effects models of equation (1). In either case, and as previously related, the structure of panel data allows us to net out health worker-vaccination rate relationships from unobserved provincial characteristics which may be related to both (e.g., physical infrastructure). Second, to allow for differing relationships over time between types of health workers, we interact HRH densities with our time trend variable. Third, to explore possibilities of different HRH-vaccination relationships by level of development, we estimate all models stratified by level of provincial GDP per capita.

Standard errors are clustered by province to be robust against heteroskedasticity inherent in aggregate data. Such clustering precludes a traditional Hausman specification test to evaluate the random effects model assumption that $Cov(X_{it}, \alpha_i) = 0$. Consequently, we conduct an alternative specification test described in [13]. This methodology tests the joint significance of time-varying variables which have been demeaned and entered directly into the random effects estimation; joint significance implies that $Cov(X_{it}, \alpha_i) \neq 0$ and that the random effects estimates are not consistent. All analyses are conducted in STATA 9.0.

RESULTS

Descriptive Statistics

Overall vaccination rates of EPI immunizations range from 74% to 82% over the study period for a six-year average of around 74% (see Table 2). Vaccination rates for measles, DPT, polio and BCG are generally higher than the overall EPI average, those of HBV around the average, and those of TT2 the lowest among each type of immunization. There has been an increase in immunization coverage from baseline to endline (e.g., from 0.74 to 0.82 for all EPI immunizations), but there is no clear pattern of a consistent increase in vaccination coverage over time.

In terms of human resource indicators, Table 3 indicates that overall nurse and physician densities are at comparable levels — around 2.4 and 2.0 per 10,000 population, respectively — with relatively greater numbers of midwives per 10,000 population (3.7, on average). The density of primary care doctors held steady from 2000 to 2002 but then fell by around 1 doctor per 5,000 population by 2005. Conversely, nurse and midwife densities have experienced a modest increase over the study period of around 1 nurse per 3,000 population and 1 midwife per 2,000 population. Fluctuations in midwives and nurse densities appear to positively coincide with those of vaccination rates. Drops in vaccination coverage in 2002/2003 occur in tandem with decreases in nurse/midwife densities while rising vaccination coverage in 2004/2005 corresponds to rising nurse/midwife densities. While relatively elevated vaccination rates from 2000 to 2002 correspond to the highest doctor densities of the study period, vaccination rate fluctuations in the last three years do not appear to be positively associated with physician

density. Indeed, doctor density in 2005 — the year with the highest vaccination rate — is lower than in 2003 — the year with the lowest vaccination rate.

There are also regional differences in both vaccination coverage and health worker density that appear to break down along provincial socio-economic lines. Provinces in the Eastern and Southeastern Anatolia regions are among the most rural, poorest and least developed in Turkey. Indeed, the data indicates that, in 2000, over 90% of the region's 23 provinces fell below the country's mean GDP per capita of USD 6,470; this compares to 33% among the other five provinces. Similarly, adult female adult illiteracy in Eastern and Southeastern Anatolia in 2000 (37%) was twice as high as that of the other provinces and almost 15% above the national average of 23%. Table 4 indicates differences in vaccination rates and HRH densities that go alongside these socio-economic disparities. Over the six-year time period, vaccination rates average 13% to 19% higher in the richer regions compared to Eastern and Southeastern Anatolia. Similarly, densities of doctors, nurses and midwives are uniformly higher in Turkey's wealthier regions.

Regressions

Table 5 presents results from the random and fixed effects models for EPI vaccinations. In terms of the random effects models, Model I of Table 5 indicates significantly positive associations between aggregate HRH density and EPI vaccination coverage. This relationship is strictly positive in the model without interacting HRH density with the time trend ($\beta = 0.25$; $p = 0.01$), while the model with the interaction suggests a strongly positive main effect association ($\beta = 0.46$) that has diminished over time ($\beta = -0.09$) to essentially little remaining positive influence

by 2005. Model II provides indications that different categories of HRH may be playing different roles in EPI vaccination coverage. Doctor density and its interaction with time exhibit the same pattern of relationships as aggregate HRH density in Model I ($\beta = 0.56$ and $\beta = -0.22$, respectively; both individually and jointly significant at the 1% level). For nurses and midwives, a non-significant and negative main effect term in the interacted version of Model II ($\beta = -0.05$) has been more than counteracted by a positive association thereafter (interaction term $\beta = 0.10$; joint F-test of nurse-midwife density and interaction term p-value <0.01). Both joint F-tests of no HRH effects in the interacted models are highly significant ($p = 0.024$ and $p < 0.01$, respectively), suggesting that the interacted models justify the cost of loss of degrees of freedom.

In terms of control variables, adult female illiteracy has a large and negative association with vaccination coverage wherein a 10% increase is associated a 41% reduction in odds of completed EPI vaccination schedule. This is to be expected given the well-established micro-level link between education and vaccination coverage [8], including previous research from Turkey [14-16]. However, neither GDP per capita, land area nor the time trend are significantly associated with vaccination coverage. Time trend coefficients from the interacted models are all negative and significant, predicting from a 0.64 to 1.14 reduction in log odds of EPI vaccinations.

Together, the explanatory variables account for around one-half of variation in our outcome variable. While most of this variation is between provinces, within-province variation explained by Model II (R-squared = 0.11) is more than twice that of Model I (R-squared = 0.04).

Results from the fixed effects estimation models are consistent with those from the random effects. HRH coefficients for both versions of Model I are attenuated slightly. Though the non-

HRH coefficient in the non-interacted model loses significance, the coefficients from the interacted version of Model I remain jointly significant ($p = 0.04$). The interacted version of Model II suggests that combined nurse/midwife density has had an unconditionally positive relationship with EPI vaccinations over time, wherein both the main effect and interaction terms are positive and jointly significant (density $\beta = 0.029$ and density * time $\beta = 0.12$; joint significance test p -value < 0.01). As with the random effects analyses, joint F-tests of no HRH effect suggest that the interacted versions of each model are appropriate. The interacted version of Model II (i.e., disaggregated densities) explains more within-province than between-province variation, while Model I (i.e., aggregate HRH density) explains primarily between-province variation.

Specification tests for Model II reject the appropriateness of the random effects estimates (joint F-tests of no HRH density fixed effects p -value < 0.01). This test is more ambiguous in Model I wherein only the interaction term version is rejected (p -value = 0.01) This suggests that while doctor, nurse and/or midwife densities are correlated with unobserved provincial characteristics, the correlations may be, to some degree, canceling each other out for an apparent null association when combined into overall HRH density.

In light of the descriptive-level associations previously highlighted between provincial socio-economics and vaccination rates/HRH densities, we explore how the vaccination-HRH density relationship may vary by level of provincial development. Given the above-described findings for the full sample, we also restrict analysis to the interacted versions of each model and the fixed effects specifications. Table 6 presents the results stratified by provincial GDP per capita.

For provinces falling below mean GDP per capita (i.e., “low-income provinces”), results are comparable to and even stronger than those for the whole sample. Indeed, the remarkable similarities between coefficient signs and magnitude as well as model specification tests suggest that the overall results are largely being driven by relationships among these provinces. For example, EPI fixed effects estimates from Model II suggest that while a positive relationship with doctor density (main effect $\beta = 0.21$) is offset by 2001 and negative thereafter (interaction $\beta = -0.22$; joint F-test p-value = 0.01), nurse-midwife density is both positive ($\beta = 0.43$) and increasing over time (interaction $\beta = 0.029$; joint F-test p-value = <0.01). In addition, the differences in explained variation between Models I and II are even more apparent in these provinces compared to the full sample. That is, Model I primarily accounts for between-province variation (R-squared = 0.52) whereas Model II almost exclusively explains within-province variation (R-squared = 0.24).

A much different picture emerges among Turkey’s higher-income provinces. Among these provinces, neither model provides evidence of significant relationships between HRH densities and log vaccination odds at the 5% level, either in terms of individual or aggregate densities. Indeed, the parameters estimated in the fixed effects models explain a substantially lower degree of variation in vaccination rates in these provinces compared to in lower-income provinces (though all model Wald tests of significance remain significant). It is likely that this finding reflects reduced power to detect relationships than in lower-income provinces: there is a lower degree of variability in terms of both our outcome and HRH density variables in these provinces compared to lower-income provinces.

DISCUSSION

An emerging literature has begun to establish links between human resources for health (HRH) and population health. At the cross-national level, there appears to be positive relationships between HRH densities and vaccination coverage as well as health status. To our knowledge, ours is the first study in the field of health to extend such research within a developing country context and analyzing changes over time. Our study generally corroborates positive relationships between HRH densities and vaccination coverage, and also suggests that HRH densities in Turkey have significantly influenced vaccination rates over time. Our main findings can be summarized as follows. First, combined doctor, nurse and midwife density is positively and significantly associated with provincial-level vaccination rates EPI immunizations, though this positive association diminished over the study period. Combined density primarily accounts for differences in vaccination rates between provinces for any given year, with lesser bearing on variations over time.

Second, our disaggregated analyses indicate that different categories of health workers exhibit differing relationships with vaccination rates. The positive/diminishing relationships of the aggregate HRH density analyses appear to be driven primarily by physician density which exhibits the same patterns. For nurse/midwife densities, there is greater evidence of unconditionally positive relationships over time. Given that nurses and midwives at the primary care level are responsible for administering vaccinations, the positive relationship is perhaps not surprising. It is also consistent with previous research from Turkey indicating that follow-up visits from midwives are a determinant of vaccination rates [16]. Further, the independent physician density and nurse-midwife density relationships are related in large part to variations over time.

Third, we find evidence of a distributional dimension in which gains in immunization rates have been greatest among Turkey's poorer provinces. In provinces with income levels below the national average, findings mirror and even amplify those for the whole sample. By contrast, there is less evidence pointing to relationships between densities and vaccination rates among Turkey's relatively well-off provinces. Lack of evidence among these latter provinces likely emanates from lower variability/higher levels of both our outcome and HRH variables. That is, there is a lower degree of power to detect HRH density-vaccination rate relationships among higher-income provinces where both outcome and HRH density variables exhibit less variability. More substantively, the lack of findings could also indicate an upper bound to HRH influences on vaccination rates. Indeed, random effects models of our stratified analyses provide little evidence that any of the time-invariant explanatory variables bear relationships to EPI vaccination rates in Turkey's higher-income provinces. This contrasts markedly with random effects findings among low-income provinces in which GDP per capita bears a positive (and borderline significant) relationship while female adult literacy continues to bear a strongly negative relationship (results not shown). While HRH densities and socio-economic factors appear to be important on the whole, then, there is much stronger evidence of such relationships in less well-off provinces.

Our analysis has a number of policy implications for Turkey and developing countries more generally as well. First, it suggests that investing in nurses and midwives may be a cost-effective way to bring about future increases immunization coverage. According to fixed effects results for all of Turkey's provinces, the positive association between nurse/midwife density and EPI

vaccination rate over the study period is roughly equivalent to density of doctors' association with EPI vaccinations. Yet an average nurse salary in the public sector is only two-thirds that of a general practitioner physician in the public sector [17]. This suggests that investment in primary care nurses and midwives may have been more cost-effective for the government than investments in physicians. Additionally, the model with disaggregated nurse/midwife densities has primarily explained variation in immunization rates over time, not just variation between provinces within a given year. In terms of increasing future immunization coverage, then, these results suggest that targeting investments in nurses and midwives would be the more cost-effective strategy than investing in training of additional doctors.

Second, the findings suggest an importance in focusing on shared provision of health services. The differing relationships we find between EPI vaccination rate and physician and nurse/midwife densities, respectively, may arise for any number of reasons. This finding may indicate a kind of substitution effect across cadre of health worker. Or it might reflect a diminishing need for close physician supervision and increasing capacity of nurses and midwives to provide vaccination services over the study period. Whichever the reasons, it should be underscored that combined density consistently exhibits an overall positive relationship with EPI vaccination rates. Together, our findings are consistent with a model of care in which roles and responsibilities are shared across types of health workers. In this vein, the recent introduction of a family medicine model of care in Turkey could help maintain positive HRH-vaccination associations. The MOH is currently emphasizing the role that primary health care must play in addressing Turkey's disease priorities [18]. The family medicine model emphasizes an approach to care in which physician-nurse and physician-midwife teams provide services. Our findings

that multiple types of health workers are important for increasing vaccination coverage suggest that a team-based approach may be important in helping Turkey bring its level of childhood mortality more in line with its European neighbors through improved vaccination coverage.

Third, it provides an empirical justification for encouraging HRH service in relatively disadvantaged areas of the country. As in many other countries, Turkey faces the ongoing challenge of finding an adequate number of health personnel to work in rural and poorer areas of the country. In fact, our yearly HRH densities in provinces above the mean GDP per capita have uniformly exceeded those in lower-income provinces (from 4.4 to 7.7 HRH / 10,000 population). The MOH has employed various measures to encourage such service, including increased pay, quicker progression along the civil service deployment scale and compulsory service[19]. The findings from this study provide evidence that such efforts can bear fruit and some of the country's greatest health gains may be found in those same disadvantaged regions.

Finally, our analysis suggests that dividends from adequate densities of health personnel can be felt at a level of development well-above that of the world's poorest countries. As a middle income country, Turkey possesses relatively high levels of health personnel, vaccination rates and development compared to low-income countries. Even so, it is only among Turkey's most economically advanced provinces that evidence of positive relationships between HRH density and vaccination rates begin to taper off. With per capita GDP of around USD 3,400 at baseline, the average income level of Turkey's lower-income provinces is triple that of the world's least developed countries (USD 1,110) and close to the average of all low- and middle-income countries (USD 3,700) [20]. This finding suggests that a threshold of diminishing returns may

be quite high (in terms of both level of development and vaccination rates), and Turkey's lessons are relevant for many other developing countries.

LIMITATIONS

Previous studies have raised concerns about the accuracy of immunization rates reported by routine registry systems. In a study of 45 countries, Murray et al. found that officially reported DPT coverage levels were systematically higher than those from Demographic Health Surveys [21]. However, comparison of Turkey's officially reported estimates for 2003 and DHS data of the same year do not suggest the presence of an upward bias over all EPI vaccinations. Though the official estimate of 68% for DPT is higher than that of the DHS (64%), estimates for polio are identical and country estimates for BCG, measles and tetanus are lower than the DHS [22]. This is more suggestive of random measurement error than systematic biases. If so, we would expect this error to attenuate our HRH coefficient estimates towards the null rather than inflate them.

The narrow/long nature of our dataset (i.e., high number of panels compared to time periods) warrants caution when drawing conclusions about the role of HRH densities and vaccination rates over time. That is, the relatively limited number of years does increase the chance of spurious associations due to chance. However, additional analyses (not shown) suggest that the results are robust. When we include a dummy variable for the year 2005 — the year with the highest vaccination rate of all years — the same patterns of associations still result: aggregate HRH density is positively associated with vaccinations and has a negative interaction term. This appears still to be driven by physician density coefficients whereas nurse/midwife densities exhibit opposite relationships (the magnitude of the negative time trend is reduced and, as

expected, the year 2005 has a positive coefficient. Further inclusion of a dummy variable for 2003 (the year with the lowest vaccination rates) also does not change the pattern of associations. Though significance of individual densities are reduced with inclusion of year dummies, joint HRH density is consistently significant. Thus even under these models increasingly unrestricted (and over-fitted) in terms of yearly fluctuations, the results are similar.

Finally, the findings are limited to provincial-level vaccination rates and cannot be directly linked to individual-level outcomes. For instance, our EPI analyses suggest that HRH densities have positive relationships with the odds of administering a full set of immunizations for the population at hand. This is different from the odds of an individual child in that province receiving those vaccinations. Indeed, as highlighted previously, recent DHS data suggests those rates are much lower (less than 50%). Nevertheless, we would expect our outcome rates — number of doses administered per eligible age population — to be correlated with individual-level degree of vaccination schedule completion. Further, our outcomes remain indicative of health system capacities to reach its citizens. The policy lessons described earlier therefore remain.

COMPETING INTERESTS

None.

AUTHORS' CONTRIBUTIONS

AM performed the statistical analyses and drafted the manuscript. TJ participated in developing the research question and drafting of the manuscript. WY participated in statistical analyses. SM participated in drafting of the manuscript.

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REFERENCES

1. United Nations: **The Millennium Development Goals Report: 2006**. New York: United Nations; 2006.
2. **Core Health Indicators. Turkey**.
[<http://www.who.int/whosis/database/country/compare.cfm?country=TUR&indicator=MorChildBoth&language=english>]
3. **Millennium Development Goals**. [http://ddp-ext.worldbank.org/ext/GMIS/gdmis.do?siteId=2&contentId=Content_t15&menuId=LNAV01HOME1]
4. Ministry of Health of Turkey: **National Burden of Disease and Cost Effectiveness Project: Burden of Disease Final Report**. Ankara: Refik Saydam Hygiene Center Presidency, Refik Saydam School of Public Health Directorate, Baskent University; 2004.
5. Hacettepe University Institute of Population Studies: **Turkey Demographic and Health Survey, 2003**. Ankara, Turkey: Hacettepe University Institute of Population Studies; 2004.
6. D Guris, Y Bayazit, U Ozdemirer, V Buyurgan, C Yalniz, I Toprak, S Aycan: **Measles epidemiology and elimination strategies in Turkey**. *J Infect Dis* 2003, **187 Suppl 1**:S230-4.

7. S Anand, T Barnighausen: **Health workers and vaccination coverage in developing countries: an econometric analysis.** *Lancet* 2007, **369**:1277-85.
8. S Anand, T Barnighausen: **Human resources and health outcomes: cross-country econometric study.** *Lancet* 2004, **364**:1603-9.
9. N Speybroeck, Y Kinfu, M Dal Poz, D Evans: **Reassessing the relationship between human resources for health, intervention coverage and health outcomes.** Background paper prepared for the World Health Report 2006. Geneva: World Health Organization; 2006.
10. C-A DuBois, M McKee: **Cross-national comparisons of human resources for health – what can we learn?** *Health Economics, Policy and Law* 2006, **1**:59-78.
11. **Ministry of Health.** [<http://www.saglik.gov.tr/>]
12. **State Institute of Statistics.** [<http://www.tuik.gov.tr/Start.do>]
13. JM Wooldridge: **Econometric analysis of cross section and panel data.** Cambridge, Mass.: MIT Press; 2002.
14. A Topuzoglu, GA Ozaydin, S Cali, D Cebeci, S Kalaca, H Harmanci: **Assessment of sociodemographic factors and socio-economic status affecting the coverage of compulsory and private immunization services in Istanbul, Turkey.** *Public Health* 2005, **119**:862-9.
15. SD Torun, N Bakirci: **Vaccination coverage and reasons for non-vaccination in a district of Istanbul.** *BMC Public Health* 2006, **6**:125.
16. B Ozcirpici, S Sahinoz, S Ozgur, AI Bozkurt, T Sahinoz, A Ceylan, E Ilcin, G Saka, H Acemoglu, Y Palanci, et al: **Vaccination coverage in the South-East Anatolian Project (SEAP) region and factors influencing low coverage.** *Public Health* 2006, **120**:145-54.

17. **Six percent civil servant price increase - What will be the salary?**
[<http://hurarsiv.hurriyet.com.tr/goster/haber.aspx?viewid=430091>]
18. Ministry of Health of Turkey: **Family Medicine: The Turkish Model**. Ankara, Turkey: Ministry of Health of Turkey; 2006.
19. Ministry of Health of Turkey (Deputy Undersecretary): **Personal Communication**. Ankara, 13 March 2007.
20. **World Development Indicators**. [<http://nrs.harvard.edu/urn-3:hul.eresource:wdionlin>]
21. CJ Murray, B Shengelia, N Gupta, S Moussavi, A Tandon, M Thieren: **Validity of reported vaccination coverage in 45 countries**. *Lancet* 2003, **362**:1022-7.
22. **Immunization Profile - Turkey**. [http://www.who.int/immunization_monitoring/en/]

TABLES

Table 1. Inter-EPI antigen correlations (2000 – 2005)

	Measles	DPT	Polio	BCG	HBV
DPT	0.90				
Polio	0.90	0.99			
BCG	0.80	0.81	0.81		
HBV	0.85	0.87	0.87	0.84	
TT2	0.60	0.63	0.63	0.66	0.77

Table 2. Mean vaccination rates, by year

Year	Measles	DPT	Polio	BCG	HBV	TT2	All EPI
2000	0.84	0.82	0.82	0.79	0.73	0.43	0.74
2001	0.84	0.83	0.83	0.79	0.74	0.43	0.75
2002	0.82	0.78	0.78	0.75	0.74	0.43	0.72
2003	0.74	0.68	0.69	0.72	0.69	0.42	0.66
2004	0.79	0.84	0.83	0.75	0.77	0.47	0.74
2005	0.88	0.89	0.89	0.85	0.84	0.55	0.82

Table 3. Mean HRH densities (per 10,000 population), by year

Year	Doctors	Nurses	Midwives
2000	2.6	1.9	3.8
2001	2.5	2.2	3.9
2002	2.6	2.1	3.4
2003	2.3	1.8	3.3
2004	2.0	2.1	3.9
2005	2.1	2.2	4.0

Table 4. Vaccination Rates and HRH densities — by regions

Regions	Vaccination Rate — EPI	HRH / 10,000 population		
		Doctor	Nurse	Midwife
Akdeniz, Ege, Karadeniz, Marmara, Western Anatolia	0.79	2.6	2.2	4.1
Eastern and Southeastern Anatolia	0.60	1.8	1.7	2.9

Table 5. Random and fixed effects estimates of EPI vaccination rates on HRH densities (β coefficients presented; standard errors in parentheses)

	Random Effects				Fixed Effects			
	Model I		Model II		Model I		Model II	
Log HRH density	0.25*	0.46**			0.21	0.39		
	(0.10)	(0.20)			(0.20)	(0.20)		
Log HRH density * Time Trend		-0.093*				-0.10*		
		(0.04)				(0.04)		
Log MD density			0.06	0.56**			-0.26	0.35
			(0.10)	(0.20)			(0.10)	(0.20)
Log MD density * Time Trend				-0.22**				-0.27**
				(0.06)				(0.06)
Log nurse / midwife density			0.19*	-0.049			0.37**	0.029
			(0.09)	(0.20)			(0.10)	(0.20)
Log nurse / midwife density * Time Trend				0.097*				0.12*
				(0.05)				(0.05)
Time trend	0.03	-0.64*	0.03	-1.14**	0.03	-0.71*	0.01	-1.38**
	(0.02)	(0.30)	(0.02)	(0.40)	(0.02)	(0.30)	(0.02)	(0.40)
Percentage adult female illiteracy	-4.14**	-4.18**	-4.15**	-4.29**				
	(0.60)	(0.60)	(0.60)	(0.70)				
Log GDP / capita	0.00	0.00	0.00	0.01				
	(0.10)	(0.10)	(0.10)	(0.10)				
Log land area	0.02	0.02	0.02	0.01				
	(0.03)	(0.03)	(0.03)	(0.03)				
Constant	3.59**	5.16**	3.74**	6.16**	2.55	3.89*	1.70	4.24*
	(1.20)	(1.50)	(1.30)	(1.70)	(1.30)	(1.70)	(1.40)	(1.90)
Observations [†]	485	485	485	485	485	485	485	485
Number of Provinces	81	81	81	81	81	81	81	81
R-squared (within)	0.014	0.037	0.015	0.110	0.014	0.038	0.032	0.130
R-squared (between)	0.750	0.750	0.750	0.730	0.350	0.320	0.009	0.090
R-squared (overall)	0.470	0.470	0.470	0.490	0.180	0.120	0.016	0.005
F-test: HRH = 0 ^{††}		8.10	7.43	19.70		3.48	5.40	7.78
P-value		0.017	0.024	<0.01		0.036	<0.01	<0.01
F-test: MD = MD * Time Trend = 0				12.90				10.40
P-value				<0.01				<0.01
F-test: Nurse/Midwife = Nurse/Midwife * Time = 0				11.20				7.76
P-value				<0.01				<0.01
F-test: HRH ^{††} Fixed Effects = 0	0.12	8.54	19.5	42.4				
P-value	0.73	0.01	<0.01	<0.01				

[†] One missing value occurs because one province (Duzce) was created after the year 2000

^{††} Includes all main effects and interaction terms, where applicable

Table 6. Fixed effects estimates of EPI vaccination rates on HRH densities — by low/high provincial income (β coefficients presented; standard errors in parentheses)

	Fixed Effects			
	Low-income		High-income	
Log HRH density	0.80*		-0.031	
	(0.40)		(0.20)	
Log HRH density * Time Trend	-0.18**		0.012	
	(0.06)		(0.05)	
Log MD density	0.21		0.50	
	(0.20)		(0.40)	
Log MD density * Time Trend	-0.22**		-0.26*	
	(0.07)		(0.10)	
Log nurse / midwife density	0.43		-0.36	
	(0.30)		(0.30)	
Log nurse / midwife density * Time Trend	0.029		0.16*	
	(0.07)		(0.07)	
Time trend	-1.26**	-1.67**	0.07	-0.98
	(0.50)	(0.50)	(0.30)	(0.60)
Constant	6.51*	5.77*	1.25	2.95
	(2.70)	(2.80)	(1.50)	(2.50)
Observations	245	245	240	240
Number of Provinces	41	41	40	40
R-squared (within)	0.150	0.240	0.002	0.051
R-squared (between)	0.520	0.002	0.049	0.013
R-squared (overall)	0.300	0.074	0.001	0.024
F-test: HRH = 0 [†]	4.42	7.55	0.03	1.48
P-value	0.018	<0.01	0.97	0.23
F-test: MD = MD * Time Trend = 0		5.05		2.76
P-value		0.011		0.076
F-test: Nurse/Midwife = Nurse/Midwife * Time = 0		5.61		2.29
P-value		<0.01		0.11

[†]Includes all main effects and interaction terms, where applicable