Business Analytics - Assignment #8:
Controling budgets and sustaining efficiency in US hospitals

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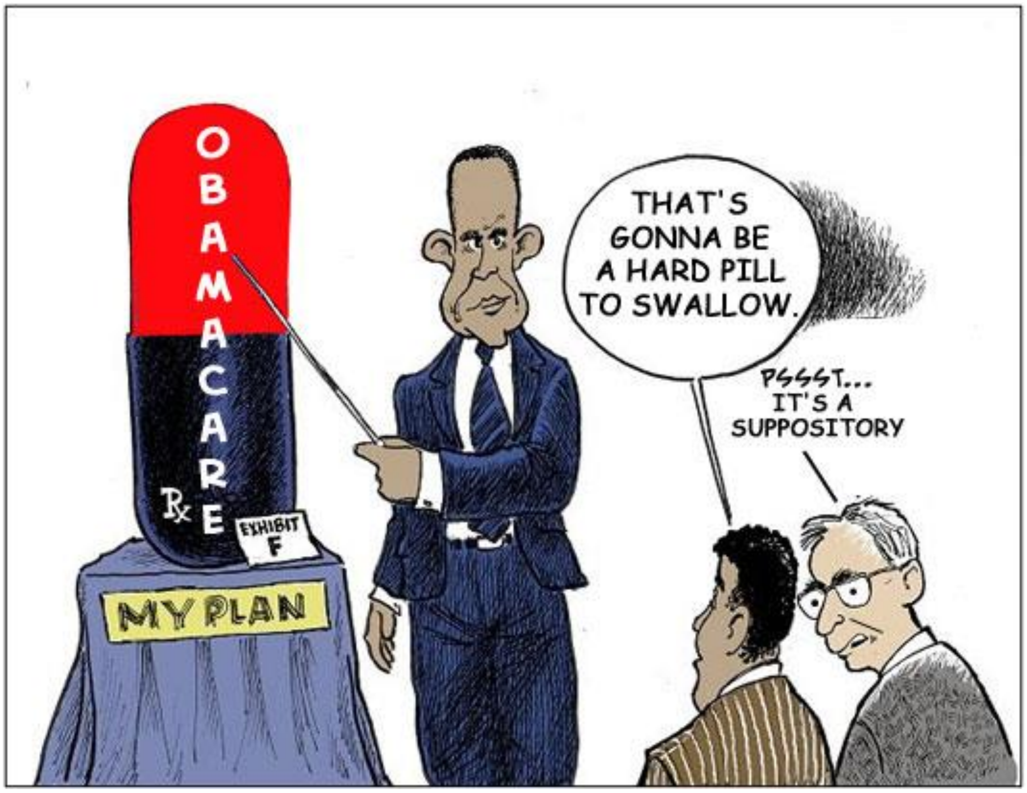
December 1, 2015



Background:

In the aftermath of the Affordable Healthcare Act (aka Obama Care), public expenditures in in US hospitals climb while outputs are stagnant. Dr. Francis S. Collins, the director of the National Institute of Health (NIH), is invited to a congressional committee to offer strategies for budget control and efficiency improvement in the hospital sector. Dr. Collins intends to use financial and operational hospital data collected in Washington State to identify hospitals operating at sub-optimal efficiency and offer improved budget constrains for this hospitals. Facing proposed 20% budget cut in public hospital spending, the objective of Dr. Collins is to defend the budgets of hospitals operating efficiently, curb budgets in hospitals operating wastefully, and boost the budgets of growing hospitals.

Problem Statement:

1. How can efficiency level in hospital operation be determined?
2. How to predict future expenditures in multiple hospitals?
3. How should future budgets be revised to improve efficiency and maintain healthcare delivery?

Data and Methodology

Operational data from about 50 general hospitals in the state of Washington during the years 1974 to 1996 was collected and processed by Menon, Lee and Eldenburg (2000). In accordance with classical economic theory, hospital budgets were processed by Menon et al. as capital or labor input resources. Capital resources are human-made goods, including tools, machines and buildings, while labor resources include human efforts, mostly in the form of wages. Input resources of capital and labor are further divided into three categories, including: IT, Medical (MD) and Medical-IT (MDIT). IT refers to administration IT (billing systems etc.), MDIT refers to expenditure related to digital imaging (CT, MRI) and other technologies employed in hospital care. MD refers to non-IT medical and laboratory services. In addition to these six continuous input factors (IT-capital, IT-sal, MDIT-capital, MDIT-sal, MD-capital, MD-sal). The output of these hospitals is expressed as adjusted patient days (YHAPDS), computed from billing records to approximate inpatients and outpatients revenues.

Truncating incomplete records and estimating absent values in several cases, a subset of this dataset was further analyzed, including 46 hospitals with continuous records over 18 years of operations. Data Envelop Analysis (DEA) was chosen as an analytic framework for comparison of efficiency levels in the hospital sector. Hospital operations over the most recent three years in the Menon data set (hence after years 18, 19 and 20) were examined to determine scale efficiencies. Non-parametric DEA models with constant return to scale (CRS), variable return to scale (VRS), and non-increasing returns to scale (NIRS) were computed in EMS. These efficiency scores were than used to determine scale efficiency of hospitals on the production frontier as increasing returns to scale (IRTS), most productive scale size (MPSS) or decreasing return to scale (DRTS). Future hospital budgets in study years 21 to 25 were computed using an excel macro and further adjusted according to hospital category.

Results:

To inspect the rate of expenditures in the hospital sector, aggregated input factors per year (expressed in inflation deflated 1996 dollars) and aggregated patient days were graphed (**Figure 1**). This analysis reveals a consistent annual increase of about 6.8% in expenditures over the last five years (**Figure 1**). Importantly, aggregated hospital output levels, expressed in adjusted patient days, are sagging in the last three years, indicating a potential decline in productivity.

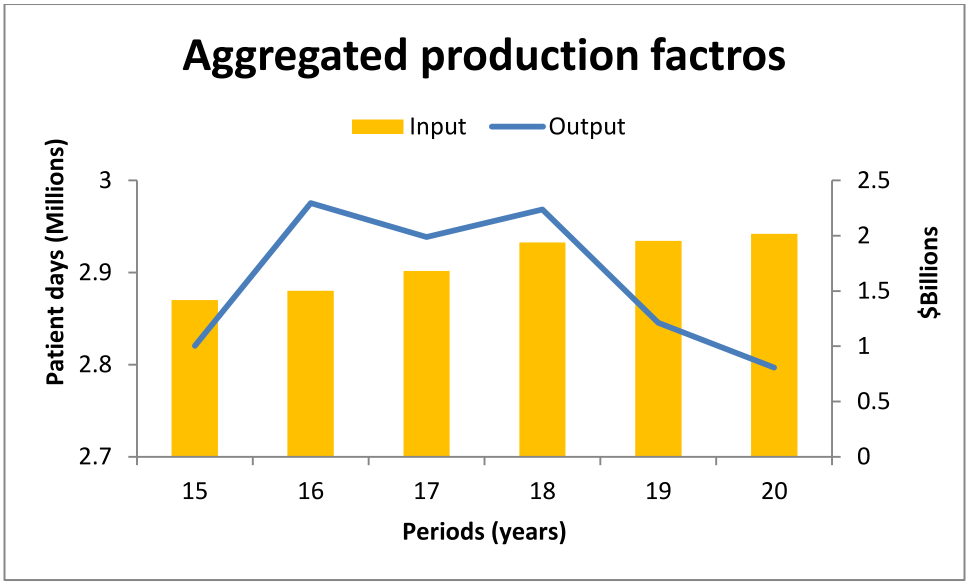


Figure 1: Rising expenditures and declining outputs in Washington State public hospitals (1991-1996). Aggregated input factors, including capital and labor expenditures are represented by bars. Aggregated adjusted patient days are depicted by line graph.

Scale inefficiencies in Washington State hospitals

Hospitals in the Menon data set are very heterogeneous, with operation scales ranging from tiny hospitals hosting about 4,000 patient days annually (~100 beds), to giant hospitals hosting 285,000 patient days in one year (~ 1,000 beds). Recording capital and labor expenses for each hospital in the Menon dataset enables convenient comparison of scale efficiencies in this heterogeneous group. To inspect utilization of resources across multiple Washington State hospitals, DEA was performed, assuming autonomous operation in each hospital (controlling its own level of input and output factors). Using EMS, CRS, VRS and NIRS scores were calculated for 138 cases of 46 hospitals operating over the last three years. Cases with all scores equal one (or 100%) were annotated as operating efficiently (MPSS). Cases with both VRS and NIRS scores larger than CRS score were annotated as operating inefficiently in decreasing return to scale (DRTS, **Appendix 1**). But, when VRS score was larger than CRS score, and NRS score was equal to one, the hospital was annotated as operating inefficiently with increasing returns to scale (IRTS). In this panel of 138 cases, 18 cases (12%) were operating efficiently (MPSS), 20 cases (13%) were in need of more input factors for growth (IRTS), and 100 cases (75%) were operating inefficiently in decreasing returns to scale. This analysis indicates that the most hospitals in the Menon dataset are operating inefficiently. Furthermore, DRTS hospitals are typically very large hospitals, with average annual budgets of $50 million, treating about 75,000 patient days a year (**Figure 2**). Increasing return hospitals are much smaller, with average annual budgets under $10 million and with limited average treatment capacity (under 20,000 patient days, **Figure 2**). Hospitals operating efficiently have budgets of about $30 million on average and capacity to treat up to 50,000 patient days annually (**Figure 2**).

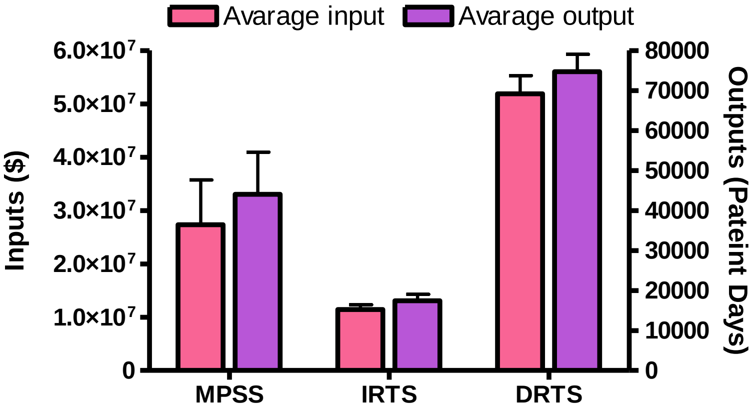


Figure 2: Average size of inputs and outputs in the three efficiency categories.

Examining input oriented efficiency scores reveals consistent average efficiency of 68% for DRTS hospitals in the last year of study, while efficiency in IRTS hospitals is sliding to just below 60% (**Figure 3**).

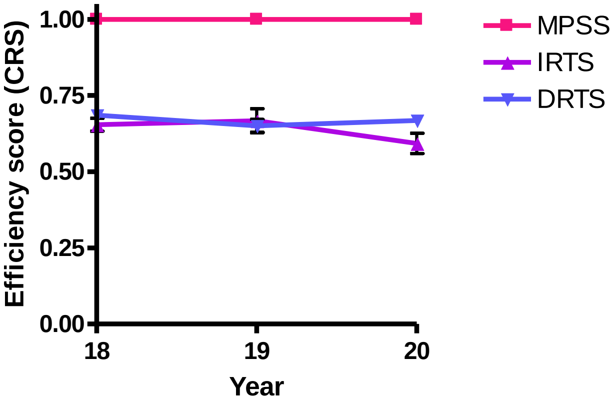


Figure 3: Input oriented efficiency scores for each hospital category.

As expected, the large size of DRTS hospitals and the high frequency of DRTS in the Menon cohort, implies that decreasing-return-to-scales is dominating annual hospital budgets in Washington State with 65% of total hospital budget (**Figure 4**, excluding drug costs etc. as reflected in the Menon dataset).

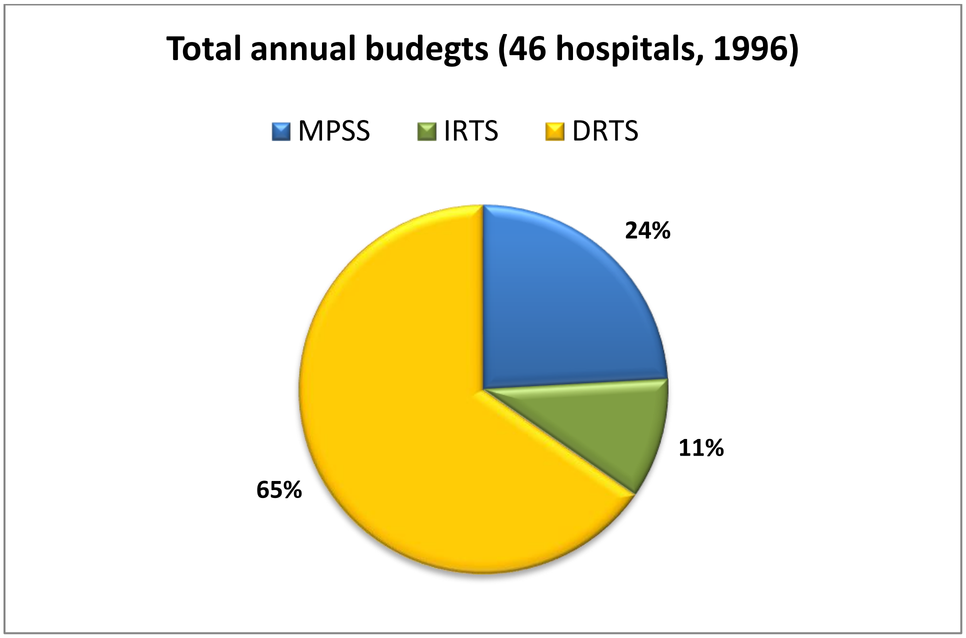


Figure 4: Total annual budgets in the last year of study.

This broad strokes analysis reveals that if operation efficiency in DRTS hospitals will be restored to the MPSS levels 30% of DRTS hospital budgets can be recovered, about 19.5% of global annual budget, with in the target of the proposed budget cuts. If implemented correctly, the new budgets will have only minimal negative impact on healthcare outputs, since only inefficient hospitals will be targeted. However, some budget increases might be required to adjust for population changes, epidemics, and the required growth in IRTS hospitals.

Inspecting internal allocation of resources among the three categories of hospitals reveals that efficient hospitals (MPSS) are allocating more resources to their medical staff (52% vs. 41%) and fewer resources to their medicalIT staff (27% vs. 33%) (**Table 1**). This finding could assist DRTS hospitals in adjusting their budgets, using MPSS hospitals as a benchmark. The vast majority of hospital expenses in the Menon data set are attributed to labor expenses (88% in MPSS hospitals, **Table 1**). In an attempt to discover how input factors are optimally correlated to output factors in MPSS hospitals, labor salaries were plotted against patient capacity (**Figure 5**). While second order polynomials could be fitted to the MPSS data in excel with high confidence ($R^2 > 0.93$, **Figure 5**), these equations were still not accurate enough to describe the data (leaving gaps of millions of dollars when applied to the acquired data). Removing a high expenditure outlier from the MPSS dataset did not improve the accuracy of the labor models (**Appendix 2**).

Table 1: Allocation of input factors

	DRTS	IRTS	MPSS
itsall	11.25%	13.09%	9.27%
itcapl	2.85%	1.88%	1.68%
medcapl	8.07%	7.55%	7.98%
medsall	41.43%	41.47%	51.97%
meditsall	33.20%	32.39%	26.89%
meditcapl	3.20%	3.62%	2.21%
Total	100.00%	100.00%	100.00%

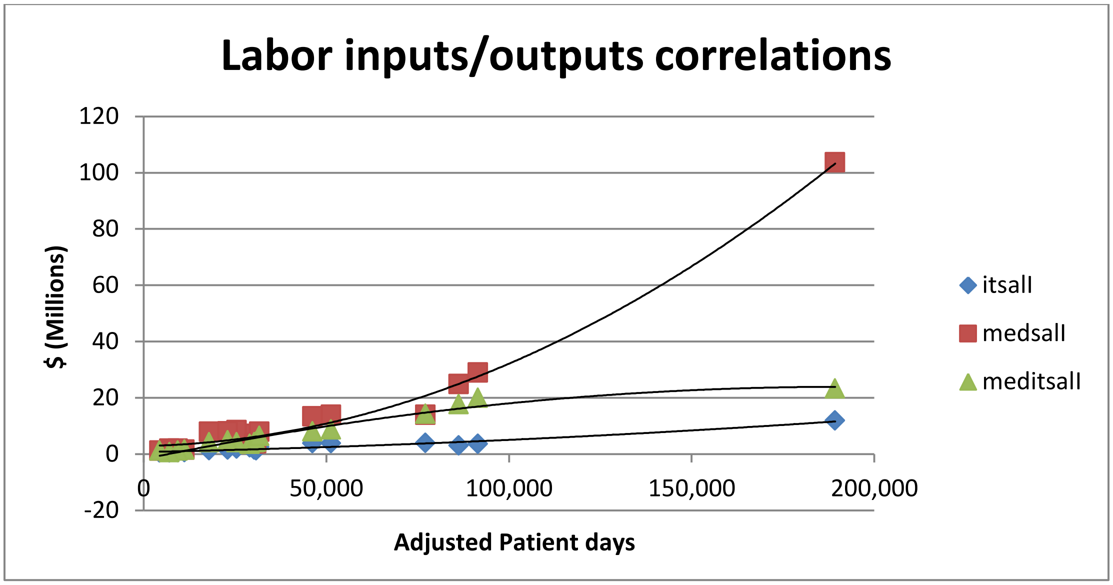


Figure 5: Input/Output scatter plots for labor input factors in MPSS hospitals (years 18-20). MEDsal = $0.0027x^2 + 26.525x + 3E+06$ ($R^2 = 0.9859$), MEDITsal = $-0.0007x^2 + 267.84x - 2E+06$ ($R^2 = 0.9582$), ITSAL = $0.0002x^2 + 27.556x + 718088$ ($R^2 = 0.9276$)

Budget projections

Planning of future budgets in the hospital sector require predictive models. Relying on historical changes in the six input factors over twenty years recorded in the Menon dataset a predictive model of aggregated hospital outputs was constructed using SPSS modeller (**Figure 6).** While this model have a good fit to historical data, as indicated in **Figure 6**, this model have a wide range of future possibilities, as indicated by the upper and lower limits. Better prediction accuracy might be achieved with additional environmental variable such as demography, local income levels, crime levels etc. Alternatively, a quick-and-dirty approach can estimate future expenditures in each input and output category in every hospital by extrapolating trends from the last five years of the Menon data. An excel macro to automate this repetitive task across the entire data panel was written (**Appendix 3**). Expected output and input levels according to the extrapolation Excel model are presented in **Figure 7** and **Figure 8**, respectively.

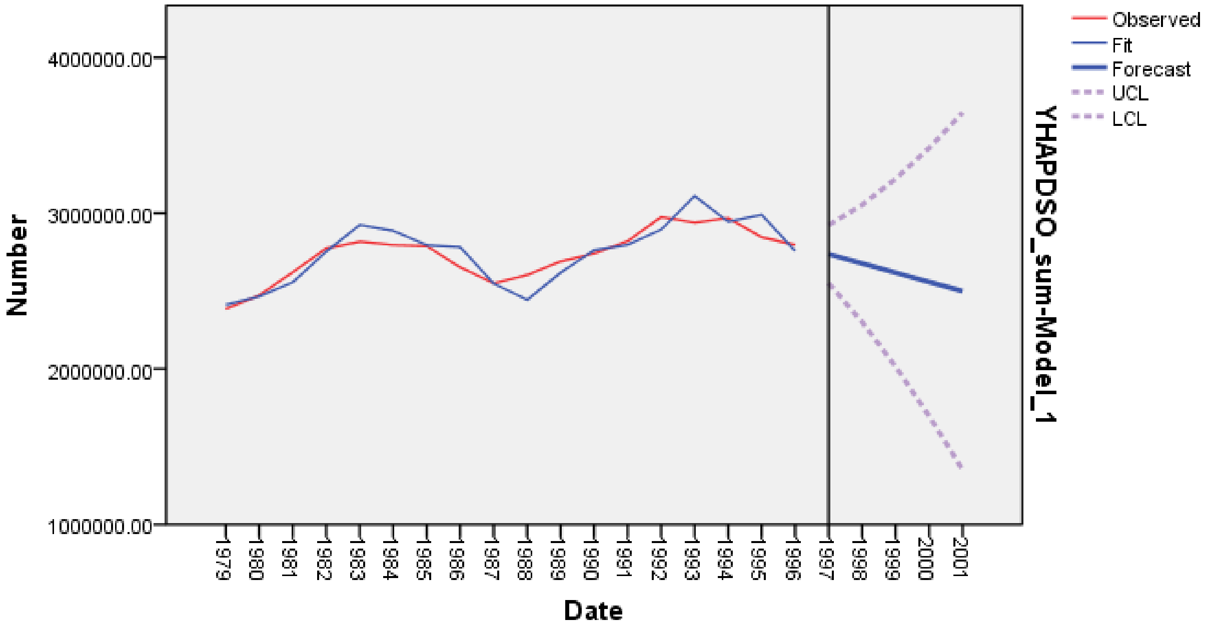


Figure 6: Future projections of hospital capacity using SPSS modeller

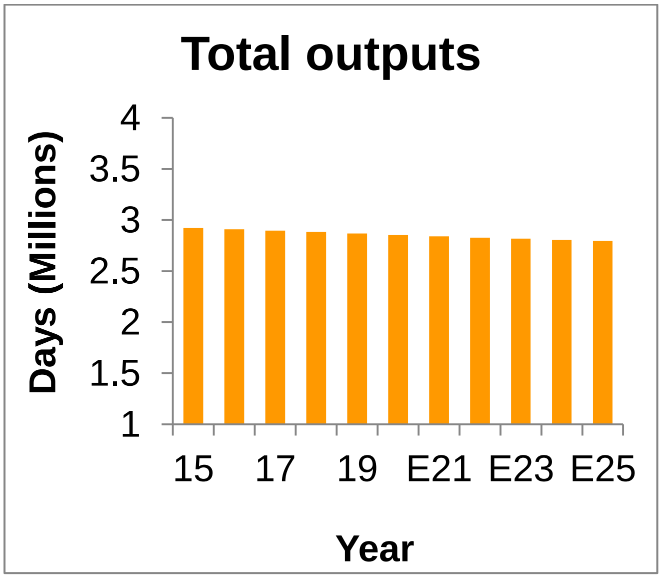


Figure 7: Future projections of hospital capacity using excel.

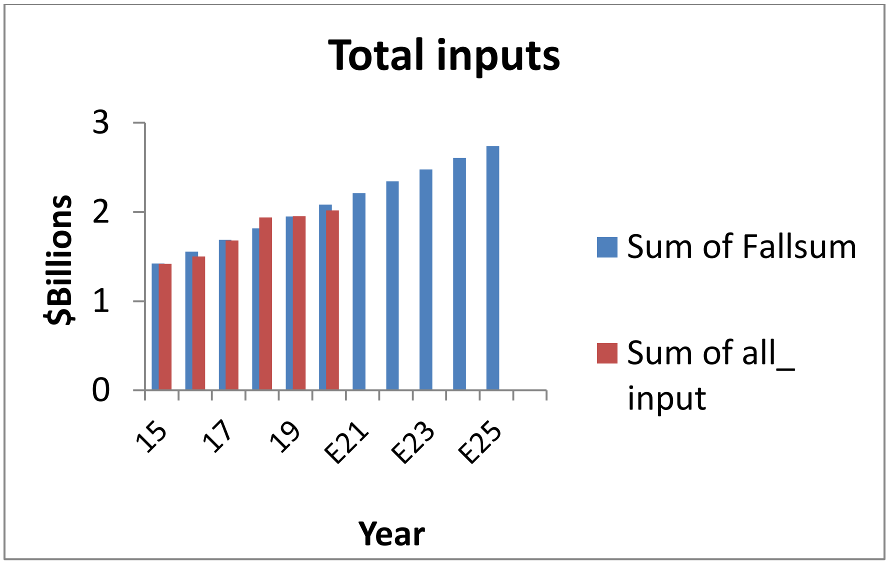


Figure 8: Observed and expected aggregated input factors. Disaggregated input factors are presented in appendix 3.

Conclusions:

Aggregated costs per adjusted patient days have tripled from 1978 to 1996, indicating declining efficiency in public hospitals. However, the precise monetary or economic value of patient day is not easily determined, precluding more accurate analysis at this point. Panel envelope analysis of a representative sample of 46 public hospitals in Washington State indicates that only 12% of hospitals are operating efficiently, while 75% of hospitals are operating at decreasing returns to scale, and 13% operate at increasing returns to scale. DRTS hospitals tend to be larger hospitals with higher budgets, effectively dominating 65% of the annual hospital budget in Washington State. Average input oriented efficiency in DRTS hospitals is only 68%, suggesting that these inefficient hospitals can sustain budgetary cuts of 30% and still maintain their output capacity. Dr. Collins should recommend a 30% cut in the budgets of DRTS hospitals, and no changes in the budgets of efficient MPSS hospitals. IRTS hospitals, controlling only 11% of the annual hospital budget, will explore amalgamation to increase scales of operations were possible. Alternatively, new technology to boost productivity will have to be developed.

References

Menon, N. M., Lee, B., & Eldenburg, L. (2000). Productivity of information systems in the healthcare industry. Information Systems Research, 11(1), 83-92.

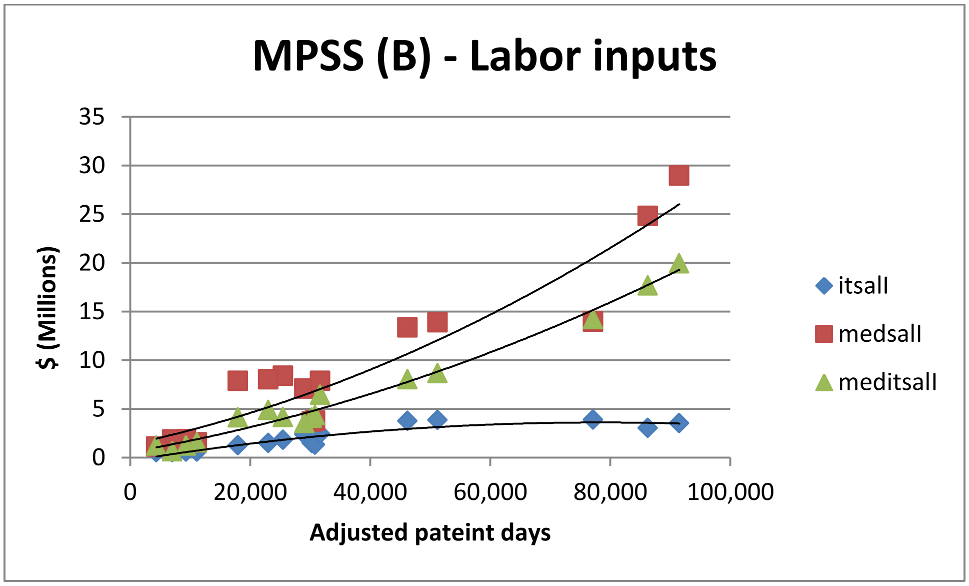
Appendix 1: DRTS hospitals – DEA analysis

DMU	CRS	VRS	NRS	CRS/VRS	NRS/CRS	SE
H102P18	0.7502	1.0113	0.8204	0.741817	1.093575	DRTS
H104P18	0.7250	1.0198	0.7316	0.710924	1.009103	DRTS
H10P18	0.6315	1.0165	0.7348	0.621249	1.163579	DRTS
H126P18	0.6280	1.0149	0.7220	0.61878	1.149682	DRTS
H128P18	0.5740	1.0084	0.7941	0.569219	1.383449	DRTS
H130P18	0.6015	1.0305	0.6814	0.583697	1.132835	DRTS
H131P18	0.5647	1.0308	0.6416	0.547827	1.136179	DRTS
H138P18	0.8776	1	1.0000	0.8776	1.139471	DRTS
H139P18	0.7526	1.0128	0.8388	0.743088	1.114536	DRTS
H145P18	0.6329	1.0219	0.7539	0.619337	1.191183	DRTS
H14P18	0.5024	1.0407	0.5618	0.482752	1.118232	DRTS
H155P18	0.5280	1.0237	0.6220	0.515776	1.17803	DRTS
H159P18	0.5877	1.0279	0.7530	0.571748	1.281266	DRTS
H161P18	0.6092	1.0487	0.6315	0.58091	1.036605	DRTS
H162P18	0.7900	1	1.0000	0.79	1.265823	DRTS
H164P18	0.5722	1.0324	0.6197	0.554243	1.083013	DRTS
H168P18	0.8641	1	1.0000	0.8641	1.157273	DRTS
H171P18	0.7295	1	1.0000	0.7295	1.370802	DRTS
H176P18	0.5668	1.0205	0.7254	0.555414	1.279817	DRTS
H183P18	0.8506	1	1.0000	0.8506	1.175641	DRTS
H191P18	0.7157	1.0348	0.7494	0.691631	1.047087	DRTS
H1P18	0.6457	1	1.0000	0.6457	1.548707	DRTS
H26P18	0.7583	1.0006	0.8898	0.757845	1.173414	DRTS
H27P18	0.6436	1.0104	0.7399	0.636975	1.149627	DRTS
H29P18	0.6623	1	1.0000	0.6623	1.50989	DRTS
H32P18	0.6764	1.0055	0.8842	0.6727	1.307215	DRTS
H38P18	0.7462	1.0199	0.8166	0.73164	1.094345	DRTS
H3P18	0.7149	1	1.0000	0.7149	1.398797	DRTS
H50P18	0.7263	1.0182	0.7561	0.713318	1.04103	DRTS
H58P18	0.8081	1.0056	0.9054	0.8036	1.120406	DRTS
H63P18	0.7306	1.0245	0.7769	0.713128	1.063373	DRTS
H78P18	0.7845	1.0228	0.7975	0.767012	1.016571	DRTS
H81P18	0.8466	1	1.0000	0.8466	1.181195	DRTS
H84P18	0.4983	1.0851	0.5310	0.45922	1.065623	DRTS
H102P19	0.6643	1.0259	0.7376	0.647529	1.110342	DRTS
H10P19	0.6129	1.0258	0.7075	0.597485	1.154348	DRTS
H126P19	0.6558	1.0157	0.7765	0.645663	1.18405	DRTS
H128P19	0.5430	1.0274	0.7153	0.528519	1.317311	DRTS
H130P19	0.5922	1.0325	0.6867	0.573559	1.159574	DRTS
H131P19	0.5198	1.0459	0.5809	0.496988	1.117545	DRTS

H138P19	0.7078	1.0026	0.8823	0.705964	1.246539	DRTS
H139P19	0.7785	1.0078	0.8710	0.772475	1.118818	DRTS
H142P19	0.8418	1.0136	0.8754	0.830505	1.039914	DRTS
H145P19	0.5945	1.0322	0.7075	0.575954	1.190076	DRTS
H146P19	0.9228	1	1.0000	0.9228	1.083658	DRTS
H14P19	0.6150	1.012	0.7053	0.607708	1.146829	DRTS
H155P19	0.5097	1.0263	0.5989	0.496638	1.175005	DRTS
H159P19	0.5488	1.0373	0.6940	0.529066	1.264577	DRTS
H161P19	0.5924	1.0457	0.6147	0.56651	1.037643	DRTS
H162P19	0.6896	1	1.0000	0.6896	1.450116	DRTS
H164P19	0.5641	1.0264	0.6321	0.549591	1.120546	DRTS
H168P19	0.7823	1.0086	0.8629	0.77563	1.10303	DRTS
H171P19	0.6317	1.0126	0.7938	0.62384	1.256609	DRTS
H176P19	0.5535	1.0323	0.6922	0.536181	1.250587	DRTS
H1P19	0.6235	1	1.0000	0.6235	1.603849	DRTS
H26P19	0.7590	1.0003	0.9007	0.758772	1.186693	DRTS
H27P19	0.6384	1.0205	0.7394	0.625576	1.158208	DRTS
H29P19	0.6481	1	1.0000	0.6481	1.542972	DRTS
H32P19	0.6405	1.0024	0.8870	0.638966	1.384856	DRTS
H38P19	0.6926	1.0247	0.7336	0.675905	1.059197	DRTS
H3P19	0.6618	1.0086	0.8550	0.656157	1.291931	DRTS
H50P19	0.6786	1.034	0.6875	0.656286	1.013115	DRTS
H58P19	0.7066	1.0107	0.8138	0.699119	1.151712	DRTS
H81P19	0.7257	1.0106	0.8149	0.718088	1.122916	DRTS
H84P19	0.6290	1.0579	0.6888	0.594574	1.095072	DRTS
H102P20	0.6076	1.0276	0.6792	0.591281	1.117841	DRTS
H126P20	0.6349	1.0224	0.7095	0.62099	1.117499	DRTS
H128P20	0.5380	1.0293	0.7056	0.522685	1.311524	DRTS
H130P20	0.5933	1.0271	0.6975	0.577646	1.175628	DRTS
H131P20	0.5294	1.0559	0.5839	0.501373	1.102947	DRTS
H134P20	0.6569	1.0388	0.6665	0.632364	1.014614	DRTS
H138P20	0.7034	1.0121	0.8577	0.694991	1.219363	DRTS
H139P20	0.7853	1.0029	0.9033	0.783029	1.150261	DRTS
H142P20	0.7589	1.0142	0.8771	0.748275	1.155752	DRTS
H145P20	0.5647	1.0608	0.6102	0.532334	1.080574	DRTS
H146P20	0.8896	1	1.0000	0.8896	1.124101	DRTS
H14P20	0.4342	1.0738	0.4713	0.404358	1.085444	DRTS
H155P20	0.4984	1.0263	0.5754	0.485628	1.154494	DRTS
H159P20	0.4996	1.0524	0.6052	0.474724	1.211369	DRTS
H161P20	0.6143	1.0345	0.6431	0.593813	1.046883	DRTS
H162P20	0.7046	1	1.0000	0.7046	1.419245	DRTS
H164P20	0.5041	1.052	0.5618	0.479183	1.114461	DRTS
H168P20	0.7081	1.0251	0.7767	0.690762	1.096879	DRTS
H171P20	0.6597	1.006	0.8669	0.655765	1.314082	DRTS
H176P20	0.6148	1.0054	0.7870	0.611498	1.280091	DRTS

H183P20	0.7347	1.0081	0.7505	0.728797	1.021505	DRTS
H191P20	0.9217	1.0014	0.9350	0.920411	1.01443	DRTS
H1P20	0.5925	1.0082	0.8677	0.587681	1.464473	DRTS
H26P20	0.8235	1	1.0000	0.8235	1.214329	DRTS
H27P20	0.5877	1.0322	0.6802	0.569366	1.157393	DRTS
H29P20	0.6456	1.0016	0.8793	0.644569	1.361989	DRTS
H32P20	0.5806	1.0144	0.7457	0.572358	1.284361	DRTS
H37P20	0.9340	1.0031	0.9512	0.931114	1.018415	DRTS
H38P20	0.6735	1.0453	0.6751	0.644313	1.002376	DRTS
H3P20	0.6379	1.0197	0.8123	0.625576	1.273397	DRTS
H58P20	0.6538	1.0201	0.7437	0.640918	1.137504	DRTS
H63P20	0.6247	1.0588	0.6365	0.590008	1.018889	DRTS
H73P20	0.6402	1.0397	0.7112	0.615755	1.110903	DRTS
H81P20	0.7745	1.0074	0.8750	0.768811	1.129761	DRTS
H84P20	0.5171	1.091	0.5368	0.473969	1.038097	DRTS

Appendix 2: Modelling the relations of labor factors to outputs (one outlier removed).



medsal = $0.0015x^2 + 131.74x + 1E{+}06$ ($R^2 = 0.8786$)

meditsal = $0.0011x^2 + 106.18x + 555397$ ($R^2 = 0.9813$)

itsal = $-0.0006x^2 + 100.07x - 329700$ ($R^2 = 0.8451$)

Appendix 3: The extrapolation model of future budgets

```
For i = 2 To 497 Step 11

Range("P" & i).Activate

Range(ActiveCell, ActiveCell.Offset(10, 0)).Select

Selection.DataSeries Rowcol:=xlColumns, Type:=xlLinear, Date:=xlDay, _

Trend:=True

Next i
```

Note: “P” is the destination column containing expenditure data in the years 15 to 20, after sorting for hospital id so that each hospital data is sub-sorted by year from 15 to 25. The simple macro is using an excel function to compute a trend from existing data and extrapolate for the next 5 years.