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Hospital efficiency with risk adjusted mortality as undesirable output: the Turkish case

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Abstract We analyze the operational performance of 202 Turkish rural general hospitals. To help improve performance on both input and output space, we adopt a directional distance approach. We treat a mortality based measure as a "needs indicator". We derive pure technical, scale and output congestion inefficiency measures and show how they vary across size classes. We show that "reducing mortality" involves sacrificing some good outputs. This is a trade off that holds at the potential output level. Second stage regressions of the inefficiency scores against hospital and rural district level variables, pinpoint critical areas for performance improvement. In particular we show the relative scarcity of nurses is linked to output congestion.

1 Introduction

When compared with other OECD countries, Turkey has a poor health care system. Turkey ranks last or among the worst in many important public health indicators: life expectancy, infant mortality, health care expenditure (both in nominal terms and share of GDP). Yet, Turkey's health care performance is comparable with other upper middle-income countries (OECD 2008). Among OECD members, Turkey ranks last in physicians' density with only 1.6 practicing physicians per 1000 population. However, number of physicians is constantly increasing and this figure may converge to the OECD average in a few decades. Shortage of nurses is perhaps more worrying than the shortage of physicians. There are only 1.4 nurses

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per physician, less than half of the OECD average of 3.2.[1] Worse yet, with a nurse graduation rate of 30.7 per 1000 nurses, there aren't enough new nurses to replace the ones that are retiring (OECD 2008, p. 80).

In Turkey, there are 6760 primary care facilities and 1205 hospitals. Although their main function is providing secondary and tertiary care, the public is known for ignoring the referral chain and going directly to a hospital. Low quality of care at the primary care level and lack of financial incentives to follow the referral chain contributed to this problem. This resulted in routine cases being treated in more expensive specialty and teaching hospitals, causing wasted resources and inefficiency. For instance prior to the introduction of the Health Transformation Program in 2003, only 40% of the consultations were made in primary care facilities while the remaining 60% were performed in hospitals (OECD 2008, pp. 84 and 113).

In 1961 the so-called "Socialization of Health Services Act"[2] which centralized the management of health care institutions (they were mostly managed by municipalities then) was passed. Although there were some attempts to introduce universal health coverage in the late 1960s and early 1970s, the multi scheme system (one for salaried workers, one for the self-employed and another for the civil servants) was retained until 2006. In 1992 the green card scheme, free health care services for low income people, was introduced (Mo 2009).

In 2003 the Turkish Ministry of Health started a wide ranging Health Transformation Program (HTP). The HTP includes the implementation of Universal Health Insurance (UHI) by consolidating the three public health insurance schemes under one roof and improving access to and effectiveness of primary care services by introducing family medicine (Mo 2003). HTP is conceived as a ten year reform program. It is designed to address long standing shortcomings in the health sector including (a) lagging health outcomes compared to other OECD countries, (b) inequities in access to health care, (c) fragmentation in financing and delivery in health care leading to inefficiencies and (d) poor quality of care (OECD 2008).

Sahin et al. (2011) provide a comprehensive summary of the HTP. They track the year to year performance of 352 general hospitals over 2005-8, using Malmquist analysis. We adopt a narrower focus and concentrate on efficiency and adequacy of care issues in one segment of the health sector, namely rural hospitals during 2006. We choose to focus on rural and small town general hospitals for two reasons. First, as pointed out by OECD (2008, pp. 11–12) prior to 2003 "there were regional and urban-rural disparities in utilization of health care services, and accessing health services in rural areas was significantly harder and more expensive". Lack of personnel was an important problem whereby "12% rural health centers and did not have doctors and two-thirds of rural health posts did not have midwives" (OECD 2008, p. 37). The HTP, via increasing the number of health personnel by 100,000 and enforcing the requirement for newly trained doctors to serve in rural areas, has brought about significant improvements in the distribution of both physicians and nurses. Nevertheless, significant disparities remain (OECD 2008, p. 74). Therefore wringing out inefficiencies in small town and rural settings is more urgent compared to urban centers.

Second, restricting the analysis to rural and small town hospitals allows lessening the heterogeneity of the external environment. Since nondiscretionary factors influencing health outcomes, like hygiene awareness, nutritional practices or income levels, are likely to be

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[1] The problem is related to traditionally low female labor force participation rates; 1923—foundation year of the Turkish Republic—records show only 4 nurses and 554 physicians working in public institutions and in 1960 there were 1658 nurses working with 8214 physicians.

[2] Law 224, 05.01.1961.

more varied in urban settings, by focusing on rural and small town hospitals we reduce the impact of nondiscretionary or contextual factors on efficiency estimates, thereby enhancing their precision. Since World Bank (2003, Chap. 2) reports that knowledge of health related issues and income disparities have an important impact on health outcomes in Turkey, we think research strategies reducing the role of such contextual factors are desirable.

The rest of this paper is organized as follows. The next section reviews the literature and discusses modeling issues. Section 3 presents our directional distance model. Our data overview and inefficiency estimates are in Sects. 4 and 5 respectively. Section 6 contains the regression results and the final section offers a summary.

2 Literature review

It seems likely that the first application of DEA to health issues is unpublished work dating from 1979 dealing with family planning centers in Costa Rica and Guatemala (Ray 2004, p. xi). Nunamaker and Lewin (1983) is the first published work applying Data Envelopment Analysis to health care, whereas Sherman (1984) was the first author to use DEA to evaluate overall hospital efficiency. By now there is a very extensive literature surveyed by O'Neill et al. (2008), Ozcan (2008) and Hollingsworth (2008). The first paper emphasizes national differences in hospital efficiency research. The second monograph has a broader scope: it encompasses every aspect of health care delivery, as well as providing an overview of existing techniques. The last author classifies 317 published papers into various subcategories and offers comments as to their practical usefulness.

In addition to the already cited Sahin et al. (2011), the works dealing with the Turkish health care system comprise Ersoy et al. (1997), Sahin and Ozcan (2000) and Sahin (2009). The first study computes CRS efficiency scores for 573 acute general hospitals and identifies 90.6% of them as inefficient. The second paper treats the public hospital system in each one of Turkey's 80 provinces as a DMU. The average VRS efficiency score turns out to be 0.88, the standard deviation being 0.15. This paper carefully analyzes the structure of input excesses. The authors conclude excess nurses and other personnel are 13% and 12% whereas excess specialists and practitioners are 6.5% and 5% respectively. The final paper by Sahin (2009) contains useful institutional information about the Turkish health care system and its evolution over time.

As stressed by Jacobs et al. (2006), efficiency analysis should be based on *outcomes* of care. However researchers are often constrained to examine efficiency on the basis of *measured* activities like patients treated or surgeries performed. When there is room to suspect the effectiveness of such measured activities differs between institutions, it is imperative to augment activity counts with indicators of quality of outcome. Although direct measures of health gain are best, the few analysts addressing the issue are typically forced to use proxies like mortality, e.g. Sahin and Ozcan (2000), Dismuke and Sena (2001) or readmission rates, e.g. Arocena and Prado (2007). For instance of the 317 studies surveyed by Hollingsworth (2008) only 9% use *outcome* measures like change in health status, mortality or quality of care.

In this study we use 'risk adjusted mortality' figures of each hospital as a potential for congestion indicator. Clearly, mortality is a 'bad 'or 'undesirable' output. The efficiency literature, e.g. Scheel (2001), classifies approaches to deal with it, into direct and indirect ones. Indirect approaches involve some data transformation—like inverting or subtracting the bad output from a large number to convert it to a good one. Ideally one wants the results obtained with such transformed data to coincide with those to be obtained by using the true or untransformed data. However this is rarely the case. Such approaches yield different results since in each case the units defining the efficient frontier are different. In other words the production possibility frontier constructed with transformed data does not—in general—coincide with the true one. When the transformation is linear additive, in some cases, invariance is possible. Pastor (1996) as well as Seiford and Zhu (2002) show that converting the bad into a good output by subtraction from a large number, leaves the optimal solution unchanged under input oriented BCC. Similarly output oriented BCC model's solution is invariant to input translation. This is due to the convexity condition helping eliminate the additive constant from the input (output) equations under output (input) orientation. Ray (2004, p. 109) contains a neat exposition and Pastor (1996) an extensive discussion. Note that the CCR model—both orientations—is not translation invariant. Inverting the bad output into a good one is a non-linear transformation. As such it demolishes the convexity condition which is the key to translation invariance, Hua and Bian (2007, p. 109). As a result taking the reciprocal of the bad output to obtain a good output is not classification invariant. In other words, a DMU which is truly efficient can be classified as inefficient as well as vice versa. Using a small data set with one input, one good and one bad output Thanassoulis et al. (2008, pp. 301–304) demonstrate this point. They show that the production possibility set obtained under treating the bad output as input and the one resulting from converting the bad into good by subtraction from a large positive number are the same, whereas the PPS obtained via inversion differs.

Direct approaches avoid transformation and use data as they stand. Therefore the true production possibility frontier prevails. Most recent studies, carefully surveyed in Thanassoulis et al. (2008) follow this route. Liu et al. (2010) present a systematic investigation of undesirable input and output models used in the DEA literature. They argue in favor of avoiding data transformation. They point out under strong disposability of bad outputs, data transformation is not needed. It suffices to treat bad outputs as inputs. They show that many existing DEA models have *implicitly* adopted this route. Giving the example of a service sector firm where serving customers is the good output and received complaints is the bad one, they argue *strong disposability* would be the appropriate modeling strategy for a monopolistic and *weak disposability* for a competitive environment. The intuition being a public or private monopoly *can* but a competitive firm *cannot* afford to ignore complaints.

From this perspective we can say the adoption of the HTP by the Turkish Health Ministry and the concomitant emphasis on adequacy of care requires adopting weak disposability as a modeling strategy. In the next section we show the difference between the efficiency scores obtained under the two approaches also gives an estimate of the price paid for reducing mortality.

3 Non-oriented directional distance

The model we use has its origins in the environmental efficiency literature, Chung et al. (1997), Fare and Grosskopf (2004), where undesirable by products like sulfur emissions are of interest. The directional distance approach allows output expansion and input contraction simultaneously. Thus data transformation which distorts the production possibility frontier is avoided.

O'Neill et al. (2008) point out the hospital efficiency literature prefers the input orientation since in most countries, but particularly the US, cost containment has been and is the order of the day. Even in the US though, the debates and controversies surrounding President Obama's health care reform legislation show meaningful access to such care eludes and is desired by a substantial portion of the electorate. Thus as stressed by Hollingsworth and Spinks (2009) the public wants *both* good health outcomes *and* cost containment. In the Turkish case, OECD (2008) finds its bed occupancy rate of 69% *below* the OECD average of 75% and calls for its increase. This implies output expansion, since to increase the occupancy rate via input contraction would be tantamount to saying there are too many hospital beds in Turkey. In reality that is not the case. According to OECD (2009), Turkey has 2.7 acute hospital beds per 1000 population, substantially less than the OECD average of 3.8. However since prior studies find considerable 'input waste' we adopt a non-oriented approach.

The CRS version of the directional distance model consists of

$$\begin{aligned}
&\text{Max} \quad \{\beta, \lambda\} \quad \beta \\
&\text{ST:} \quad \sum_{j=1}^{N} \lambda_j g_{rj} \geq (1+\beta_o) g_{ro}, \quad r = 1 \text{ to } R \quad \text{(Good outputs)} \\
&\qquad \sum_{j=1}^{N} \lambda_j b_{kj} \geq (1-\beta_o) b_{ko}, \quad k = 1 \text{ to } K \quad \text{(Bad outputs)} \\
&\qquad \sum_{j=1}^{N} \lambda_j x_{ij} \leq (1-\beta_o) x_{io}, \quad i = 1 \text{ to } I \quad \text{(Inputs)}
\end{aligned}$$

where 'r' indexes the 'R' good outputs, 'k' indexes the 'K' bad outputs and 'i' indexes the 'I' inputs. As discussed by Liu et al. (2010, p. 180), this amounts to treating the bad output(s) as input(s). The choice variables $\{\beta, \lambda\}$ represent the radial expansion-contraction factor and the intensity variables respectively. The "$\geq$ or GTE" inequality for the bad outputs imposes strong disposability. It means the 'bad', in our case 'risk adjusted mortality' is expanded together with the good outputs since it can be disposed of 'freely'. In other words the institutional environment is such that it is in some sense 'tolerated'. In such a setting reducing mortality does not compete with other useful hospital activities. The VRS model is obtained by appending the convexity constraint $\sum_{j=1}^{N} \lambda_j = 1$. This yields the VRS-strong disposability model:

$$\begin{aligned}
&\text{Max} \quad \{\beta, \lambda\} \quad \beta \\
&\text{ST:} \quad \sum_{j=1}^{N} \lambda_j g_{rj} \geq (1+\beta_o) g_{ro}, \quad r = 1 \text{ to } R \quad \text{(Good outputs)} \\
&\qquad \sum_{j=1}^{N} \lambda_j b_{kj} \geq (1-\beta_o) b_{ko}, \quad k = 1 \text{ to } K \quad \text{(Bad outputs)} \\
&\qquad \sum_{j=1}^{N} \lambda_j x_{ij} \leq (1-\beta_o) x_{io}, \quad i = 1 \text{ to } I \quad \text{(Inputs)} \\
&\qquad \sum_{j=1}^{N} \lambda_j = 1.
\end{aligned}$$

Weak disposability requires *replacing* the inequality of the bad outputs equation(s) with equality. This implies reducing 'bads' is costly; it may necessitate the reduction of good outputs. In our case where ‘risk adjusted mortality’ is the bad output, reducing it, means less tolerance for inadequacy. It follows that the implementation of HTP, which emphasizes improved performance, can be modeled by imposing weak disposability and recognizing the possibility of sacrificing some good outputs. As will be shown subsequently, this modeling strategy will allow pinpointing hospitals where such a trade off occurs and therefore more inputs are needed. So the VRS-weak disposability version of the directional distance model becomes:

$$\begin{aligned}
\text{Max}\quad & \{\beta,\lambda\}\quad \beta \\
\text{ST:}\quad & \sum_{j=1}^{N}\lambda_j g_{rj} \geq (1+\beta_o)g_{ro}, \quad r=1 \text{ to } R \quad \text{(Good outputs)} \\
& \sum_{j=1}^{N}\lambda_j b_{kj} = (1-\beta_o)b_{ko}, \quad k=1 \text{ to } K \quad \text{(Bad outputs)} \\
& \sum_{j=1}^{N}\lambda_j x_{ij} \leq (1-\beta_o)x_{io}, \quad i=1 \text{ to } I \quad \text{(Inputs)} \\
& \sum_{j=1}^{N}\lambda_j = 1.
\end{aligned}$$

In the environmental literature where this model originates, good and bad outputs are produced jointly as a *technological necessity*. Thus in environmental applications a null jointness property is imposed by multiplying the LHS of both good and bad output equations with a parameter ρ ($0 \leq \rho \leq 1$). This makes the model non-linear and necessitates a grid search for the value of ρ over [0, 1] to solve it as an LP problem.[3] See, Picazo-Tadeo and Prior (2005). In our case to impose null jointness is tantamount to saying “the only way to produce zero ‘risk adjusted mortality’ is to **not** treat anyone medically!” So, we feel null jointness is inappropriate for health applications. Also its imposition did not change our results at all. Namely the optimum occurred at $\rho = 1$ for every hospital.

4 Data-inputs and outputs

In Turkey there are 1205 hospitals, 42 military and 1163 civilian. The Ministry of Health is in charge of civilian hospitals. It directly owns and operates 769 hospitals and oversees the rest (394). Out of this total 332 are private, 56 are university hospitals and the remaining 6 are operated by municipalities. However since private hospitals are smaller, the share of the public/semi-public sector is larger than the ownership figures suggest. For instance the public sector accounts for 92% of overall bed capacity. The functional breakup of these 831 public/semi-public hospitals is as follows: 603 general, 117 specialty, 56 university and 55 teaching. Out of these 603 general hospitals 406 are located in rural areas or small towns and the rest in metropolitan areas or provincial capitals. Data considerations forced us to restrict our sample to 202 such hospitals. Nurse, other personnel and operating expenses

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[3] This means optimizing iteratively, varying ρ between [0, 1] by increments of, say, 0.1 and choosing the solution yielding the largest β. We thank Diego Prior for clarifying this point.

were available only for 219 rural hospitals. We had to discard 9 of them since no surgeries were performed and our 'risk adjusted mortality' measure involved dividing deaths with the number of surgeries. A further 8 were dropped due to data irregularities[4].

The remaining 202 hospitals have similar characteristics; they all are either the single or one of two hospitals in their respective towns or villages. Although we do not know the specialties of the physicians in our 202 hospitals for 2006, we do know them for 2009. The distribution of these specialties is rather concentrated. For instance, out of 55 specialties defined by the Ministry of Health, 24 are absent from all the hospitals in the dataset (these are advanced specialties or subspecialties such as immunology, radiation oncology… see footnote 7 for a complete listing). On the other hand, some specialties are very common; 194 of the 202 hospitals employed at least one general surgeon, 187 employed gynecologists and obstetricians, while 182 employed at least one specialist of internal medicine. All in all, 69.2% of specialists (5165 of 7467) are of 10 common specialties[5]. Being present in at least 51 (25%) of the hospitals, a further 12 specialties and sub specialties[6] can be labeled as moderately common. These moderately common specialties account for 28.7% (2144 of 7467) of the physicians employed in provincial hospitals. In other words, 97.9% (7309 of 7467) of all specialists belong to one of the 22 moderately or highly common specialties, only 2.1% (158) have one of the 9 uncommon specialties while 24 are not present at all[7]. Considering the average of 12.5 different specialties per hospital, this implies considerable homogeneity of cases treated. Thus cases requiring uncommon specialties are in general referred to urban and metropolitan center hospitals.

Table 1 lists our variables and their definitions. Tables 2a, b display the summary statistics. These 202 hospitals represent about 72% of the overall rural/small town bed capacity. According to the 2008 electronic population registry figures, roughly 39% of Turkish people live in rural areas and small towns. Since roughly 19% of overall bed capacity is in such hospitals, our sample represents about $(0.72 \cdot 0.19)$ 14% of Turkish bed capacity.

Most of our data is from the Ministry of Health's website[8]. We use 6 inputs: beds, specialists, general practitioners, nurses, other personnel and operating expenses. We have 1 bad output and 3 good outputs. The good ones are: outpatient visits, inpatient discharges and surgeries. There is no diagnostic related groupings index in Turkey. Therefore outputs were not weighted on a DRG basis. However major, medium and minor surgeries were converted into a major surgery equivalent. The weights were major $= 1$, medium $= 1/3$ and minor $1/7$, see Buyukkayikci and Sahin (2000). We used two alternative bad output or "risk adjusted

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[4] For instance, one hospital reported 2865 deaths, more than six times the next highest number and ten times the average mortality rate.

[5] These are: Internal medicine, general surgery, pediatrics, gynecology and obstetrics, anesthesiology, ophthalmology, otolaryngology, orthopedics and traumatology, urology, biochemistry.

[6] They are: neurosurgery, dermatology, cardiology, pulmonology, neurology, physical medicine and rehabilitation, infectious diseases, microbiology, pathology, radiology, psychiatry, family medicine.

[7] Uncommon ones: Cardiac surgery, thoracic surgery, pediatric surgery, plastic surgery, emergency medicine, public health, nuclear medicine, hematology, gastroenterology. Whereas *Child and adolescent psychiatry, forensic medicine, physiology, radiation oncology, endocrinology, medical oncology, nephrology, rheumatology, immunology, geriatrics, allergies, allergic thoracic diseases, gastroenterologic surgery, surgical oncology, pediatric cardiology, pediatric hematology, pediatric nephrology, pediatric gastroenterology, pediatric infectious diseases, pediatric neurology, pediatric endocrinology, pediatric allergies, pediatric immunology, neonatology* are absent.

[8] http:/www.saglik.gov.tr. Also, we are grateful to Yasar Ozcan, Hacer Ozgen and Ismet Sahin for sharing their data on nurses, other personnel and operating expenses. In addition Yasar Ozcan generously guided us to another data source.

Table 1 Variable definitions and explanations

Variable	Definition and explanation
Inputs	
Beds	The total number of staffed beds in the hospitals
Specialists	The total number of specialists who are full time employees (FTEs) in the hospitals
General Practitioners, GPs	The total number of general practitioners who are full time employees (FTEs) in the hospitals
Nurses	The total number of nurses who are full time employees in the hospitals, including midwives
Other personnel	The total number full time employees of all other supporting medical and non medical personnel (pharmacists, medical technologist, medical technicians, medical radiological technologists, dietitians, administrative personnel etc.) not including contracting out personnel such as maintenance, security and housekeeping in the hospitals
Operational expenses	The amount of operational expenses measured in US $1000, not including payroll, capital or depreciation expenses
Outputs	
Outpatients	The total number of patients to outpatient departments and emergency rooms (unadjusted)
Inpatients	The total number of inpatients (unadjusted)
Surgeries	The total number of inpatient and outpatient surgeries (surgeries adjusted by major surgeries = 1, moderate surgeries = $1/3$, minor surgeries = $1/7$)
D/S Ratio	Number of deaths divided by total number of surgeries

Table 2 (a) Summary input statistics of 202 provincial hospitals for 2006. (b) Summary output statistics of 202 provincial hospitals for 2006

(a)

	Beds	Specialists	General Practitioners	Nurses	Other Personnel	Operating Expenses
Min	47	2	0	10	13	298
Max	540	87	35	219	283	15,416
Mean	112	19	9	57	71	2919
St. Dev.	81	16	5	39	38	2385

(b)

	Outpatient Discharges	Inpatient Visits	Surgeries	Deaths/Surgeries D/S Ratio
Min	33,690	222	3	0.0000
Max	1,073,004	21,503	5520	0.1215
Mean	215,674	4845	1169	0.0285
St. Dev.	148,649	4193	1303	0.0299

mortality" measures: deaths to surgeries ratio and deaths to inpatients ratio for each hospital.[9] The results were very similar. The correlation coefficients between the respective

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[9] Sahin and Ozcan (2000) use this latter measure.

Table 3 Input and Output averages by hospital size

# of Beds	Hospitals	Specialists	GPs	Nurses	Other	OpEx	OutPat.	InPat.	Surgeries	D/S Ratio
<50	43	8	6	28	44	1337	114,088	1805	278	0.03
51–75	53	10	7	35	52	1695	140,044	2397	433	0.03
76–100	27	15	8	49	64	2315	186,669	3642	976	0.02
101–150	34	19	11	65	82	3276	232,681	5607	1290	0.03
151–200	22	33	12	87	91	4352	311,213	7771	2213	0.03
201+	23	50	18	131	134	7505	497,393	13,659	3583	0.04

inefficiency scores ranged from 0.97 to 0.99. Therefore we report only those obtained with the first measure. Admittedly “deaths to surgeries” ratio is a quite noisy measure of care adequacy. As one referee pointed out “5 deaths in 1000 surgeries would be too high in a birthing hospital for young women whereas 110/500 may be very low in a hospital for old people with rare cancers”. In self defense we argue that in the absence of better measures, we use it as a last resort solution. As a partial justification we would like to point out the surgeries performed in our rural hospitals, are by necessity of a “basic or common variety”. In other words as explained previously surgeries requiring “uncommon” specialties are to a large extent referred to urban or metropolitan centers.

Five of our hospitals had zero GPs. Zero input values require extra care because at least one DMU with a zero input will always be efficient *irrespective* of the levels of its remaining inputs or outputs. Thanassoulis et al. (2008, p. 311) provide a neat exposition of this point. In case the zero input value reflects genuine management choice, there is no cause for concern. However in our 5 hospitals, the absence of general practitioners reflects a case of ‘shortage’ rather than deliberate choice by hospital management[10]. In such situations Kuosmanen (2002) suggests replacing the zero input value by a sufficiently large positive number M. This procedure will force the DMU to assign a zero weight to that input value and therefore the resulting efficiency score will be the same as that obtained when the input in question is excluded from the analysis. We chose this route and set M to 10,000 for these 5 hospitals. Naturally, for compiling the information presented in Tables 3 and 5 we used the original—zero-values.

Table 3 presents the break-up of these 202 hospitals according to bed capacity and their average input-output levels. As can be seen average input usage and average output levels rise with hospital size except for the Deaths/Surgeries Ratio.

5 Inefficiency estimates

We computed CRS, VRS—strong and weak—, Scale and Output Congestion inefficiencies using our directional distance model. The CRS and VRS-strong figures are obtained directly, assuming strong disposability. Subtracting the VRS estimate from the CRS one, yields the scale inefficiency estimate. The difference between the VRS figures obtained under strong vs. weak disposability respectively, gives the ‘congestion’ inefficiency. This figure shows whether and to what extent reducing ‘risk adjusted mortality’ competes with producing other desirable hospital activities. Thus an output congestion inefficiency of zero implies no such

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[10] Our Introduction briefly outlines this ‘lack of personnel’ problem faced by rural health care facilities.

Table 4 Directional distance inefficiency estimates

Beds	CRS	VRS-strong	VRS-weak	Scale	Congestion	$\sum_{j=1}^{N} \lambda_j = 1$
# efficient	56	97	117	56	144	
<50	0.095	0.005	0.003	0.090	0.002	0.782
51–75	0.093	0.042	0.032	0.051	0.010	0.810
76–100	0.100	0.083	0.066	0.017	0.017	0.872
101–150	0.096	0.084	0.071	0.013	0.013	1.099
151–200	0.090	0.065	0.057	0.025	0.008	1.189
201+	0.075	0.038	0.036	0.037	0.002	1.626
Overall Average	0.092	0.049	0.040	0.044	0.009	0.995
Overall SD	0.097	0.073	0.069	0.072	0.023	0.436
Significance	All different from *zero* at 0.037 or below					All different from *one* at 0.01 or below

‘competition’, whereas a positive figure means reducing mortality involves giving up some desirable activities. In other words congested hospitals, after removing inefficiencies, need more resources. *We stress this trade-off pertains to the frontier, namely at projected input-output levels*. Table 4 displays the average inefficiencies by hospital size as the well overall means and standard deviations.

Our estimates suggest overall CRS inefficiency is around 9.2% which breaks up as 4.9% VRS and 4.4% scale, any discrepancy being due to rounding. The scale inefficiency figures together with the information on ‘lambda sums’—the last column of Table 4—indicate the 101–150 bed range as the best hospital *size* followed by the adjacent 76–100 range. Note that the *scale* inefficiency is lowest (0.013) in the 101–150 hospital range and $\sum_{j=1}^{N} \lambda_j = 1$ test can not reject CRS—i.e. equality to one—for the 76–125 range. Small hospitals with less than 50 beds exhibit relatively high levels of scale inefficiency, followed by the 51–75 range. Their ‘lambdas sum’ test shows the sum to be less than one, indicating *increasing returns to scale*. This suggests economically, operating such small hospitals may not be the best use of available resources. As policy makers have to balance the conflicting objectives of maximizing access to health care and minimizing cost, except in remote and isolated locations shifting resources from these hospitals to primary care could be considered to provide “*more equitable, inclusive and fair*”[11] health care service. The sum of lambdas meaningfully *exceed* one , especially for the greater then 150 beds range, indicating scale *diseconomies* or decreasing returns to scale (DRS) becoming operative. However the extent of DRS is not as serious as that of IRS. Note that for the IRS (<50 to 75) range scale inefficiencies are much larger (0.090, 0.051) than those of the DRS (151 and above) range (0.025, 0.037).

The difference between the VRS-strong and VRS-weak scores gives the output congestion inefficiency. Our results indicate for 58 (202–144) hospitals reducing ‘risk adjusted mortality’ involves sacrificing some useful hospital activities. The next few paragraphs carefully explain the nature of this trade-off. Here we note such congestion is most serious in the 76–150 beds range. The *reduction* of our pure technical or VRS inefficiency estimates when one *switches* from strong to weak disposability can be interpreted as follows. For those units where the ‘bad output’ constraint holds as an equality at the strong disposability optimum,

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[11] From Director-General’s message, World Health Report 2008, WHO.

Table 5 Quantity vs. quality tradeoff: efficient input-output levels under strong-weak disposability for two congested hospitals

	Beds	Specialists	GPs	Nurses	Other	OpEx	OutPat.	InPat.	Surgeries	D/S Ratio
"Aydin"	Congestion(0.030) = VRS_S(0.097) − VRS_W(0.067)									
vrs-s prjctns	53	8	8	28	40	1213	174,009	2405	410	0.005
slacks-s	0	0	3	10	0	0	0	328	0	0.003
vrs-w prjctns	55	8	9	24	41	1253	169,329	2021	399	0.002
slacks-w	0	0	2	16	0	0	0	0	0	0.000
Difference: W-S inputs S-W outputs	2	0	1	−4	1	40	4680	384	11	0.003
"Balikesir"	Congestion(0.020) = VRS_S(0.020) − VRS_W(0.000)									
vrs-s prjctns	65	9	4	16	24	906	129,961	1865	354	0.081
slacks-s	8	0	0	18	0	0	0	0	97	0.073
vrs-w prjctns	75	9	4	34	24	924	127,471	1829	253	0.008
slacks-w	0	0	0	0	0	0	0	0	0	0.000
Difference: W-S inputs S-W outputs	10	0	0	18	0	18	2490	36	102	0.073
Mean difference: 58 congested hospitals	4	0	0	1	7	−21	8594	250	909	0.019

the switch to weak disposability, namely imposing equality onto the 'bad output' constraint does not matter. But for those hospitals where the same constraint holds as an inequality under the strong disposability optimum, the switch to weak disposability does matter. In such cases the obligation to decrease 'bad output' i.e. 'risk adjusted mortality' levels which are no longer tolerated will require reducing good outputs and/or more inputs. In other words eliminating the possibility of freely disposing the bad output[12]—i.e. not tolerating 'some' risk adjusted mortality, increases resource requirements needed to attain the same level of good outputs or involves foregoing some good outputs. Thus estimated inefficiency falls for such units. This interpretation leads to viewing the difference between the two estimates as a measure of congestion. Ray (2004, pp. 175–178, 186) provides an exposition. From this viewpoint a nonzero congestion value for a hospital indicates, a need for more resources or less workload.

Table 5 illustrates these points for two hospitals. The "Aydin" hospital has the efficient, namely projected, input-output levels shown on the third row of Table 5 under strong disposability. The fourth row lists the associated slack values. Recall that changing the inequality to equality for the bad output (namely risk-adjusted mortality) constraint imposes a change of regime. Therefore D/S Ratio's slack value of 0.003 indicates the switch from a strong to weak disposability regime will be binding. The fifth row gives the input output projections for the weak disposability regime. Note that the output projections are uniformly lower; indicating the fall in the level of risk-adjusted mortality from 0.005 to 0.002 is achieved at the

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[12] This elimination, from a purely mathematical standpoint, decreases the optimal scores via tightening the 'bad output' constraint. Institutionally it corresponds to HTP's insistence on improved performance or imposition of tough regulations in the environmental case.

expense of decreasing the good output levels. The seventh row lists these differences. Thus the 'price' of reducing risk-adjusted mortality by 0.003—which previously was 'freely' disposed of or 'tolerated'—involves 11 fewer surgeries, 384 fewer inpatients and 4680 fewer outpatients. For the "Aydin" hospital the switch also requires 2 more beds, 1 more GP as well as other personnel and $40,000 more operational expenses but releases 4 nurses.

Table 5 also provides similar information for a "Balikesir" hospital. As shown on the tenth row listing VRS-Strong slack values, the D/S Ratio (our measure of risk-adjusted mortality) has an excess equaling 0.073 under a strong disposability regime. This means, under a weak disposability regime, output levels—both good and bad- will have to fall because to 'freely' dispose of (or to tolerate) the 0.073 units of "excess risk adjusted mortality" will not be possible. Row thirteen displays the 'price' to be paid for decreasing the D/S Ratio by 0.073 units—from 0.081 to 0.008. It involves performing 102 fewer surgeries and treating fewer inpatients (36) and outpatients (2490). To achieve this bad output reduction also requires more inputs: 10 more beds, 18 extra nurses plus $18,000 additional operational expenses[13]. The congestion inefficiency estimate is a summary measure of this tradeoff. For each input or output value, actual amount times the congestion estimate (plus the difference in slacks) gives the foregone output (extra input) necessary for reducing the D/S ratio. Thus the foregone inpatients figure for "Aydin" (384) equals $1894 \cdot 0.03 + (328 - 0)$ where 1894 stands for the actual inpatients discharged from that hospital. Similarly for the "Balikesir" hospital the number of foregone surgeries (102) equals $253 \cdot 0.02 + (97 - 0)$[14].

Since we have 58 congested hospitals we also computed the means involved. The last row of Table 5 displays these numbers. 0.019 means 19 deaths to 1000 surgeries. Thus to reduce risk adjusted mortality by that amount, our "typical" congested hospital needs to perform 909 fewer surgeries and treat 250 and 8594 fewer in and outpatients respectively. In addition it requires more inputs by the indicated amounts, e.g. 4 more beds, 1 more nurse and 7 other personnel. However operating expenses can be reduced by $21,000.

6 Regression

We use regression analysis to identify factors that influence the VRS, scale and congestion inefficiencies for each hospital. The additional explanatory variables used are defined in Table 6. We present their averages broken by hospital size in Table 7. We adopt the seemingly unrelated regression (SUR) method. This approach exploits the fact that all 3 dependent variables pertain to the same hospital and therefore the disturbances of each equation may be correlated. Thus the 3 equations are treated as a system. The greater the correlation across the disturbances, the larger is the efficiency gain. On the other hand the less correlation there is across the explanatory variables of each equation, the greater is the gain from adopting a system approach. A Lagrange multiplier test indicated significant precision gains from using SUR. Within the DEA tradition the method was first used by Fried et al. (1996). Here we utilize the bootstrap SUR estimator to obtain heteroskedasticity consistent standard errors. This approach accounts for the high proportion of zeroes corresponding to efficient hospitals. Assuming homoskedasticity yields identical estimates with higher Z values.

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[13] Thus for "Balikesir", unlike "Aydin", input requirements uniformly rise. In each case the mix of inputs, the mix of outputs as well as the substitutability versus complementarity relations within them, which depend on the techniques involved, will be decisive.

[14] Any discrepancy is due to rounding error.

Table 6 Regression explanatory variables

Variable	Definition
BED TURNOVER_RATE	(Inpatients + Deaths) · 100/Number of beds
INP_OUTP_RATIO	(Inpatients + Deaths) · 100/Outpatients
BED_OCCUPANCY	(Hospital bed days) · 100/(Number of beds · 365)
EXCESS_BEDS	Allotted Beds − Staffed Beds. Source: Ministry of Health website (http://www.saglik.gov.tr)
POP_90	1990 population of the district where the hospital is located
POP_CHNG_90_07	District's % population change from 1990 to 2007. Source: Turkstat website (http://www.turkstat.gov.tr)
POP/HOSP	Population per hospital (2006) for the *whole* province where the district is located. Source: Mo (2006)
SHARE_TAX_REVENUE	Share of income and corporate taxes collected in that district within the national total for year 2000. Source: SPO (2004)

Table 7 Explanatory variable averages by hospital size

# of Beds	Turnover	InpOutpRatio	Occupancy	Excess Beds	Share_Tax_Rev	Pop/Hosp	Pop_90	Pop_Chng
<50	36.4	1.60	37.6	2	0.02	62,993	48,220	−0.056
51–75	36.7	1.72	36.0	5	0.01	61,434	51,964	−0.016
76–100	39.9	2.01	46.2	8	0.05	65,905	71,064	0.093
101–150	46.0	2.44	49.1	10	0.04	64,885	75,420	0.074
151–200	44.0	2.61	53.0	7	0.06	65,266	89,090	0.134
201+	48.5	2.92	59.9	4	0.11	68,114	125,295	0.221

Table 8 displays our regression results. They suggest pure technical inefficiency rises with, INPatient to OUTPatient RATIO and number of SPECIALISTS. This latter finding lends credence to the common perception that some specialists use their public hospital jobs as a means of attracting patients to their private practices. The impact of the INPatient to OUTPatient RATIO merits further consideration. Because the lack of a DRG based case mix weighting tends to "show" large hospitals with many specialists as inefficient. To some extent the same applies to our finding about SPECIALISTS. On the other hand VRS inefficiency falls with BED_TURNOVER RATE and number of SURGERIES performed which is consistent with prior expectations.

Scale inefficiency falls with SURGERIES performed, BED OCCUPANCY and the two demographic measure, POP_90—population level in 1990—and POP_CHNG_90_07—population change from 1990 to 2007 in the hospital's catchment area. We think these negative relationships reflect the presence of increasing returns to scale in small hospitals.

In particular, the coefficients of the population variables exhibit the impact of the rural to urban migration characterizing ongoing Turkish trends, Tas and Lightfoot (2005). Given decision making and implementation lags, it is reasonable to suppose current hospital capacity reflects past population size. In that sense POP_90 would proxy for current hospital capacity.

Table 7 shows smaller localities have registered the largest population loss from 1990 to 2007. It follows such districts will have the smallest activity scale relative to capacity which would imply the need to increase scale, namely increasing returns to scale.

Table 8 Seemingly unrelated regression: Directional distance inefficiency scores

Equation ($n = 202$)	R-square	Chi^2	P value
VRS (4 parameters)	0.159	37.81	0.000
Scale (5 parameters)	0.171	45.02	0.000
Congestion (4 parameters)	0.109	26.75	0.000
VRS; Corr (VRS resid. Scale resid.) = −0.291	Coefficient	Z value	P value
BED_TURNOVER RATE	−0.0013	−4.55	0.000
INP_OUTP_ RATIO	0.0165	2.43	0.015
SURGERIES	−0.00003	−3.31	0.001
SPECIALISTS	0.0024	3.01	0.003
Constant	0.051	3.68	0.000
Scale; Corr (Scale resid, Congestion resid) = 0.006	Coefficient	Z value	P value
BED_ OCCUPANCY	−0.0010	−2.97	0.003
SURGERIES	−0.00002	−2.44	0.015
SPECIALISTS	0.0022	2.91	0.004
POP_90	−4.41e–07	−2.59	0.009
POP_CHNG_90_07	−0.0443	−2.90	0.004
Constant	0.0961	5.37	0.019
Congestion; Corr(VRS resid, Congestion resid) = 0.289	Coefficient	Z value	P value
EXCESS BEDS	0.0001	2.12	0.034
NURSES	−0.0001	−2.06	0.039
POP/ HOSPITAL	2.48e–07	2.44	0.015
SHARE_TAX_REVENUE	0.0967	1.46	0.145
Constant	−0.0024	−0.51	0.612

On the other hand scale inefficiency rises with number of SPECIALISTS. This might point out to decreasing returns in the relatively few large hospitals performing the bulk of surgeries (out of 202 hospitals, the 23 (45) largest perform 35% (55%) of the surgeries). An alternative explanation would involve the ones mentioned above, namely private use of public jobs coupled with the measurement difficulty arising from the absence of DRG based case mix weighting.

Finally, in the congestion inefficiency equation, the positive POP/HOSPITAL-number of people per hospital in that *province*—and SHARE_TAX_REVENUE—the share of taxes paid in that particular district in total tax revenue—point out to the role played by demand for hospital services in generating congestion[15]. The Ministry of Health, in addition to the number of staffed beds, also provides the number of allotted beds for each hospital. Staffed beds can be above or below the allotted ones depending on local conditions. We obtain EXCESS BEDS by subtracting the former from the latter. For our 202 hospitals the average equals 6 with a standard deviation of about 25. The positive EXCESS BEDS and the negative NURSES coefficients together imply an input mix problem and point to nurses as a critical

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[15] We believe SHARE_TAX_REVENUE is a good proxy of a district's socioeconomic development level.

input. This finding is fully consistent with OECD (2008, p. 92) which reports a relative scarcity of nurses in Turkey.

7 Summary

We focus on the efficiency and care adequacy improvement effects of Turkey's Health Transformation Program on rural and small town hospitals. To this end we develop a directional distance model with risk adjusted mortality as an indicator of potential input shortages or excess workloads. Using 2006 data on 202 rural general hospitals we calculate CRS, VRS—strong and weak—, Scale and Output Congestion inefficiencies. We argue inadequate versus less inadequate quality of care regimes can be approximated by using the strong versus weak disposability of bad outputs models. Adopting such an approach we provide some estimates of the trade-off involved when health care quality inadequacy is reduced. We regress these inefficiency scores against a number of hospital and district level variables using SUR. Our main findings include: (a) scale inefficiency is concentrated in the 96 smallest hospitals; (b) there is some evidence of decreasing returns to scale in the largest hospitals; (c) congestion inefficiency is most serious in the 75–150 beds range, seems to be an input-mix problem and is related to a lack of nurses; (d) the observed pure technical inefficiency in public hospitals could be linked to some specialists' using their public jobs to attract patients for their private practices and (e) more precise analysis requires introducing DRG based case mix weighting and objective measures of care quality e.g. change in health status or readmission rates.

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