Resource Allocation within Academic Units: DEA and Goal Programming Approach with an Application to an Arabian Gulf University

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Abstract

This research focuses on developing a methodology for possible salary adjustments to attract and retain quality faculty at a national university in the Arabian Gulf area. These adjustments are to be allocated with a specially sanctioned budget. We address two closely related issues: market adjustment based on market demand for business Ph.D.'s and merit adjustment based on faculty members' performance levels in the areas of teaching, research and service, and we propose a methodology that addresses the former through *goal programming* and the latter through *data envelopment analysis*. Finally, with a small set of real data we demonstrate how this approach works.

1. Introduction

In this paper, we address two issues related to attracting quality faculty members from the 'western academic labor market' to the business school of a state-run Arabian Gulf university. Being the only university in the country that provides free higher education to nationals where the faculty is largely composed of foreign academicians, it has become clear to the administration that in order to lure Ph.D.'s in business disciplines, the university should introduce a salary structure based on market demand and merit factors.

A bulk of research work appeared in the literature, where issues such as *compression* and *inversion* are discussed at length (Gomez-Mejia and Balkin, 1987). In our model we check on both issues. But, we picked Sun (2002) as the most relevant to our work, where a multiple-objective programming model is proposed for annual salary adjustment. But the situation discussed there and the model is significantly different from ours. Moreover, a major distinction between Sun (2002) and ours is that we treat market and merit adjustments separately, whereas in Sun's they are treated together.

This research has involved in developing two models: one for market adjustment and the other for merit adjustment. The market adjustment is handled through *goal programming* (Schniederjans 1995). The merit adjustment is handled primarily through *data envelopment analysis* (Cooper et al. 1999). The models developed in this paper, although specific to our unique situation, can be extended to other situations where adjustments to salaries are necessary to retain and hire high quality work force.

2. Methodology

As we said above, there are two components in our model. The first that deals with market adjustment is rather simple. We need a *salary norm* by rank and discipline and the data on our compensation structure. The norm is available from information on 9-month salaries published by organizations such as AACSB. The local data are available to us and do not need any adjustment. We choose to work with monthly salaries.

First we define,

r = rank index (1=assistant professor; 2=associate professor; 3=full professor)

I(r) = set of indexes of faculty members in rank r

d = discipline index (1=accounting, 2=economics, and so on)

$NORM_{rd}$ = salary norm for an average faculty member at rank r in discipline d

$BSAL_{ir}$ = base salary for faculty member i at rank r

ALW = university allowance as a % of $BSAL_r$ (7.5%)

$NYRS_i$ = number of service years of faculty member i in current rank

MAXYRS = maximum number of years in a rank (7 years)

NC = annual increment as a % of $BSAL_r$ (5%)

$MKAD_{rd}$ = market adjustment for rank r and discipline d as a % of $BSAL_r$
$MEAD_{ird}$ = merit adjustment for faculty member i of rank r in discipline d as a multiple of $NC*BSAL_r$

Next, we define;
D^+_{rd} = positive deviation between salary norm and avg. adjusted salary for r and d
D^-_{rd} = negative deviation between salary norm and avg. adjusted salary for r and d
α_{rd} = weighting factor for D^-_{rd} that reflects the relative importance of ranks within a discipline
$AVGD^-_d$ = weighted average of negative deviation for d = $\sum_r \Sigma_i \alpha_{ird} D^-_{ird}$
BGT = budget for market adjustment

We now describe the goal program (GP) with the objective being to minimize $AVGD^-$ subject to the budget and certain policy restrictions on the salary structure.

$$\text{Min} \quad \sum_d \sum_r \Sigma_i \alpha_{ird} D^-_{ird}$$

$$\text{st} \quad D^+_{ird} - D^-_{ird} - BSAL_{ir}(1 + ALW + NYRS_i*NC + MKAD_{ird} + MEAD_{ird}*NC) + NORM_{ird} = 0$$

$$\text{for all i in I(r), r and d} \qquad (1)$$

$$BSAL_{ir}(1+ ALW + 7*NC + MKAD_{ird}) - BSAL_{i(r+1)}(1+ ALW + MKAD_{i(r+1)d}) \leq 0$$

$$\text{for r=1,2 and all i in I(r) and d} \qquad (2)$$

$$\sum_d \sum_r \Sigma_i \ MKAD_{ird}*BSAL_{ir} \leq BGT \qquad (3)$$

$$MKAD_{ird}, D^+_{ird}, D^-_{ird} \qquad \text{for all i in I(r), r and d} \qquad (4)$$

We address the question of merit adjustment using data envelopment analysis (DEA) that yields faculty efficiency scores. Data are collected on faculty performance in the areas of teaching, research and service as outputs, and the incentives provided as inputs. In total, we have 4 inputs and 7 outputs. These data are standardized (see Tab. 1). We also include an idealized reference for each rank and discipline. This reference is a hypothetical entity that receives average incentives and whose performance warrants an average merit adjustment. This entity is much like the average faculty member in GP in terms of the incentives (input); its performance (output) is determined based on university guidelines and the expectations of the discipline.
Let a= area index (1=teaching; 2=research; 3=service)
d = discipline index
i = index of faculty member
i^*_{rd} = index of the idealized reference for r and d
j = index of input
k = index of output
X_{idja} = standardized j-th input in area a for faculty member i in discipline d
Y_{idka} = standardized k-th output in area a for faculty member i in discipline d
U_{ja} = weight for the j-th input in area a
V_{ka} = weight for the k-th output in area a

In our DEA model, common inputs include years of experience, salary, benefits, and general support (including library and computing) etc. Teaching output contains teaching load, versatility, student evaluation of teaching, etc. Research output highlights last 5-year and career publications (journal articles, books/monographs, conference proceedings, etc.). Service output reflects administrative/committee work, student supervision, consulting/project work, etc.

The DEA model that we present here is a variation of the original CCR model (Charnes et al. 1978) and is called CCR - Archimedean (Thompson et al. 1993, 1996). The following linear program is solved for each faculty member i in discipline d. Only the faculty members from discipline d along with the associated idealized references for each rank r in that discipline d are included and each area a is considered one at a time.

$$\text{Max} \quad \sum_k Y_{idka} V_{ka}$$

$$\text{st} \quad \sum_k Y_{i'dka} V_{ka} - \sum_j X_{i'dja} U_{ja} \le 0 \quad \text{for all i in d (including } i^*_{rd}) \tag{6}$$

$$\sum_j X_{idja} U_{ja} = 1 \tag{7}$$

$$U_{ja} \ge 0 \quad \text{for all j in a} \tag{8}$$

$$V_{ka} \ge 0 \quad \text{for all k in a} \tag{9}$$

Solution of the above LP yields the DEA efficiency score θ_{ida} with respect to area a for faculty member i in discipline d.

Once the DEA score θ_{ida} is obtained, the composite DEA score θ^c_{id} for faculty member i in discipline d is assumed to follow a uniform distribution over [0,1], and $\theta^c_{id} = \Sigma_a\, \delta_{da}\, \theta_{ida}$, where δ_{da} is the relative weight discipline d attaches to area a. Thus, $\theta^c_{id} = U(\theta^c_{id})$, where $U(\bullet)$ is the cumulative distribution function of uniform [0,1] random variable. Here we follow (40%, 40%, 20%) weight structure for teaching, research, and service. Finally, the merit adjustment for faculty i in discipline d is given by, $MEAD_{id} = \theta^c_{id} + \max\ \{0, \theta^{c\,*}_{i\ d} - \theta^c_{id}\}$, where $\theta^{c\,*}_{i\ d}$ is the DEA composite score of the idealized faculty reference in the respective rank. This measure shows that a faculty member who is more efficient (in DEA sense) than the corresponding idealized reference collects an increment over the idealized reference and his own composite score. On the other hand, one who is less efficient collects only one's own composite score.

Now, we can put all pieces together. From GP, we get the market adjustment $MKAD_{I(r)d}$ for each rank r in any discipline d. From DEA and the subsequent manipulations, we get the merit adjustment $MEAD_{i(r)d}$ for a faculty member i at rank r in discipline d. Letting $NYRS_{i(r)d}$ be i's number of years in rank r, we compute i's adjusted salary AJS_{id} as follows:

$$AJSAL_{id} = BSAL_r + ALW{*}BSAL_r + NYRS_{ird}{*}NC{*}BSAL_r + MKAD_{ird}{*}BSAL_r + MEAD_{ird}{*}NC{*}BSAL_r \tag{10}$$

3. Results

We performed the analysis with salary and performance data available on the business school faculty in one specific discipline. So, in our analysis, d = 1. To maintain confidentiality, all data are being standardized. Our group has 5 assistant professors, 1 associate professor and 2 full professors. All have joined the university at the base salary level. The numbers of years in the rank vary from 1 to 7. We need their personal salary data just for DEA computation, and they are presented in Table 1. The table also contains data on the idealized references for each rank. In our notation, I(1) = {4, 5, 6, 7, 8}, I(2) = {3}, I(3) = {1, 2}

Table 2 presents the DEA scores for each faculty member in the areas of teaching, research and service. It goes on to show the computation of composite DEA scores based on (0.4, 0.4, 0.2) distribution and finally the merit adjustment factor MEAD.

We used LINDO to run the GP model and compute market adjustments $MKAD_{ir}$. Then, using (10), we compute adjusted salary, AJSAL, for each faculty member. See table 3.

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Table 1. Standardized input/output data

		Years Experience	Salary	Benefits	Support	Teaching Load	Versatility	Teaching Evaluation	5 Years Research	Career Research	Consulting	Administration
MEMBER	RANK	X1	X2	X3	X4	Y1	Y2	Y3	Y4	Y5	Y6	Y7
1	Full	2.313016	5.957298	3.31664	3.609196	2.102873	4.285316	6.633279	3.432019	1.66575	2.037386	3.609196
2	Full	3.945734	6.156705	3.31664	3.609196	3.154309	4.285316	4.974959	1.872011	3.429485	2.037386	2.406131
3	Assoc	1.496658	4.337112	2.211093	1.203065	4.205745	2.856878	6.633279	2.340013	0.832875	1.018693	1.203065
4	Asst	1.088478	4.137705	1.105547	3.609196	1.051436	1.428439	8.291599	0.468003	0.146978	2.037386	3.609196
5	Asst	1.632717	4.013075	1.105547	1.203065	4.205745	2.856878	6.633279	0	0.048993	1.018693	2.406131
6	Asst	1.224538	3.763816	1.105547	2.406131	4.205745	2.856878	8.291599	0.312002	0.097985	3.056079	1.203065
7	Asst	0.952419	3.639186	1.105547	3.609196	4.205745	4.285316	8.291599	2.028012	0.636904	3.056079	2.406131
8	Asst	0.408179	3.514556	1.105547	1.203065	3.680027	1.428439	6.633279	1.092006	0.146978	0	1.203065
9	Full-Ref	1.700747	5.857594	3.31664	2.406131	3.154309	2.856878	6.633279	1.560009	0.73489	3.056079	3.609196
10	Assoc-Ref	1.020448	4.561446	2.211093	2.406131	3.154309	2.856878	6.633279	1.560009	0.489926	2.037386	2.406131
11	Asst-Ref	0.340149	3.701501	1.105547	2.406131	3.154309	2.856878	6.633279	0.936005	0.244963	1.018693	1.203065

Table2. DEA (CCR) Efficiency Scores and Merit Adjustment

Member	RANK	Teaching	Research	Service	Score	Difference	MEAD
1	Full	0.7837	1	0.8193	0.87734	0.15802	1.03536
2	Full	0.7694	1	0.5837	0.8245	0.10518	0.92968
3	Assoc	1	1	0.6667	0.93334	0.09966	1.033
4	Asst	1	0.2308	1	0.69232	-0.30768	0.69232
5	Asst	1	0.0429	1	0.61716	-0.38284	0.61716
6	Asst	1	0.1852	1	0.67408	-0.32592	0.67408
7	Asst	1	1	1	1	0	1
8	Asst	1	1	0.9556	0.99112	-0.00888	0.98224
9	Full-Ref	0.6766	0.6217	1	0.71932		
10	Assoc-Ref	0.8211	0.7894	0.9474	0.83368		
11	Asst-Ref	1	1	1	1		

NOTE: Difference = $\theta^{c^*}_{i\,d} - \theta^{c}_{id}$

Table 3. Market Adjustments and Adjusted Salaries

Member	RANK	BSAL	NYRS	MKAD	MEAD	AJSAL
1	Full	1770	4	0.1513	1.03536	2616.18
2	Full	1770	5	0.1513	0.92968	2695.328
3	Assoc	1330	1	0.2073	1.033	1840.654
4	Asst	1030	2	0.2308	0.69232	1483.628
5	Asst	1030	3	0.2308	0.61716	1531.258
6	Asst	1030	4	0.2308	0.67408	1585.689
7	Asst	1030	5	0.2308	1	1653.974
8	Asst	1030	6	0.2308	0.98224	1704.559