Analyzing demand-side efficiency in global health: an application to maternal care in Vietnam

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Accepted on 20 April 2016

Abstract
This article investigates demand-side efficiency in global health—or the efficiency with which health system users convert public health resources into health outcomes. We introduce and explain the concept of demand-side efficiency as well as quantitative methods to empirically estimate it. Using a robust nonparametric form of technical efficiency analysis, we estimate demand side efficiency and its social determinants. We pilot these methods looking at how efficiently pregnant women in Northern Vietnam convert public health resources into appropriate maternal care as defined by national policy. We find that women who live in non-mountainous geographies, who are formally employed, who are pregnant with a boy and who are ethnic minorities are all more likely to be efficient at achieving appropriate care. We find no significant association between wealth or education and efficiency. Our results suggest that, in the Vietnamese context, women who are the most likely to achieve appropriate care, are not necessarily the most likely to do so efficiently. Women who live in non-mountainous geographies and who are formally employed are both more likely to achieve appropriate care and to do so efficiently. Yet ethnic minority women, who do not systematically achieve better care, are more likely to be efficient or to achieve better care when compared with those with the same endowment of public health resources. On the methodological level, the pilot highlights that this approach can provide useful information for policy by identifying which groups of people are more and less likely to be efficient. By understanding which groups are more likely to be efficient—and in turn how and why—it may be possible to devise policies to promote the drivers of, or conversely address the constraints to, optimizing demand-side efficiency.

Key words: Antenatal care, demand side, maternal health, order-m method, Vietnam, Technical efficiency analysis
Key Messages

- We introduce the concept of demand-side efficiency in global health—or the efficiency with which health system users convert public health resources into health outcomes—as well as quantitative methods to empirically estimate it.
- We apply a robust nonparametric form of technical efficiency analysis followed by regression analysis to estimate demand side efficiency and its social determinants. Specifically, we look at how efficiently pregnant women in Northern Vietnam convert maternal health resources into appropriate care.
- Women who live in non-mountainous geographies, who are formally employed, who are pregnant with a boy and who are ethnic minorities are all more likely to be efficient at achieving appropriate care. In the Vietnamese context, women who are the most likely to achieve appropriate maternal care, are not necessarily the most likely to do so efficiently.
- On a methodological level, our pilot application of these methods highlights that this approach can provide useful information for policy by identifying which groups of people are more and less likely to be efficient.

Introduction

Achieving efficiency, which is defined as maximizing the outputs achieved per unit of input invested (Palmer and Torgerson 1999), is naturally of great interest to national governments, international donors and other stakeholders in the health sector. As a result, it has been studied extensively. One approach to understanding efficiency in the health sector is Cost-Effectiveness Analysis which estimates the ratio of the cost of an intervention to the health gains it achieves. Unlike Cost Effective Analysis which generates a ratio of costs to outcomes, technical efficiency analysis generates an efficiency frontier representing the highest level of output observed at each level of resource. In the field of health, technical efficiency analyses have been used to estimate which health providers are most efficient at converting a set of inputs—such as the number of beds and personnel (Geitona et al. 2012; Mané 2012) or operating expenses (Nayar et al. 2013)—into outputs—such as the number inpatients treated (Geitona et al. 2012) or births attended (Mané 2012). This type of analysis has been used to assess and compare efficiencies across hospitals, health centers, clinical divisions and other health care institutions.

Yet these technical efficiency analyses all take a supply side perspective. That is, they consider how efficiently various facets of the health system use health resources to produce services. We were not able to identify any studies which focus primarily on health systems users utilizing health system resources to secure appropriate services. That is, just as a hospital uses the inputs of doctors and beds to produce the output of patients treated, an individual uses the inputs of available health facilities and health workers to secure a series of health services. By seeking care and requesting services, the individual has an active role in converting health system inputs into the output of appropriate care. Thus in considering demand-side efficiency, we assess the degree to which each individual secures appropriate care compared to other individuals with equal or lesser health system resources. For the purposes of this article, an individual who achieves the most appropriate care at their observed level of resource endowment is considered efficient. An individual who achieves less appropriate care than other individuals with equal or less resources is considered inefficient.

Estimating an optimal level of output based on varied levels of inputs requires technical efficiency analysis, as described above. In choosing from a variety of approaches to technical efficiency analysis, we are cognizant of two factors that can undermine validity. The first is making unfounded assumptions about the functional form of the efficiency frontier, or the relationship between inputs and outputs. For example, it may seem intuitive to assume that, as inputs increase, outputs too will increase in a linear, or at least monotonic, fashion. However, these assumptions are difficult to justify either theoretically or empirically. In the absence of a justification for these assumptions, the most valid and conservative approach to defining the efficiency frontier is a non-parametric approach that traces the observed input-output combinations as closely as possible without making any further assumptions about the shape of that frontier. The second factor which can jeopardize the validity of technical efficiency analysis is that, if applied deterministically, the method is highly sensitive to outliers. Because technical efficiency analysis identifies the highest output at each resource level, then defines every observation short of that output as inefficient, an unlikely observation with very low input and very high output can make the entire sample look inefficient. For these reasons we chose to use the order-m method (Cazals et al. 2002) for this analysis which is both non-parametric and robust to outliers due to a stochastic adaptation further explained in the Methods section.

In a series of papers more broadly focused on the efficient conversion of individual resources into general well-being, Binder and Broekel (2011, 2012) utilize the order-m method to analyze the efficient conversion of personal resources (such as income) into well-being outcomes (such as life satisfaction) followed by a regression analysis estimating the relative influence of social factors (such as education, geography or gender) on efficiency (Binder and Broekel 2011; Binder and Broekel 2012). They highlight the usefulness of this method for policy makers explaining that understanding who is more and less efficient provides two pathways for interventions to improve outcomes: (1) by allocating more resources to those who require more inputs to achieve equal outcomes or (2) by addressing the constraints that prevent the less efficient groups from deriving maximum benefit from their resource endowment (Binder and Broekel 2011; Binder and Broekel 2012).

Here, we apply these methods to a specific health issue, investigating how efficiently pregnant women in Vietnam convert maternal health resources into appropriate maternal care, as defined by Vietnamese national policy. To our knowledge, this is the first application of these methods in a developing country and the first in the field of global health.

Health and geographic context: maternal care in Vietnam

In order to understand the value and potential challenges of these methods, we piloted them with respect to the issue of maternal care in a rural district in Northern Vietnam. Vietnam presents a dynamic if complex context ripe for efficiency analysis. Rapid economic development and significant focus and investment in social services on
the part of government have resulted in overall poverty reduction and improvements in health indicators (World Bank Group 2012). Yet, by some measures, both health and economic inequalities persist particularly across the dimensions of ethnicity, wealth, education, geography and degree of urbanization (Bauch 2010; Duc et al. 2011; Axelson et al. 2012). With respect to the health issue of appropriate maternal care, an analysis of the 2000–2001 National Household Survey found that both ethnic minorities and less educated women were less likely to receive antenatal and delivery care (Sepehri et al. 2008). A more recent analysis found that while access to antenatal and delivery care had improved significantly between 2006 and 2010, inequality had also increased with ethnic minority women nearly 20 times more likely to give birth outside a health facility in 2010 (Målvist et al. 2013). Looking specifically at how Reproductive Maternal Neonatal and Child Health inequalities in Vietnam have evolved across several social dimensions—including wealth, ethnicity, rural-urban, education and region—Axelson et al. (2012) tell a more nuanced story. Comparing data from 1997 to 2006, they find that across nearly all dimensions, inequalities in access to health services are decreasing. Furthermore, they found that among the different aspects of appropriate care, coverage of immobilization and family planning were the most equally distributed across nearly all social dimensions. By contrast, access to interventions requiring more intensive engagement with the health system—such as having a minimum of four antenatal visits and skilled attendance at birth—were still the least equally distributed across the social dimensions. More recent studies have suggested that, in specific contexts, some of these gaps may have further narrowed. For example, a recent multivariate analysis of a more expansive Ba Vi dataset has indicated no relationship (positive or negative) between ethnicity and appropriate ANC utilization (Tran et al. 2012). This study further found that ethnic minorities even outperformed the less well-off. In other words, this dynamic raises the possibility that, in some cases, the less well-off may be more efficient—an interesting hypothesis to confirm and clarify.

Vietnam is also an interesting context in which to evaluate demand-side efficiency as the landscape of health resources has evolved dramatically in recent decades. Public sector health facilities have proliferated rapidly; as of 2008, 99% of communes had a health center (Rheinlander et al. 2011). In addition, the market reforms which have contributed to rapid economic development and poverty reduction have also led to the rapid emergence of a private health sector. Since private healthcare provision was legalized in 1989, the number of private clinics has mushroomed to over 30 000 nationwide. The private sector has reduced some of the patient load on the public sector (Tran 2012) and in many cases provides customer-service oriented healthcare that strives for a pleasant and satisfying patient experience. At the same time, due to both the lack of oversight and the overuse of technology, the private sector has been shown to offer an inferior quality of care (Tuan et al. 2005) while exclusive use of the private sector has been specifically associated with a lesser likelihood of receiving appropriate antenatal care in Ba Vi and nearby districts (Tran et al. 2012). Thus while health resources have increased overall, individuals are required to navigate an increasingly complex landscape with variable quality in order to obtain appropriate care. It is important for policymakers to understand who is able to secure for themselves the nationally defined standard of appropriate care from this changing system and in turn how and why.

The evolution of the health system in Vietnam, including the rapid emergence of private sector health care, means that the very nature of health resources in Vietnam has shifted. As a result, it is critical to understand who is best navigating this new resource landscape in order to ultimately target inefficiencies and optimize the benefit that all groups derive from public health resources.

**Methods**

**Order-m efficiency analysis**

As discussed in the Introduction, in evaluating efficiency we are looking to compare the level of care of each individual in the sample to all other individuals with equal or less health system resources. If the reference individual achieves the most appropriate care among this group, she has achieved efficiency by our definition. If she has achieved less appropriate care than others in the comparator group (those with equal or less resources) she has not achieved efficiency by our definition. This type of comparison is carried out by technical efficiency analysis. Among a wide range of approaches to technical efficiency analysis, we choose the non-parametric and robust Order-m method detailed in Binder and Broekel (2011).

Following the methods proposed in (Binder and Broekel 2011; Binder and Broekel 2012), we employ a two-stage analytic approach which (1) generates a score for each individual denoting efficiency or inefficiency and (2) measures the relative contribution of social factors to the likelihood that a woman is efficient. In the first step, we estimate an efficiency frontier using the robust non-parametric order-m method (Cazals et al. 2002). The order-m method is a stochastic adaptation of Free Disposal Hull (Tulkens 1993), a non-parametric method which generates efficiency scores by benchmarking each individual’s achievement against the highest achieving individual with equal or less resources in the sample. However, Free Disposal Hull is highly susceptible to outliers and stochastic noise. To address this issue, the order-m method instead benchmarks each individual against the expected maximum achievement based on the best outcome among m randomly drawn individuals with equal or less resources. Formally, the order-m method compares the individual with resource set xk to m randomly drawn individuals with resource sets in which all components are equal to or less than xk. It then calculates the ratio between the achievement of that individual y0 and the achievement of the best performing individual in the subsample Yj in each of j-q dimensions.

\[ \lambda_m(x_k, y_0) = \max_{l=1,...,k} \left\{ \min_{j=1,...,q} \left( \frac{Y_j^l}{y_0} \right) \right\} \]

Intuitively, this means that the first-stage efficiency score, \( \lambda_m \), corresponds to the minimum factor by which the reference individual would have to increase their output, y0, in all dimensions, in order to make that individual efficient. Thus an individual who is already efficient has an efficiency score of 1. An inefficient individual, whose output would need to be increased in order to achieve the maximum output observed among people with equal or less resources, has an efficiency score of greater than 1.
To further ensure robustness, the final order-m efficiency score, \( \hat{\lambda}_m \), is generated using a Monte-Carlo simulation to iterate the calculation of, \( \hat{\lambda}_m \), a large number of times, \( B \), and take an average.

\[
\hat{\lambda}_m(x_0, y_0) = \frac{1}{B} \sum_{b=1}^{B} \lambda^b_m(x_0, y_0)
\]

This application of the order-m method is described in more detail in (Binder and Broekel 2011; Binder and Broekel 2012). After generating efficiency scores for each individual in the sample, we use logistic regression analysis to estimate the influence of social factors on the likelihood that an individual is efficient at converting health resources into health outcomes. Unlike many models which use a health outcome as a dependent variable, this model uses a binary variable indicating whether individuals were efficient as its dependent variable. Using a binary dependent variable is theoretically appropriate as this analysis aims to determine whether some groups of people are more likely to be efficient than others—which is exactly what the results of a binary logistic regression tell us. Conversely, if we used a continuous dependent variable the regression results would indicate the positive or negative influence of social factors on an efficiency score without distinguishing between the achievement of efficiency or just varying levels of inefficiency. This latter model would thus elide the comparison of efficient versus inefficient with simply stating that an x% increase or decrease in an efficiency score which cannot be directly interpreted given the multidimensionality of the resource and outcome.

Thus the comparison of less inefficient versus more inefficient. Yet the first distinction seems more important conceptually and also lends itself to a more meaningful interpretation: the increased/decreased odds of being efficient is a more tangible finding than an x% increase or decrease in an efficiency score which cannot be directly interpreted given the multidimensionality of the resource and outcome sets used in this case. The independent variables included in our model are key social factors identified through both the Vietnam-specific literature as well as control variables presented in greater detail below.

\[
\log \left( \frac{P(\text{being efficient})}{1 - P(\text{being efficient})} \right) = \beta_0 + \beta_{1..n} \text{social factors}_{1..n} + \beta_{k..k} \text{controls}_{k..k} + \epsilon
\]

Data and Variables

The Filabavi HDSS dataset

We conducted this analysis using secondary data from Ba Vi, a rural district approximately 60 km Hanoi, Vietnam. The data used here was collected as part of the Filabavi Health and Demographic Surveillance Site and Epidemiological Field Laboratory. Ba Vi was selected as the site for this field laboratory because its geography, demographics, and health context are roughly representative of Vietnam, and particularly rural Vietnam, as a whole. While the generalizability of any findings must be weighed carefully, the field laboratory was intended to be a microcosm of the country at large (Chuc and Diwan 2003). Table 1 below compares statistics in Ba Vi with those for rural Vietnam as well as the national averages. In most cases, the statistics are comparable with the biggest difference being somewhat higher primary school completion rates in Ba Vi.

Established in 1999, Field Laboratory Ba Vi (Filabavi) is operated by Hanoi Medical University in collaboration with international partners. Data is collected using a stratified random sampling approach to identify clusters and households for sampling. The resulting sample contains 67 clusters including roughly 11,000 households and 55,000 individuals (Chuc and Diwan 2003; Tran 2012).

Beginning in 1999, the Filabavi HDSS collected baseline data at the household level—including household infrastructure, assets and distance to health facilities—and individual level—including demographic factors such as age, gender, education, employment, ethnicity and marital status. This complete set of data has since been re-collected every 2 years. Data on birth, death, migration, pregnancy, illness and care seeking are collected on a quarterly basis (Tran 2012). The data is collected by field surveyors who are secondary school graduates hailing from the communities surveyed. Extensive training of surveyors, re-surveying and spot checking ensures data quality (Chuc and Diwan 2003). The subset of the Filabavi data we analyze here includes yearly observation taken in Quarter 4 of each year from 2005 to 2011. Quarter 4 sees the highest number of births in Ba Vi.

Health resource and appropriate care sets

In order to calculate the efficiency score for each woman we created both a health resource set and an appropriate care set for each woman. The health resource set comprises a series of measures of government-provided health resources available to each woman. In order to understand the efficiency with which women convert those resources into appropriate maternal care, the appropriate care set comprises measures of whether the woman achieved appropriate care as defined by the Government of Vietnam (see Table 2).

As seen in Table 2 and Table 3, we used measures of government provided health resources including both infrastructure and human resources. To capture the availability of health infrastructure, or

<table>
<thead>
<tr>
<th>Table 1. Summary statistics for Ba Vi district, Rural Vietnam and All Vietnam</th>
<th>Average for rural areas</th>
<th>National average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life expectancy</td>
<td>75.2 in 2001</td>
<td>76.2% in 1998 VLSS</td>
</tr>
<tr>
<td>% in Agriculture</td>
<td>81% in 2003</td>
<td>63% in 2002 VLSS</td>
</tr>
<tr>
<td>% Ethnic majority (Kinh)</td>
<td>91% in 2003</td>
<td>83% in 2002 VLSS</td>
</tr>
<tr>
<td>% Completing primary school</td>
<td>69% in 2003</td>
<td>86% in 2002 VLSS</td>
</tr>
<tr>
<td>% Completing high school</td>
<td>9% in 2003</td>
<td>(Not Available)</td>
</tr>
</tbody>
</table>

33% in 2000. The data is collected by field surveyors who are secondary school graduates hailing from the communities surveyed. Extensive training of surveyors, re-surveying and spot checking ensures data quality (Chuc and Diwan 2003). The subset of the Filabavi data we analyze here includes yearly observation taken in Quarter 4 of each year from 2005 to 2011.
Table 2. Health resources and appropriate care variables

<table>
<thead>
<tr>
<th>Components of health resource set</th>
<th>Components of appropriate care set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to Commute Health Center, Time to District Hospital, Number of Doctors, Assistant Doctors, Nurses, Midwives, Pharmacists for ANC at nearest CHC</td>
<td>Number of core services received (At least 1 visit in the first trimester, at least 3 visits total, a skilled medical attendant at delivery, tetanus shot, weighed, measured, blood pressure taken, urine sample, abdominal check); number of recommended services received (blood sample, ultrasound, iron pills, vitamin A, pregnancy record)</td>
</tr>
</tbody>
</table>

Table 3. Summary statistics for health resources variables (n = 1417)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time to Closest Health Center (min)</td>
<td>9.99</td>
<td>0.3</td>
<td>50</td>
</tr>
<tr>
<td>Travel Time to District Hospital (mins)</td>
<td>22.03</td>
<td>1.5</td>
<td>65</td>
</tr>
<tr>
<td>Doctors for ANC at Closest Health Center</td>
<td>0.87</td>
<td>0.0</td>
<td>2</td>
</tr>
<tr>
<td>Assistant Doctors for ANC at Closest Health Center</td>
<td>4.27</td>
<td>1.0</td>
<td>8</td>
</tr>
<tr>
<td>Midwives for ANC at Closest Health Center</td>
<td>0.74</td>
<td>0.0</td>
<td>2</td>
</tr>
<tr>
<td>Nurses for ANC at Closest Health Center</td>
<td>1.88</td>
<td>0.0</td>
<td>6</td>
</tr>
<tr>
<td>Pharmacists for ANC at Closest Health Center</td>
<td>0.72</td>
<td>0.0</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4. Summary statistics for appropriate care variables (n = 1417)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core services</td>
<td></td>
</tr>
<tr>
<td>Weighed</td>
<td>0.731</td>
</tr>
<tr>
<td>Height measured</td>
<td>0.568</td>
</tr>
<tr>
<td>Blood pressure measured</td>
<td>0.754</td>
</tr>
<tr>
<td>Gave a urine sample</td>
<td>0.533</td>
</tr>
<tr>
<td>Skilled attendant at delivery</td>
<td>0.998</td>
</tr>
<tr>
<td>Abdominal examination</td>
<td>0.908</td>
</tr>
<tr>
<td>Tetanus shot</td>
<td>0.972</td>
</tr>
<tr>
<td>ANC visit in the 1st trimester</td>
<td>0.733</td>
</tr>
<tr>
<td>At least 3 ANC visits</td>
<td>0.857</td>
</tr>
<tr>
<td>Summed set of core services (9 Total)</td>
<td>7.054</td>
</tr>
<tr>
<td>Recommended services</td>
<td></td>
</tr>
<tr>
<td>Took iron pills</td>
<td>0.241</td>
</tr>
<tr>
<td>Received vitamin A</td>
<td>0.230</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>0.874</td>
</tr>
<tr>
<td>Had a record of pregnancy</td>
<td>0.278</td>
</tr>
<tr>
<td>Gave a blood sample</td>
<td>0.389</td>
</tr>
<tr>
<td>Summed set of recommended services (5 Total)</td>
<td>2.011</td>
</tr>
</tbody>
</table>

Social factors related to efficiency and control variables

Our second stage of analysis, examining the relative contribution of social factors to the likelihood of efficiency, requires variables for the social factors we expect might influence efficiency as well as control variables. Given that the empirical literature on the social determinants of efficiency is extremely limited, we draw on the literatures regarding social determinants of appropriate care in Vietnam specifically. These literatures differ from our study in that they look at the influence of social factors on appropriate care rather than the efficiency with which it is achieved. However, because calculating efficiency relies in part on the level of care achieved by individuals at various resource levels, it is possible that some of the same factors could be influential. Furthermore, differentiating whether groups achieving the most appropriate care are also the most efficient makes a critical distinction: Are these groups achieving the most appropriate care because they are taking better advantage of available resources or do they simply start off with a larger resource endowment? Based on the available literature, we consider the influence of the following social factors on efficiency: wealth (Duc et al. 2011; Axelson et al. 2012), ethnicity (Baulch et al. 2012), education (Axelson et al. 2012), geographic area (Byass 2003; Tran et al. 2012), formal employment (Benach et al. 2007; Tran et al. 2012) and gender of the baby (Tran 2012). Summary statistics for the social factor variables are presented in Table 5 below. Pairwise correlations of all regression variables are included in Supplementary Table 1, available at HEAPOL online.

Our control variables include a dummy variable for each year 2005–2011 covered by the sample and a dummy variable equaling 1 for the small number of women (85) who appeared multiple times in the sample because they gave birth multiple times within the included periods. We also accounted for the fact that the survey was collected using a clustered sampling approach estimating the model with cluster robust standard errors. Accounting for within cluster correlation in this way also accounts for the fact that women from the same cluster have a common health center. We would expect

health facilities, we used variables for time to closest commune health center and time to the district hospital to measure this dimension. Travel time required to reach a health facility most closely reflects the women’s actual access. This is particularly important in light of the geographic variability in Ba Vi district where living 1 km from a health center on flat, paved lowland roads affords a different level of access than living 1 km from a health center on steep, narrow, dirt roads in the mountains. The relative access afforded at a certain distance is also mediated by the different means of transport available to different women. Travel time to health facility is based on the respondent’s own estimate of how long it takes her to reach the health facility based on the mode of transportation she would normally use. To capture the human resources for health available to each individual we included variables for the number of doctors, assistant doctors, nurses, midwives and pharmacists working on maternal health at the closest health center.

The set of variables which we used to analyze the efficient conversion of available health resources into appropriate maternal care reflects the Government of Vietnam’s definition of appropriate care (Ministry of Health Government of Vietnam 2009; Tran et al. 2012). In keeping with national policy and following Tran (2012), we include two types of variables: measures of core services and measures of recommended services. The core services include that every woman should have at least one ANC visit in the first trimester, at least 3 visits total, a skilled attendant at delivery as well as measurement of height, measurement of weight, blood pressure taken, urine test, abdominal examination and a tetanus vaccination. The recommended services include having a blood test, an ultrasound, receiving iron supplements, receiving vitamin A and having a written record of the pregnancy. We used a dummy variable for each element representing 1 where the standard was met and 0 where it was not. The core service variables were then summed into one number and, separately, the recommended variables summed into another number. We included the sum of core services and the sum of optional services as separate components so that an optional service could not be substituted for a core service in the total score of services received (Table 4).

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some greater similarities between women using the same commune health center due to differences in facilities as well as the overall quality of care.

Missing observations
After excluding individuals with missing observations from the original sample of 1830, the sample for which efficiency scores were generated contained 1417 women. The characteristics of the group dropped for missing observations differs only slightly from the group with complete observations who were retained in the analysis. Specifically those dropped for missing observations ranked on average slightly lower on the asset-based wealth index. This is worth noting though unlikely to affect the final results as we control for all of these factors in the second stage regression.

Results
Using these health resource and appropriate care variables, we generated efficiency scores indicating how efficiently each woman converted health resources into appropriate care.

Efficient conversion of health resources into appropriate care
The efficiency analysis indicates that 39% (549) of the 1417 women in the sample were efficient at converting health resources into appropriate care. The mean efficiency score was 1.29 indicating that, on average, a woman would have to improve her output by 29% in order to achieve efficiency. A histogram of the efficiency scores (see Figure 1) demonstrates that the distribution is clustered near a score of 1 (indicating efficiency) with a long tail but relatively few observations above 2 indicating that most inefficient women had at least half as many of the services required for appropriate care as the most efficient woman at the same resource level. Due to the iterative and multidimensional nature of the methods we cannot directly interpret the scores more specifically than this, however, they clearly indicate varying efficiency and room for improvement among the majority of the population.

Social factors influencing efficiency
In our second stage of analysis we identify the relative contribution of social factors to the likelihood that a woman is efficient at converting maternal care resources into the outcome of appropriate care. We find that ethnic minority women, formally employed women, and women who were pregnant with a boy were all more likely to be efficient. Wealth and education had no statistically significant influence on the likelihood of efficiency. Women who lived in the mountains were less likely to be efficient (See Table 6). As a robustness check, we have run the logistic regression using dichotomous variables for wealth and education. This did not have a substantial impact on the significance, magnitude or direction of any of the adjusted odds ratios.

Discussion
Implications in the Vietnamese context
Our findings contribute to the understanding of maternal care in northern Vietnam by revealing that the social determinants of appropriate care are sometimes, but not always, social determinants of demand side-efficiency. Some social groups that previous studies suggest are more likely to achieve appropriate care are also more likely to do so efficiently. Previous studies have shown that people in non-mountainous regions are more likely to access appropriate care for injuries (Hang and Byass 2009) and infectious disease (Rheinlander et al. 2011), more likely to give birth in a health facility (Nga et al. 2010) and that women in areas which are generally more urban are more likely to have adequate antenatal care (Tran et al. 2012). Here we find that women in non-mountainous areas are also more likely to be efficient at achieving those care outcomes, meaning that women with an equal endowment of infrastructural and human resources for health are likely to achieve more appropriate maternal care in non-mountainous contexts. One possible explanation is that some health centers in the mountains may not offer some of the more complex recommended services such as blood tests, making it harder for the women nearest those health centers to achieve these elements of appropriate care. Another is that the quality of care may be better in non-mountainous regions.

Likewise, Tran (2012) found that formally employed women in Ba Vi district are more likely to receive appropriate care (Thorson et al. 2006; Tran et al. 2012). Our findings suggest these women are also more likely to achieve that care efficiently, or with equal or less public health resources. One possible explanation is that women who are formally employed are better able to take advantage of available resources because they have health insurance. Vietnamese law mandates comprehensive health coverage for those employed in the formal sector. Having health insurance has in turn been linked to increased use of health care resources in rural Vietnam (Liu et al. 2012).

Finally, recent research in Vietnam suggests that women in Ba Vi who were pregnant with boy children were more likely to deliver at the district hospital, as opposed to a lower level health facility (Tran 2012). In a more expansive study of eight districts in Quang Ninh province, boys were more likely than girls to be delivered at a district hospital while girls were more likely than boys to be delivered at home (Hoa et al. 2012). Researchers suggest that son preference may in this case be driving women (and families) to seek what they perceive of as better care when a woman is pregnant with a boy (Hoa et al. 2012; Tran 2012). This hypothesis would also help explain our findings that women pregnant with boy children are more likely to be efficient at converting available resources in appropriate care. It would suggest that women (and their families) may be more careful, more assiduous and more willing to commit personal resources such as time and money to ensuring the full spectrum of appropriate maternal care when a boy child is expected.

Yet, we also find that other groups more likely to achieve appropriate care are not significantly more likely to be efficient. Wealthier and more educated women have also been found to be more likely to have appropriate maternal care in Vietnam (Axelson et al. 2012) and in Ba Vi district specifically (Tran et al. 2012). However we find no statistically significant influence of these factors on the likelihood

Table 5. Summary statistics for social factor variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wealth quintile</td>
<td>3.200284</td>
<td>1.276745</td>
<td>1408</td>
</tr>
<tr>
<td>Ethnic minority</td>
<td>0.0529287</td>
<td>0.223973</td>
<td>1417</td>
</tr>
<tr>
<td>Lives in mountains</td>
<td>0.2208892</td>
<td>0.4149924</td>
<td>1417</td>
</tr>
<tr>
<td>Education level</td>
<td>3.318278</td>
<td>1.145939</td>
<td>1417</td>
</tr>
<tr>
<td>Not formally employed</td>
<td>0.8432203</td>
<td>0.3637214</td>
<td>1416</td>
</tr>
<tr>
<td>Baby is a girl</td>
<td>0.4580099</td>
<td>0.4984096</td>
<td>1417</td>
</tr>
</tbody>
</table>
of being efficient. These groups may achieve better care but it is not clear whether they do so with more or less public health resources. Perhaps most interestingly though, one group, ethnic minorities, found less likely to achieve appropriate care are overwhelmingly more likely to be efficient. Perhaps the most surprising of our findings pertains to ethnic minorities who are more than four times more likely to be efficient at converting maternal health resources into appropriate care. We have not been able to identify any studies suggesting that ethnic minority women achieve better maternal care outcomes in Vietnam. Previous research in Ba Vi and nationally, ethnic minority women are systematically more likely to fall into these categories. Furthermore, recent studies in Vietnam have found that receiving ANC in the private sector reduced the likelihood of receiving appropriate care (Tran et al. 2012; Trinh et al. 2007). A lack of oversight, prevalence of unqualified practitioners, lack of infrastructure and equipment (Tuan et al. 2005) as well as a tendency to over-provide higher fee services (Dang et al. 2007; Nguyen 2011) rather than ensuring a comprehensive package of basic care, have all been found to contribute to the poor quality of the private health sector in Vietnam. If ethnic minority women are less likely to rely on private sector services they may be more likely to achieve optimal care compared to others of equal resources. Together, our results point to a significant overall finding for Vietnam: that the women who are most likely to achieve appropriate maternal care are not necessarily the most efficient. Some women are achieving better outcomes because they are making the optimal use of resources while others may simply have a greater endowment of public health resources to begin with. Similarly, some groups of women, in particular ethnic minorities, whose are less likely to achieve appropriate care, are actually more likely to achieve better care when compared against those who have comparable resource endowments. While the literature on care seeking and quality of care in Vietnam allows us to hypothesize about the preferences and behaviors underpinning our findings, understanding exactly how and why some groups of women were more efficient would require further information on the women’s perceptions, opportunities and choices regarding maternal care.

Methodological implications

Our findings also have implications at the methodological level—highlighting both the value and some of the challenges of using this approach to understand demand side efficiency.

Table 6. Relative influence of social factors on the likelihood of efficiently achieving appropriate care using a multivariate logistic regression

<table>
<thead>
<tr>
<th></th>
<th>Adjusted odds ratio</th>
<th>95% confidence interval</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wealth quintile</td>
<td>1.045</td>
<td>0.923,1.182</td>
<td>0.485</td>
</tr>
<tr>
<td>Ethnic minority</td>
<td>4.211***</td>
<td>1.983,8.942</td>
<td>0.000</td>
</tr>
<tr>
<td>Lives in the mountains</td>
<td>0.285***</td>
<td>0.151,0.537</td>
<td>0.000</td>
</tr>
<tr>
<td>Education level</td>
<td>1.099</td>
<td>0.986,1.225</td>
<td>0.086</td>
</tr>
<tr>
<td>Not formally employed</td>
<td>0.616*</td>
<td>0.420,0.904</td>
<td>0.014</td>
</tr>
<tr>
<td>Baby is a girl</td>
<td>0.789*</td>
<td>0.631,0.987</td>
<td>0.038</td>
</tr>
</tbody>
</table>

*P < 0.05; **P < 0.01; ***P < 0.001.
Analyzing demand-side efficiency with this methodology yields insights that can be useful to policy makers in a few respects. First, our analysis yields a distribution of efficiency scores. This is an important finding for policy as it reveals that the rate at which public health resources are converted into appropriate care is not uniform. It varies, presumably due to differing constraints, opportunities and choices among different individuals in the population. Thus while providing health resources—such as clinics, hospitals, nurses, doctors and midwives—is essential for achieving and improving health outcomes, the degree of achievement or improvement conferred by those resources will be different for different people in the population. This distribution also indicates what percentage of the population is efficient and what percentage of the populations faces some constraint to deriving the maximum benefit from their resources. Understanding the distribution of efficiency has the potential to help planners better predict the impact of increasing resources.

In addition to revealing a distribution of efficiencies, this methodology has also revealed that efficiencies vary not just at the individual level but systematically at the level of social groups. Identifying which social groups are most likely to convert resources into appropriate care efficiently has the potential to inform policies that escape a zero sum decision about resource allocation and instead increase the overall benefit. By understanding which groups are more likely to be efficient—and in turn how and why—it may be possible to devise policies to promote the drivers of efficiency, or conversely address the constraints to efficiency, among the less efficient groups. For example, if formally employed women are achieving more appropriate care with less resources because they are more likely to have health insurance, increasing coverage among the informally employed is likely to increase the percentage of the population which is efficient and thus the overall benefit derived from existing resources.

While increasing health insurance among the informally employed may be an effective way to improve efficiency it would also be resource intensive and complex to navigate through the policymaking process. Thus when considering the application in resource limited settings, it is important to highlight that these methods also identify efficiency constraints which can be addressed at the care provider or community level with minimal additional resources. For example, we find that women who are pregnant with a male child are more efficient. According to our definition of efficiency this means that women pregnant with a boy, who have the same infrastructure and human resources for health as women who are pregnant with a girl, are more likely to achieve appropriate care. If further investigation supports our hypothesis that this is due to women taking greater care with a male child pregnancy due to son preference, interventions targeting women pregnant with girl children may improve both the efficiency and the care achieved by this latter group. These interventions could be simple and low cost, such as ensuring that care-providers discuss the sex of the child with patients and reinforce the importance of securing appropriate care to women pregnant with girls. It could also include public messaging and health promotion on this issue through specific outreach and support to women pregnant with girls through Vietnam’s extensive network of commune-level civic committees.

In addition to useful information regarding the distribution of efficiencies and the identification of more and less efficient groups, this pilot also revealed some limitations of the methodology. The first is that measuring demand side efficiency is in no way a substitute for measuring care adequacy—rather it is a complement providing additional useful information. In this case, multiple groups of people have similar or the same outcomes, yet, systematically, some groups achieve those outcomes more efficiently. Assuming that ethnic majority women are better off because they are more efficient would be inaccurate. Moreover focusing only on improving the efficiency of ethnic majorities would increase inequality.

Second, while this methodology identifies which groups are most likely to efficiently convert the resources they have, it does not tell us anything about what the return would be on additional resources, or at what point additional resources might yield no additional benefit. Thus while our findings shed light on the advantages of targeting resources to different populations, they do not tell us how much additional resources are ideal. This requires supplementary analysis estimating the return on each resource in terms of outcomes for each social group.

Conclusion

We have proposed the concept of demand-side efficiency in public health as well as analytical methods to estimate it quantitatively. We have subsequently piloted these methods to analyze the efficiency with which women in Vietnam convert available public health resources—including health facilities and human resources for health—into appropriate maternal care. We found that women who lived in non-mountainous areas, women who were formally employed, women who expected a boy child and, perhaps more surprisingly, ethnic minorities were all more likely to be efficient. Wealth and education were not significantly associated with the likelihood of being efficient. Our findings suggest that, at least in the Vietnamese context, the social groups who achieve the most appropriate care are not necessarily the most efficient at achieving that care. Our pilot also highlighted both the value and limitations of this methodology for policy makers.

Two additional factors should be considered with respect to our findings. The first is the importance of making modest assumptions around generalizability. Overall Ba Vi is representative of Vietnam in that the means of poverty, formal employment, ethnicity, education as well as epidemiology roughly reflect national means. However it is worth bearing in mind that while Ba Vi is rural it is not remote, lying only 60 km from Hanoi. Even the mountainous areas of Ba Vi are more connected and much more easily navigable than the mountainous areas of further outlying provinces such as Lao Cai or Bac Kan. Lastly, while 8% of the population identifies as ethnic minorities, these are overwhelming Muong (Chuc and Diwan 2003), which is considered the closest ethnicity, both racially and culturally, to the Kinh majority. Ethnic minorities in Ba Vi are integrated in mainstream culture, live among the ethnic majority and tend to speak Vietnamese at a native level. This is not the case for all ethnic minorities throughout the country. Thus caution is warranted in extrapolating results of this study—particularly in relation to women living in the mountainous areas and ethnic minorities to other contexts even within Vietnam.

Second, we consider demand-side efficiency with the view that distinguishing who is systematically more and less efficient is the first step in understanding the factors that systematically inhibit or enable people to derive the greatest benefit from available resources. While our study recognizes that individuals differentially navigate the landscape of health resources, our intention is not to place the onus for achieving outcomes solely, or even primarily, on the individual. On the contrary our analysis is both derived from and contributes to the idea that there are factors that systematically mediate the relationship between an individual’s access to resources and the benefit derived. Ultimately the goal is to improve the efficiency of the system and the overall level of health and care achieved not to criticize or blame groups of individuals found less likely to be efficient.
To that end, one important direction for future research would be to understand how and why the groups identified as more likely to be efficient in Ba Vi are achieving better care outcomes with equal or lesser resources. Beginning to explore this issue would benefit from a qualitative approach that samples across the social factors of interest understanding how the perceptions that shape opportunities and choices differ. From this it may be possible to begin to understand how and why people navigate the same resource landscape to arrive at different outcomes.

Another avenue for further research would be to conduct a related analysis considering the efficiency with which available resources are converted into ultimate health outcomes, such as the uncomplicated delivery of a healthy infant, in addition to the intermediate maternal care outcomes considered here.

Lastly, in terms of future research, it is possible to adapt these methods to any context where data exists on health resources and health outcomes and where it may be useful to understand who is making the most efficient use of those resources, and ultimately how and why. Such analyses could focus on a different geographic context, a different health issue, or a more comprehensive definition health comprising broader measures of health and wellness.

Acknowledgements

This publication arises from research funded by the John Fell Oxford University Press (OUP) Research Fund. The authors would like to thank Dr. Giacomo Zanollo, Oxford Department of International Development for valuable comments on the manuscript.

Conflict of interest statement. None declared.

Supplementary Data

Supplementary data are available at HEAPOL online.

Note

1. Recall that an efficiency score of 1 represents an efficient converter while a score of greater than 1 represents the factor by which that person must improve their outcomes to achieve efficiency.

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