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Resource allocation within academic units

DEA and goal programming approach with an application to an Arabian Gulf university

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Abstract

Purpose – To develop a methodology for faculty salary adjustment through market adjustment based on market demand for business PhDs and merit adjustment based on faculty members' performance levels in the areas of teaching, research and service.

Design/methodology/approach – The methodology is composed of two models: one for market adjustment and the other for merit adjustment. The market adjustment is handled through goal programming and the merit adjustment through data envelopment analysis (DEA).

Findings – The approach when applied to a sample of faculty salaries shows that the adjusted salary of each faculty member is higher than his/her current actual salary, and each faculty member in the particular discipline deserves a salary increase that reflects market demand and merit factors.

Research limitations/implications – The DEA model used in this research does not impose restrictions on the weights. Realistically, one may impose bounds on the weights and exclude unreasonable solutions from DEA analysis and also set multiple goals instead of the single goal used in the goal programming model.

Practical implications – Based on a goal programming model that addresses the market demand and a DEA model that addresses the merit-based performances, this methodology may be implemented as a solution procedure for restructuring faculty salaries.

Originality/value – The novelty in this approach is that DEA is being used as a benchmarking technique for merit adjustment of faculty salaries. In that sense, this research work may be the first, where benchmarking has been used in "faculty salary equity adjustment."

Keywords Pay, Data analysis, Benchmarking, Academic staff, Arabian Peninsula

Paper type Research paper

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 difficult for the administration to lure PhDs in business disciplines. In view of this situation, the administration has authorized the adoption of a "rarity allowance" to

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holders of business PhDs. This allowance has been computed as, 15 percent of base salary to assistant professors, 10 percent of base salary to associate professors and 5 percent of base salary to full professors. In spite of this allowance, the dean of the business school has still found difficult to recruit quality business PhDs, especially from the western academic labor market. This suggests that the university should introduce a more structured salary revision based on market demand and merit factors to reflect the realistic situation when attracting from the much lucrative western academic labor market. Any adjustment to the current salaries would have to come from a specially sanctioned budget. Our research aims are focused on equity adjustment of faculty salaries by formulating two models; one that addresses the market demand through goal programming, and the other that addresses the merit factors through data envelopment analysis (DEA) with a view to benchmarking, within budgetary constraints and university guidelines on faculty ranks.

The rest of the paper is organized as follows. In Section 2, we review the past literature on "faculty salary equity adjustment" and "DEA as a benchmarking tool." In Section 3, we propose our methodology and include the formulation of models. In Section 4, we discuss the computational results of the application to empirical data. Finally, in Section 5, we present the summary and conclusion.

2. Literature review

A majority of research publications on "faculty salary equity adjustment" that has appeared in the literature has used regression (correlation) analysis under the framework of linear models to predict the adjusted salaries. Most notable among them are, Snyder *et al.* (1994), Weiler (1990), Becker and Toutkoushian (1995), Brown and Woodbury (1998), Toutkoushian (1994), Gander (1997), Lillydahl and Singell (1992), Gomez-Mejia and Balkin (1992) and Yeh *et al.* (1998). All these articles have made a significant contribution to the subject, but the models applied were based on rigid assumptions on parameter estimation known from theory of linear models. In contrast, our approach is based on two non-parametric mathematical programming models that are free of assumptions. The most relevant to our work is Sun (2002), 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 us is that we treat market and merit adjustments separately, whereas in Sun's they are treated together.

2.1 DEA in benchmarking

A multitude of articles has appeared in the literature over the past ten years that uses DEA as a popular benchmarking tool. Homburg (2001) who uses DEA for "activity-based management" identifies pros and cons of DEA as being applied to benchmarking activities. Ross and Droge (2002) while using DEA in an integrated benchmarking framework in "supply chain management" state, "... DEA methodology has proved to be powerful for benchmarking and identifying efficient frontiers ..." Adler *et al.* (2002) in doing a complete review of "ranking methods in DEA context," discuss a two-stage procedure where DEA is used to identify efficient units as a benchmark for inefficient units. Post and Spronk (1999) present a performance measurement technique that combines DEA and interactive multiple goal programming and call it "a decision support tool to select performance benchmarks

that are both feasible and desirable." Donthu *et al.* (2004) while using DEA for benchmarking "marketing productivity" state, "We use DEA to identify benchmarks (role models) and set goals for improvement. These represent two very important steps of benchmarking." Soteriou and Stavrinides (1997) and Soteriou and Zenios (1999) have proposed DEA as a technique for benchmarking of "service delivery system characteristics of bank branches." Manandhar and Tang (2002) present a framework for simultaneous benchmarking of "performance of bank branches" using a modified DEA formulation. Cook *et al.* (2004) propose DEA-based benchmarking models by extending the standard DEA method, with an application to e-business.

3. Methodology

As stated above, our methodology has evolved by developing two models: one for market adjustment and the other for merit adjustment. The market adjustment is handled through goal programming (Schniederjans, 1995), and the merit adjustment is handled primarily through DEA (Cooper *et al.*, 1999). The novelty in our approach is that we use DEA as a best-practice benchmarking technique for merit adjustment of faculty salaries. In that sense, our paper may be the first, where DEA has been used in "faculty salary equity adjustment." 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 hire and retain high quality work force.

We need a salary norm by rank and discipline and the data on our salary structure. The norm is available from information on nine-month salaries published by organizations such as AACSB. The current faculty salaries (monthly) are available to us from the institution without any adjustment.

3.1 Formulation of models

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 percentage of BSAL_r (7.5 percent)
NYRS_i	number of service years of faculty member i in current rank
MAXY	maximum number of years in a rank (seven years)
NCR	annual increment as a percentage of BSAL_r (5 percent)
MKAD_{rd}	market adjustment for rank r and discipline d as a percentage of BSAL_r
MEAD_{ird}	merit adjustment for faculty member i of rank r in discipline d as a multiple of NCR $\times$ BSAL_r

Next, we define:

D^{+}_{ird}	positive deviation between salary norm and adjusted salary for *i, r* and $d = \max\{0, \text{AJSAL}_{ird} - \text{NORM}_{ird}\}$
D^{-}_{ird}	negative deviation between salary norm and adjusted salary for *i, r* and $d = \max\{\text{NORM}_{ird} - \text{AJSAL}_{ird}, 0\}$
NEGD^{-}_{d}	negative deviation for $d = \sum_r \sum_i D^{-}_{ird}$
BGT	budget for market adjustment

We now describe the goal program (GP) with the objective being to minimize the total negative deviations (avoid underachievement of the goal), subject to the budget and certain policy guidelines on faculty ranks and salary structure:

$$\text{Min} \sum_d \sum_r \sum_i D^{-}_{ird}$$

$$\text{s.t. } D^{+}_{ird} - D^{-}_{ird} = \text{BSAL}_{ir}(1 + \text{ALW} + \text{NYRS}_i \times \text{NCR} + \text{MKAD}_{ird} + \text{MEAD}_{ird} \times \text{NCR}) - \text{NORM}_{ird} \quad \text{for all } i \text{ in } I(r),\ r \text{ and } d \tag{1}$$

$$\text{BSAL}_{ir}(1 + \text{ALW} + 7 \times \text{NCR} + \text{MKAD}_{ird}) \leq \text{BSAL}_{i(r+1)}(1 + \text{ALW} + \text{MKAD}_{i(r+1)d}) \quad \text{for } r = 1, 2 \text{ and all } i \text{ in } I(r) \text{ and } d \tag{2}$$

$$\sum_d \sum_r \sum_i \text{MKAD}_{ird} \times \text{BSAL}_{ir} \leq \text{BGT} \tag{3}$$

$$\text{MKAD}_{ird}, D^{+}_{ird}, D^{-}_{ird} \geq 0 \quad \text{for all } i \text{ in } I(r),\ r \text{ and } d \tag{4}$$

Here, constraint (1) shows the goal to achieve, which is adjusted salary is at least equal the salary norm. Constraint (2) says that after seven years (with seven increments) in rank *r, a* faculty member's total salary is not more than his total salary in the next rank $r + 1$.

Constraint (3) says that the total market adjustments based on basic salary are within the allocated budget.

We address the issue of merit adjustment using 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 four inputs and seven outputs. These data are being standardized. We also include a "benchmark reference" for each rank and discipline. This reference is a hypothetical faculty member that receives average incentives, whose performance is viewed from a benchmarking perspective and judged on the basis of university guidelines and the expectations of the discipline. Each faculty member's performance is measured relative to that of the benchmark reference in the same rank and same discipline.

Let a, area index (1 = teaching; 2 = research; 3 = service); d, discipline index; i, index of faculty member; i^*_{rd}, index of the benchmark reference for r and d; j, index of input; k, index of output; X_{idja}, standardized jth input in area a for faculty member i in discipline d; Y_{idka}, standardized kth output in area a for faculty member i in discipline d; U_{ja}, weight for the jth input in area a; V_{ka}, weight for the kth 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, conference proceedings, etc.). Service output reflects administrative 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 corresponding benchmark references for each rank r in that discipline d are included and each area a is considered one at a time:

$$\text{Max} \sum\nolimits_k Y_{idka} V_{ka}$$

$$\text{s.t.} \sum\nolimits_k Y_{i'dka} V_{ka} - \sum\nolimits_j X_{i'dja} U_{ja} \leq 0 \quad \text{for all } i \text{ in } d \text{ (including } i^*_{rd}) \tag{5}$$

$$\sum\nolimits_j X_{idja} U_{ja} = 1 \tag{6}$$

$$U_{ja} \geq 0 \quad \text{for all } j \text{ in } a \tag{7}$$

$$V_{ka} \geq 0 \quad \text{for all } k \text{ in } a \tag{8}$$

Solution of the above LP yields the DEA efficiency score $\theta_{i(r)da}$ with respect to area a for faculty member i of rank r in discipline d.

Once the DEA score $\theta_{i(r)da}$ is obtained, the composite DEA score $\theta^c_{i(r)d}$ for faculty member i of rank r in discipline d is computed as a weighted average; $\theta^c_{i(r)d} = \sum_a \delta_{da} \theta_{i(r)da}$, where δ_{da} is the relative weight discipline d attaches to area a. Here, we follow (40, 40, 20 percent) weight structure for teaching, research, and service. Finally, the merit adjustment for faculty i of rank r in discipline d is given by:

$$\text{MEAD}_{i(r)d} = \theta^c_{i(r)d} + \max\{0, \theta^c_{i(r)d} - \theta^c_{i^*(r)d}\} \tag{9}$$

Here, $\theta^c_{i^*(r)d}$ is the DEA composite score of the benchmark reference in the respective rank. This measure shows that a faculty member who is more efficient (in DEA sense) than the corresponding benchmark reference collects an increment over the benchmark reference and his own composite score. On the other hand, one who is less efficient than the benchmark reference collects only one's own composite score.

Now, we can put all pieces together. From GP, we get the market adjustment $\text{MKAD}_{i(r)d}$, and from DEA we get the merit adjustment $\text{MEAD}_{i(r)d}$ for each 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 $AJSAL_{i(r)d}$ as follows:

$$AJSAL_{i(r)d} = BSAL_r + ALW \times BSAL_r + NYRS_{i(r)d} \times NCR \times BSAL_r + MKAD_{i(r)d} \times BSAL_r + MEAD_{i(r)d} \times NCR \times BSAL_r \quad (10)$$

4. Computational results

We applied the above-formulated models on salary and performance data available for the business school faculty in one specific discipline. So, in our analysis, $d = 1$. On the one hand, to maintain confidentiality, and on the other hand to make all inputs and outputs unit-less in the DEA model, all personal salary data are being standardized. They are presented in Table I.

Our group has five assistant professors, one associate professor and two full professors. All have joined the university at the base salary level. The numbers of years in the rank vary from 1 to 7. The table also contains data on the benchmark reference for each rank 1, 2, and 3 (Asst-Ref, Assoc-Ref, and Full-Ref). In our notation, $I(1) = \{4, 5, 6, 7, 8\}$, $I(2) = \{3\}$, $I(3) = \{1, 2\}$

We used MATLAB to compute DEA scores and Table II 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 adjustments MEAD.

We used LINDO to run the GP model and compute market adjustments MKAD. Then, using equation (10), we compute adjusted salary (AJSAL) for each faculty member in this discipline. The results are shown in Table III.

5. Summary and conclusion

In this paper, we present a methodology for "faculty salary equity adjustment" that incorporates market demand for quality PhDs and merit-based performances of hired faculty members. Based on a goal programming model that addresses the market demand and a DEA model that addresses the merit-based performances in three areas relative to those of hypothetical benchmarks, this methodology may be implemented as a solution procedure for restructuring faculty salaries in order to attract high quality PhDs from the western academic labor market.

We illustrate how this methodology works for a sample of faculty salaries. Table III shows the adjusted salary after taking into account the market and merit adjustments. With these adjustments, we notice that the adjusted salary of each faculty member is higher than his/her current actual salary, and each faculty member in the particular discipline deserves a salary increase that reflects market demand and merit factors.

As for future research, one may want to impose bounds on the weights in the DEA model to restrict the solutions, and another may want to set multiple goals in addition to constraint (1) in the GP model that reflect specific university guidelines and requirements on faculty ranks and services. Both these issues may need additional data and pave the way to a broader discussion on the subject.

Table I. Standardized input/output data

Member	Rank	Years of experience	Salary	Benefits	Support	Teaching load	Versatility	Teaching evaluation	5 Years research	Total research	Consulting	Admin service
1	Full	2.3130164	5.957298	3.31664	3.609196	2.102873	4.285316	6.633279	3.432019	1.66575	2.037386	3.609196
2	Full	3.9457339	6.156705	3.31664	3.609196	3.154309	4.285316	4.974959	1.872011	3.429485	2.037386	2.406131
3	Assoc.	1.4966577	4.337112	2.211093	1.203065	4.205745	2.856878	6.633279	2.340013	0.832875	1.018693	1.203065
4	Asst.	1.0884783	4.137705	1.105547	3.609196	1.051436	1.428439	8.291599	0.468003	0.146978	2.037386	3.609196
5	Asst.	1.6327175	4.013075	1.105547	1.203065	4.205745	2.856878	6.633279	0	0.048993	1.018693	2.406131
6	Asst.	1.2245381	3.763816	1.105547	2.406131	4.205745	2.856878	8.291599	0.312002	0.097985	3.056079	1.203065
7	Asst.	0.9524185	3.639186	1.105547	3.609196	4.205745	4.285316	8.291599	2.028012	0.636904	3.056079	2.406131
8	Asst.	0.4081794	3.514556	1.105547	1.203065	3.680027	1.428439	6.633279	1.092006	0.146978	0	1.203065
9	Full-Ref.	1.7007474	5.857594	3.31664	2.406131	3.154309	2.856878	6.633279	1.560009	0.73489	3.056079	3.609196
10	Assoc-Ref.	1.0204484	4.561446	2.211093	2.406131	3.154309	2.856878	6.633279	1.560009	0.489926	2.037386	2.406131
11	Asst-Ref.	0.3401495	3.701501	1.105547	2.406131	3.154309	2.856878	6.633279	0.936005	0.244963	1.018693	1.203065

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 $= \theta^{c}_{i(r)d} - \theta^{c}_{i^{*}(r)d}$

Table II.
DEA (CCR) efficiency scores and merit adjustment

Member	Rank	BSAL	NYRS	MKAD	MEAD	AJSAL
1	Full	1,770	4	0.1513	1.03536	2,616.18
2	Full	1,770	5	0.1513	0.92968	2,695.328
3	Assoc.	1,330	1	0.2073	1.033	1,840.654
4	Asst.	1,030	2	0.2308	0.69232	1,483.628
5	Asst.	1,030	3	0.2308	0.61716	1,531.258
6	Asst.	1,030	4	0.2308	0.67408	1,585.689
7	Asst.	1,030	5	0.2308	1	1,653.974
8	Asst.	1,030	6	0.2308	0.98224	1,704.559

Table III.
Market adjustments and adjusted salaries

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