ASSESSING THE COST-EFFECTIVENESS OF UNIVERSITY ACADEMIC RECRUITMENT AND PROMOTION POLICIES

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ABSTRACT

This paper develops an approach for higher education institutions to assess the economic efficiency of their recruitment and promotion practices concerning academic staff. Research output potential is a key criterion in most academic appointments. Generally, there is a long lead time between the conduct of research and its ultimate value in the form of disseminated knowledge. This means higher education institutions usually reward financially staff on the prospect of research output, albeit on the basis of research outputs achieved up to the point of recruitment or discretionary salary rise (e.g. through promotion). We propose a Data Envelopment Analysis (DEA) model which can be used retrospectively to set salary costs against corresponding research outputs achieved as a measure of the financial efficacy of past recruitment and promotion practices. The analysis can identify potential issues with those practices and lead to improvements for the future.

Key words: Data Envelopment Analysis, Academic Promotions, Academic Recruitment, Cost Efficiency

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1. Introduction

University academic staff are typically expected to make contributions in four broad areas: Teaching, Research, administration and 'outreach'. The first three are self-explanatory. Outreach is externally facing in the form of engagement in local or national governance, consultancy or service to the community, or a combination thereof. The remuneration of academic staff typically covers all but outreach activities and it represents a cost for their University. In general, there is considerable lead time between the conduct of research and corresponding measurable outcomes being observed. For academic research, ultimate value is gained via its dissemination and use. Yet it can take considerable time between the generation and the dissemination and/or use of the research outcomes. Firstly, the research itself may take months or even years before it becomes a self-contained, publishable in principle, unit ready for submission to be assessed. The assessment, normally by peer review, could lead to one or more iterations for revision and re-assessment before the research is ultimately accepted and later put in the public domain. Use of that research can then take still further time, possibly years after the research has been published. Thus, in practice there is normally considerable time lag between the research work of an academic and the corresponding outcomes being observed. Therefore, when it comes to research, institutions pay an academic in advance**,** on the prospect of research output, albeit the prospect itself would normally be based on prior research carried out by an academic. This is especially so when an academic is recruited to a post and to that date he/she has not contributed to research within the recruiting institution. Payment on the prospect of research output also occurs when an academic is promoted primarily on his/her research outputs to the point of promotion.

It is true that promotions in institutions can also be made on the basis of excellence in teaching, e.g. for teaching innovation and continual upgrade of content which can have long term effects for students. Thus, in a sense institutions can pay in advance for the prospect of teaching as for research excellence. However, there are still crucial differences in the role played by research versus teaching in most academic salary levels. Recruitment to a post is rarely on the basis of teaching excellence, though it can be for expertise in a teaching area, but provided the prospect of research is met. Thus given that promotion on teaching excellence is relatively recent and more rare than for research, and given recruitment on teaching alone is even less prevalent, this paper focuses on assessing recruitment and promotion practices with reference to research output by those recruited and/or promoted.

There is considerable literature on assessing research effectiveness at person, Department or University level. For a review of the use of DEA in assessing education services, including universities the interested reader is referred to Thanassoulis et al. (2016). Assessments addressing various aspects of University effectiveness can be found in De Witte and Rogge (2010). Assessments at University level can be found in Coelli (1996), Athanassopoulos and Shale (1997), Avkiran (2001), Abbott and Doucouliagos (2003) and Katharaki and Katharakis (2010). Assessments at University Department level can be found in Johnes and Johnes (1993), Johnes (1995) and Doyle et al. (1996). Assessments of Greek Universities or University Departments can be found in Anastasiou et al. (2007), Kounetas et al. (2011) and Karagiannis and Paschalidou (2017). However, none of these assessments looks at the recruitment and subsequent career payments of an individual relative to their research outputs. Such a view, when suitably aggregated across individuals, could identify any cost deficiencies in the policy of an institution on appointments and promotions of academics. The aim of this paper is to contribute an approach to addressing the issue of the cost-efficiency of the policy of recruitment and promotions at higher education institutions.

In order to assess the cost-effectiveness of the recruitment and promotion policies of a tertiary education institution we propose the use of Data Envelopment Analysis (DEA) to set the career cost for research by each academic of that institution against their research output as it has been revealed prior to and post decision points on recruitment and promotion. This is done at academic person level ensuring the academics are comparable on research by way of academic discipline and contractual obligations de facto and de jure. While at person level there could be ad hoc events that could affect the findings on relative costs of research output, when the results are aggregated across suitably defined sets of individuals they can be informative about the cost-efficiency of the policy on recruitment and promotions at constituent unit of an institution or even at institution level.

We illustrate our approach using realistic estimates of data for comparable by discipline academic staff from a Greek University. We set their estimated career remuneration for the conduct of research against measures of their research output. We identify alternative scopes for savings that might have been made under alternative scenarios. Our headline finding is that the cost of aggregate research output has limited scope to be lowered, about 7.5% of total salary bill, by simply optimising the decisions on pay level without improving the pace of research output. If, however, apart from making salary levels more in line with the pace of research output, that pace itself had been faster then the time saved would have reflected savings of 17.5% of the salary bill. It is noted that these findings are only illustrative as they are based on benchmarking on only a limited number of some 38 persons and on other subjective value judgements made in the modelling, notably on the relative values of research published pre- versus post-appointment, and on the worth of publications in differently ranked journals.

The paper is structured as follows. The next section presents the assessment model used in terms of the underlying conceptualisation, including the measures of salary cost and corresponding research outputs used. This is followed by a mathematical formulation of the model conceptualised. The fourth section presents an illustrative application of the mathematical model, using realistic estimates of data relating to 38 academic persons. The fifth section discusses policy implications that could be drawn from the results on the estimated data. The sixth section concludes.

2. Conceptualising the assessment model

We wish to set the salary component of an academic over the period the academic has been in post against the research outcomes attributable to that academic. Ideally therefore one would require the component of the academic's salary that relates to their research. Measures of the research contributions (e.g. academic papers, books etc.) can be obtained at academic person level. However, the salary of an academic typically covers all their activities and the component relating to their research output is not known. One way to proceed therefore would be to use the entire salary cost of the academic on one side and all activities (teaching, research, administration, etc.) on the other. Conceptually this is a correct approach, especially if the cost efficiency of the academic person is the object of our assessment. However, our target here is the recruitment and promotion policies of an institution and these have hitherto, as noted earlier, largely hinged on research, and especially so where recruitment of staff in the first place is concerned. Thus, another way to proceed is to use the whole salary but data only from academic staff where both the contractual and the de facto expectation is the same in terms of contributions to teaching, research and administration. This cohort, to which we shall refer as "Standard Teaching, Research, and Administration" or **STRA** academic staff would generally be core service delivery staff constituting a majority of the academics

in an institution. STRA staff would exclude academics where for any reason the balance in expectation of teaching, research and administration does not apply (e.g. by reason of senior management role within the institution, secondment outside academia, ill health etc.). In contrast, given that our aim is to assess policies rather than individuals, data from past STRA academics who have left an institution could be used, provided they remained sufficiently long at the institution for their output in research corresponding to salary payments to register. Our approach is then predicated on using only data from STRA academic staff.

For our illustrative application, we have used data from STRA staff only and so we can proceed by using the same proportion of the total salary cost of each academic person as if it reflected compensation for expected research output. Using the same proportion of salary across staff means the same expectation of research output but not necessarily the same delivery of research output. In fact, the model aims to show where delivery of research has not been in tandem with salary cost. Where research output by a STRA academic is higher relative to other STRA staff, the model will find higher cost efficiency relative to other STRA academics who have similar salary. The opposite will be the finding when research output by a STRA academic is lower relative to other STRA staff on similar salary. Thus so long as expectation in research relative to other duties is the same across all staff whose data is used in the model there will be no bias in the findings for using the same proportion of total salary as compensation for research. Where the total salary leads to an input level in the model for research compensation not in line with research output by the person the model will appropriately show this as high or low cost efficiency as the case may be.

We wish to set up a model to estimate the lowest career-aggregate cost that could have secured the career-aggregate research output of an academic, if he/she had been as productive in research quantity and quality as found in others within the sample of 38 academics we are using. The cost of a given set of research outcomes can be minimised either through producing the research in less time, or by paying a lower salary to the academic producing the research or both. The career salary profile in turn of an academic reflects the initial salary they were appointed at and any salary increases they may have received, normally through the promotions process. Our model will reflect both the appointment and the annual mean career salary of an academic. To make salaries across time comparable we have used the mean salaries of a given year (2014) for each level of post (Lecturer, Associate Professor etc.) and applied them to the duration at each post level by each STRA academic within our sample. This also controls for appointment v promotion salary inflation as could arise where the former is susceptible to the balance of supply and demand for academics which can change over a prolonged time period. In Greece base academic salaries at each level are set by the state and there is little market pressure on salaries as there is generally excess staff supply and staff mobility is limited. What the monetary values used for salary in the model will then reflect is the level of post at appointment and frequency of promotion. These will be judged by the model relative to research output by the academic concerned.

Turning to the research outputs of an academic there is no clear consensus in the literature as to how their quality should be reflected. However, judging from accepted practice, e.g. the United Kingdom periodic Research Assessment Exercises (http://www.ref.ac.uk/), papers published in peer reviewed academic journals and some measure of ‘impact’ of research are taken as reflective of quality of research. The quality of research output should in principle be assessed using judgment. However, the judgments on the quality of academic papers do tend to match in considerable measure the ranking of

the journal where the papers have appeared. Foe example, see Pidd and Broadbent (2015) on the strong association of the grading of research outputs by the Business and Management panel (UK REF 2014) and the Association of Business Schools (ABS) ranks of the journals where the papers had appeared. This was despite the fact that the panel had used judgment rather than journal ranks when grading research outputs on quality. So, one could effectively use the ranking of the journal where a paper is published as a proxy for the quality of that paper. See also Mingers et al. (2012) on this point.

For the illustration of our approach, to reflect the research outputs of an academic we have used the ranks of the journals where the papers have been published and the citations their papers have received, excluding self-citations. Specifically, we have used peer-reviewed journal papers indexed in Scopus and their citations. For quality of the papers we have used the Australian ERA2010 ranking of journals as we found this had a wider list of journals than did the Association of Business Schools ranking of journals, the latter being widely used for ranking journals in the UK. According to ERA2010, the journals are ranked from C to A+, the latter reflecting top quality under ERA2010. We have added a category D for papers found in Scopus journals that are not ranked in ERA2010. We have used the ranking of journals at the time of writing this paper (ERA2010) rather than at the time the papers in our data were each published. This level of refinement of the illustrative assessment was not deemed necessary though it can be used in a real application of our approach by an institution. We have used Scopus citations, excluding self-citations, to capture the degree of dissemination of the research of an academic person. The citations are not shared across co-authors nor allowance is made for other refinements such as allowing for the time since publication of a paper, or the ranking of the journal where the cite has occurred. These refinements are not deemed necessary for our illustrative application but can be undertaken in principle in real life applications.

Table 1 shows the specific input-output variables which we have used within our DEA model and which can serve as a general base for cost-efficiency assessments of this type of the research output at academic person level. For simplicity of expression in the remainder of this paper reference to A+ publications will include A publications converted to A+ equivalent and reference to B publications will include C and D publications converted to equivalent B publications, as converted in Table 1. In principle, there is no need to aggregate publications in different ranked journals. E.g. the outputs could be by journal rank A+, A, B etc. The aggregation here was to retain degrees of freedom due to the relatively low number of only 38 observations. It is clear that the journal rank reflects but a proxy of the quality of a paper. Some A+ papers may be no better than say an A paper and an A paper could have been worthy of publication in an A+ journal. Thus, there will always be potential stochastic error in reflecting the true quality of research output, whether journal ranking or some other method such as judgement is used for the assessment. However, when the findings are ultimately aggregated at institution level the impact of this stochasticity will to an extent be ameliorated as biases in opposite directions cancel out to an extent across papers or other research output units. This will be more so the more the research output units (papers etc.) within the assessment.

Table 1: Input-Output Variables for Assessing the Cost Efficiency of Academic Research

INPUTS

X1: First year in post;
X2: Duration in post after the first year.

OUTPUTS

Y_{AB}: Publications in A^+ journals before recruitment, including A journals using the conversion rate $A=0.5A^+$ (SAE*)
Y_{BB}: Publications in B journals before recruitment, including C and D journals using the conversion rate (B=2C=6D) (SAE)
Y_{AA}: Publications after recruitment in A^+ journals including A journals using the conversion rate $A=0.5A^+$ (SAE)
Y_{BA}: Publications after recruitment in B journals including C and D journals using the conversion rate (B=2C=6D) (SAE)
Y_C: Citations of the articles included in the foregoing four categories of journal papers.

*SAE= Single Author Equivalent, each joint author credited the same fraction of the paper.

The rationale for each variable in Table 1 is as follows:

i. First year in post, X_1=1 for all persons

This variable reflects the first year in post. It enables the model to assess the efficacy of the initial salary offered to the academic. The initial salary in most cases is fundamental in shaping the salary profile in post for an academic as it typically provides the basis for salary increments going forward. Thus, the variable is instrumental in assessing the recruitment policies of an institution in terms of salary reward for promise of research as assessed at the time of recruitment.

ii. Time in post – *X2*

This variable reflects the duration in post after the first year. It enables the model to set in context the research outputs of the academic concerned. The academic's time is a key ingredient converted to research outcomes.

iii. Publications Y_{AB} to Y_{BA}

We use the peer-reviewed publications to capture the research output of an academic. In particular, we take into account only journal papers indexed in Scopus. Conference papers, book chapters etc., even though indexed in Scopus, are not taken into account falling largely in line with practice in research assessments conducted periodically by funding agencies (e.g. the REF in the UK in 2014 (http://results.ref.ac.uk/)). Where publications are authored by more than one person we have shared the credit equally between all authors. E.g. a publication having 2 authors will count as 0.5 publications for each joint author denoted 0.5 SAE (single-author equivalent) above. For alternative ways of crediting authors of multi-authored papers see Karagiannis and Paschalidou (2017) or section 12.3.3 in Thanassoulis et al. (2016).

The publications are broken down into four categories. Two of the categories are based on timing of the publication before or after the person was recruited to their current post. This subdivision is felt necessary because while the sum total of one's publications constitutes his/her research profile, those prior to recruitment play a role in whether or not a person is

recruited and on the salary they are recruited at. Those post recruitments play a role in the retention and promotions of the person concerned. These distinct roles of pre- and post-appointment publications will enable the model to reveal the effect on the cost efficiency of the recruitment as distinct from that of the promotions process.

Each one of the pre- and post-recruitment publications is further subdivided into two categories by quality of outlet as reflected in the Australian ERA2010 ranking of journals. One category represents journals ranked as A+ or A and the other journals ranked B, C and D. Following information on how certain Australian Universities compensate staff for publishing in journals ranked A+ to C we have adopted the following assumptions: one publication appearing in a journal ranked A counts as 0.5 publications appearing in a journal ranked A+; each B ranked publication was deemed worth 2 and 6 publications appearing in C and D ranked journals respectively. As noted earlier, these conversions using subjective equivalences of papers are not necessary in principle as papers can be used by each rank of journal. However, it would be advisable to use weights restrictions, as we do below, to signal to the model at least the rank order of journal rating (e.g. on average an A paper would be of better quality than a B paper etc.).

iv. Citations- Y_C

We deemed citations to constitute a surrogate for the reach of the publications. Only citations of the papers included in the four categories of outputs Y_{AB} to Y_{BA} were considered. As noted above we are aware of issues in using raw citation counts and the arguments that citations do not necessarily reflect quality of publication. However, as we already use four surrogate variables for quality of publications, the citations are intended to simply reflect the degree to which the work of an author has been noted by others.

Clearly our choice of input, and especially output, variables is based on subjective judgments albeit made on the extant references and 'accepted wisdom' as to how quality of research is to be judged. Our assumptions are in our view sufficient to illustrate the approach being developed here. Any institution adopting our approach could replace our output variables with others more in line with its own judgement as to how research output quality and indeed quantity is to be captured (e.g. including PhD student completions or research grant income generated as reflecting research output). The generic input remains time devoted to research and the generic output is research quantity and quality.

3. Constructing the assessment model

As noted at the outset, our overarching aim is to assess the efficacy of an institution in salary payments it has made on the prospect of research output by its academic staff. Portela and Thanassoulis (2014) have proposed a general-purpose DEA model for estimating potential cost savings at a production unit when the input levels it uses and the prices it pays per unit of input are optimised simultaneously, to minimise the aggregate cost of inputs, controlling for output levels. Their model provides a useful starting point in addressing the issue of efficacy of the recruitment and promotion policies of an institution, where research by academic staff is concerned. The input in our case would be the time taken to conduct the research, while the outputs are the research outputs of an

academic. The input prices are the annual salaries of the academic. We differentiate between salary in the first-year post appointment (henceforth year 1) and annual salary in the subsequent years of an academic's duration in post at the institution. Salary in year 1 reflects publications prior to appointment and enables the analysis to assess the financial efficiency of recruitment policies. In contrast, annual salaries after year 1 reflect the financial efficiency of salary increments, notably through promotion. Certain conventions, if not legal requirements, such as no reduction in salary over time, can also be explored regarding their cost implications.

Drawing on the model by Portela and Thanassoulis (2014) we propose Model 1 for estimating the potential cost savings in achieving the research output of academic person *o*.

Model 1

$\min C1 = \gamma_1 p_{1o}\theta_1 x_{1o} + \gamma_2 p_{2o}\theta_2 x_{2o}$
$s.t.$

$\sum_{j=1}^{n} \lambda_j x_{1j} \leq \theta_1 x_{1o}$	*C1.1*	(v_1)
$\sum_{j=1}^{n} \lambda_j x_{2j} \leq \theta_2 x_{2o}$	*C1.2*	(v_2)
$\sum_{j=1}^{n} \lambda_j y_{AB,j} \geq y_{AB,o}$	*C1.3*	(u_{AB})
$\sum_{j=1}^{n} \lambda_j y_{BB,j} \geq y_{BB,o}$	*C1.4*	(u_{BB})
$\sum_{j=1}^{n} \lambda_j y_{AA,j} \geq y_{AA,o}$	*C1.5*	(u_{AA})
$\sum_{j=1}^{n} \lambda_j y_{BA,j} \geq y_{BA,o}$	*C1.6*	(u_{BA})
$\sum_{j=1}^{n} \lambda_j y_{C,j} \geq y_{C,o}$	*C1.7*	(u_C)
$\sum_{j=1}^{n} z_{1j} p_{1j} \leq \gamma_1 p_{1o}$	*C1.8*	(u_8)
$\sum_{j=1}^{n} z_{2j} p_{2j} \leq \gamma_2 p_{2o}$	*C1.9*	(u_9)
$\sum_{j=1}^{n} z_{1j} = 1$	*C1.10*	(u_{10})
$\sum_{j=1}^{n} z_{2j} = 1$	*C1.11*	(u_{11})
$2\lambda_j - z_{1j} - z_{2j} \leq 0$	*C1.12*	(u_{12})
$\sum_{j=1}^{n} \lambda_j = 1$	*C1.13*	(u_o)
$\theta_1 = 1$	*C1.14*	(δ_1)
$0 \leq \theta_2 \leq 1$	*C1.15*	(δ_2)
$-\gamma_1 p_{1o} + \gamma_2 p_{2o} \geq 0$	*C1.16*	(μ_1)
$\gamma_1 p_{1o} \geq a$	*C1.17*	(μ_2)
$\gamma_i \geq 0, i = 1,2$	*C1.18*	
$\lambda_j \geq 0, j = 1, \ldots, n$	*C1.19*	

In Model 1 x_{ij} is the level of the *i-th* input of academic *j*, where x_{1j} =1 for all *j*, is the first year in post. x_{2j} is the career duration (in years) of academic *j*, from year 2 on. y_{ABj} is the number of publications in A^+ rated journals by academic *j* before recruitment. y_{AAj} is the number of publications in A^+ rated journals by academic *j* after recruitment. y_{BBj}, and y_{BAj} are defined in an analogous manner. y_{Cj} is the number of citations of academic *j*. p_{1j} is the salary in year 1 (i.e. on recruitment) of academic *j*, while p_{2j} is the mean annual salary of academic *j* from year 2 in post on.

The variables in the model are γ, θ and λ. The constraints *C1.1* to *C1.7* inclusive define in conjunction with *C1.13* a convex feasible set of input-output levels in the traditional context of DEA under variable returns to scale. The constraints in *C1.8* to *C1.11* inclusive define a feasible set of initial and mean subsequent annual salaries, assuming a convex combination of observed salaries is feasible even if not observed.

In setting up an instance of the generic version of Model 1 that would reflect both the legal framework in which an institution functions and its own internal norms, the issue arises of how to link benchmarks on research outputs and those on salary. We would expect that if an individual person (P1) has his/her duration in post and research outputs used as benchmarks for individual *o* then so should be P1's salary levels too. Otherwise a benchmark with low research level and low salary can be used to set the target salary of an individual with a high research output which would be inappropriate. Clearly it would be difficult to argue for complete disconnect between benchmarks on research output and salaries. The only question is what should be the nature of the link. It is recalled that at the optimal solution to Model 1 positive λ values will identify benchmarks on research outputs while positive *z* values will identify benchmarks on salaries. At its simplest, the link could be set so that benchmark (i.e. referent) academics are identical both in terms of who they are and in what proportion they each contribute to targets for the academic being assessed, both where research output levels and where salaries are concerned. This approach would mean discarding the *z* variables in Model 1 and simply using the same λ variables to form convex combinations of salaries, years in post and research output measures. This in our view, while possible, would be overly restrictive. We have opted instead for the more flexible constraint $2\lambda_j - z_{1j} - z_{2j} \leq 0, j = 1 \ldots n$ in *C1.12*.

The coefficient of 2 for λ_j in C1.12 reflects the fact that we have two inputs in this assessment. The constraint ensures that if an academic *j* is a benchmark on research outputs and duration in post then that academic must also be a benchmark for at least one of the salaries, (year 1 or career mean after year 1). However, the proportions that benchmark academic contributes to target salaries need only average to the λ_j value (i.e. proportion the benchmark contributes to research output and duration in post targets). Clearly the nature of the link between benchmarks on salaries (*z* values) and research output (λ values) is subjective. For example, a user may opt for a coefficient *k* in *C1.12* different from the number of inputs (2 in our case). The higher the value of *k* relative to the number of inputs the weaker the link between benchmarks on salary versus research outputs and duration.

The objective function of the model is minimising the career salary cost of academic *o* by optimising simultaneously the values of γ and θ so that for academic *o* duration in post $\theta_i x_{io}$ and salary levels $\gamma_i p_{io}$ are optimal. Note that in constraint *C1.14* we fix θ_1 = 1 as we do not permit part-time appointments in year 1 and assume each person appointed will normally remain at least one year in post, given the legal framework. This makes the constraint *C1.1* redundant. However, we have kept it in for the completeness of the model as in the general case one may not wish to fix at the outset θ_1 =1 and/or x_{1j} =1 for all *j*. In *C1.15*, $\theta_2 \leq 1$ allows for the fact that a person's research output could have been achieved at a shorter space of time than the person took. Constraints *C1.16* and *C1.17* reflect the legal framework of appointments. Constraint *C1.16* ensures that the benchmark mean annual salary from year 2 on for academic *o* does not fall below the benchmark annual salary at which that academic could have been appointed. This is compatible with the assumption that salary reduction below the appointment salary is not permissible or at least rarely found in practice in academic institutions. Constraint *C1.17* does not permit the benchmark salary on appointment to be below the legal minimum annual salary at which an academic could have been appointed, denoted in the model *a*. This type of constraint would apply in most countries. Constraints *C1.16* and *C1.17* would need to reflect the legal framework of the country of application of the model.

Institutions would normally have views as to the relative value of publications appearing in differently ranked journals and also the worth of citations versus publications. These views are

subjective and possibly institution specific. Without claiming generality, and for illustrative purposes only, we have incorporated in this assessment the following value judgements:

- an A+ publication is worth at least 2 publications in B ranked journals; (We explore later how robust are the findings to these trade-offs.)

- 5 publications after appointment in a given rank journal are worth 6 pre-appointment publications in a journal of the same rank; This reflects the uncontroversial judgment that all being equal a publication is worth more to an institution in terms of earning it visibility and prestige if it is made by a member of its staff when he/she was an employee at the institution rather than as an employee elsewhere.

- 10 citations are worth more than a publication appearing before appointment in a B ranked journal but less than a publication appearing post appointment in a B ranked journal. It would be uncontroversial that a citation is worth less than a publication but it is subjective as to how many citations would make up for one publication. Our choice of 10 in relation to a publication of quality between A+ and B is subjective and for illustrative purposes only.

In order to illustrate the incorporation of value judgements, such as the foregoing, we formulate Model 2 as the dual to Model 1. The dual variable associated with each constraint is shown in brackets next to the labels *C1.1* to *C1.17* of Model 1.

Model 2 (dual to Model 1)

$$max\, D = \left(u_{AB}y_{AB,o}\right) + \left(u_{BB}y_{BB,o}\right) + \left(u_{AA}y_{AA,o}\right) + \left(u_{BA}y_{BA,o}\right) + \left(u_{C}y_{C,o}\right) + \mathrm{u}_o + \mathrm{u}_{1o} + \mathrm{u}_{11} + \mu_2\alpha + \delta_1 - \delta_2$$

$s.t.$

	Dual variable
$v_1x_{1o} + \delta_1 \le \gamma_1 \mathrm{p}_{1o}\mathrm{x}_{1o}$	θ_1
$v_2x_{2o} - \delta_2 \le \gamma_2 p_{2o}x_{2o}$	θ_2
$u_8p_{1o} - \mu_1p_{1o} + \mu_2p_{1o} \le \mathrm{p}_{1o}\theta_1\mathrm{x}_{1o}$	γ_1
$u_9p_{2o} + \mu_1p_{2o} \le \mathrm{p}_{2o}\theta_2\mathrm{x}_{2o}$	γ_2
$-v_1x_{1j} - v_2x_{2j} + \left(u_{AB}y_{AB,j}\right) + \left(u_{BB}y_{BB,j}\right) + \left(u_{AA}y_{AA,j}\right) + \left(u_{BA}y_{BA,j}\right) + \left(u_{C}\mathrm{y}_{\mathrm{C,j}}\right) + \mathrm{u}_o - 2u_{12} \le 0$	λ_j
$-u_8p_{1j} + u_{1o} + u_{12} \le 0$	z_{1j}
$-u_9p_{2j} + u_{11} + u_{12} \le 0$	z_{2j}
$v_i, u_8, u_9, \delta_2, u_{12}, \mu_i \ge 0, i = 1,2$	
$u_{AB}, u_{BB}, u_{AA}, u_{BA}, u_C \ge 0$	
$\mathrm{u}_o, u_{10}, u_{11}, \delta_1\ free.$	

We can add now the following constraints to Model 2 to capture the value judgments expressed above.

Constraints on weights	Dual variable
$u_{AB} \ge 2u_{BB}$	t_1
$u_{AA} \ge 2u_{BA}$	t_2
$u_{AA} \ge 1.2u_{AB}$	t_3
$u_{BA} \ge 1.2u_{BB}$	t_4
$u_C \le u_{BA}$	t_5
$u_C \ge u_{BB}$	t_6

Thus, for example, the constraint $u_{AB} \geq 2u_{BB}$ ensures that one publication in an A+ ranked journal is worth at least 2 publications in B ranked journals, both prior to appointment. The remaining restrictions above associated with the dual *t* variables are interpreted in a similar manner. Note that citations are in units of 10. Using now the additional constraints and their dual variables t_1 to t_6 as shown above we can revert back to Model 1 which modifies to Model 3, capturing the foregoing value judgements.

Model 3

$min\ C3 = \gamma_1 p_{1o}\theta_1 x_{1o} + \gamma_2 p_{2o}\theta_2 x_{2o}$
s.t.

$\sum_{j=1}^{n} \lambda_j x_{1j} \leq \theta_1 x_{1o}$	*C3.1*
$\sum_{j=1}^{n} \lambda_j x_{2j} \leq \theta_2 x_{2o}$	*C3.2*
$\sum_{j=1}^{n} \lambda_j y_{AB,j} - t_1 + 1.2t_3 \geq y_{AB}$	*C3.3*
$\sum_{j=1}^{n} \lambda_j y_{BB,j} + 2t_1 + 1.2t_4 + t_6 \geq y_{BB}$	*C3.4*
$\sum_{j=1}^{n} \lambda_j y_{AA,j} - t_2 - t_3 \geq y_{AA}$	*C3.5*
$\sum_{j=1}^{n} \lambda_j y_{BA,j} + 2t_2 - t_4 - t_5 \geq y_{BA}$	*C3.6*
$\sum_{j=1}^{n} \lambda_j y_{C,j} + t_5 - t_6 \geq y_C$	*C3.7*
$\sum_{j=1}^{n} \lambda_j = 1$	*C3.8*
$\sum_{j=1}^{n} z_{1j} p_{1j} \leq \gamma_1 p_{1o}$	*C3.9*
$\sum_{j=1}^{n} z_{2j} p_{2j} \leq \gamma_2 p_{2o}$	*C3.10*
$\sum_{j=1}^{n} z_{1j} = 1$	*C3.11*
$\sum_{j=1}^{n} z_{2j} = 1$	*C3.12*
$2\lambda_j - z_{1j} - z_{2j} \leq 0$ *j=1…n*	*C3.13*
$\theta_1 = 1$	*C3.14*
$0 \leq \theta_2 \leq 1$	*C3.15*
$-\gamma_1 p_{1o} + \gamma_2 p_{2o} \geq 0$	*C3.16*
$\gamma_1 p_{1o} \geq a$	*C3.17*
$\gamma_i \geq 0, i = 1,2$	*C3.18*
$\lambda_j \geq 0, j = 1, \dots, n$	*C3.19*
$t_r \geq 0, r = 1, \dots, 6$	*C3.20*
$z_{ij} \geq 0, i = 1,2; j = 1, \dots, n$	*C3.21*

Notation in Model 3 is as in Model 1, while the $t_r, r = 1, \dots, 6$ are dual variables associated with the additional constraints reflecting value judgements, as detailed above.

Model 3 is a generic one. It can be modified to investigate the impact of the recruitment and promotion policies of an institution within the degree of flexibility it has. For example, by setting θ_1 = θ_2 = 1 while γ_1 and γ_2 are permitted to vary the institution can investigate its recruitment and promotion policies under the prism that only salaries are under its control once a person has been appointed because firing is only permitted by law under exceptional circumstances. (In Greece for example University academics after a certain grade have tenure.) More generally, by varying the combination of the parameters θ_1, θ_2, γ_1 and γ_2 that can vary one can reflect in the assessment those aspects of duration in post, recruitment and promotion salary that are seen as falling within the gift of the institution and legitimate factors against which to assess the efficacy of its recruitment and promotion policies.

4. An illustrative use of the foregoing model

Model 3 was applied to estimated data on 38 STRA academics of a Department of a Greek University. Their academic disciplines are similar and only those who had had at least 3 years in post were included. The three-year threshold was used to ensure each academic had had sufficient time in post to deliver research output and be affected by appointment and possibly promotion policies both of which are the issue of the analysis. The input and the output data are estimated and so our findings do not necessarily reflect the true state of affairs at the institution concerned. However, our aim is not to assess individuals or the institution per se. Rather it is to illustrate the approach we have developed in this paper with realistic data and then to discuss the implications of the findings for the recruitment and promotions policy of any institution in which findings of the type our estimated data yield were to be the case.

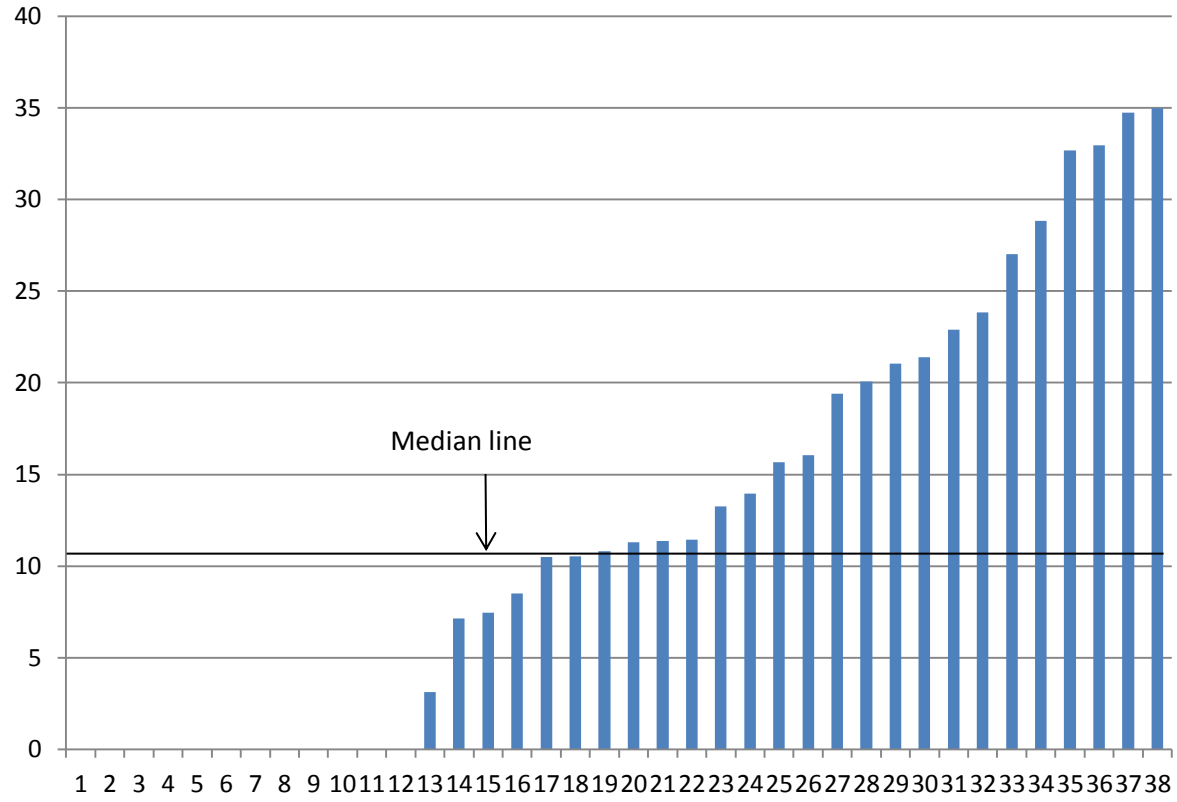
4.1 Assessing the scope for savings through optimizing research output rate and recruitment and promotion practices

We begin with an overview of the findings estimating the grand total savings that might have been possible where the component of research expenditure is concerned. For this scenario, Model 3 has been solved in the form stated above. As it has a non-linear objective function it was solved parametrically by numerical approximation varying θ_2 in the range from 0.001 to 1 in steps of 0.001. For each value of θ_2 the model becomes linear and can be readily solved. We have assumed that 40% of an academic's salary is the component attributable to their research. In the DEA approach we are using, the level of this fraction does not affect the comparative ranking for the individual persons. However, the use of a uniform percentage of salary as input means, as argued earlier, that we need to be using in our sample only data from past and current STRA staff, for whom there is a uniform expectation (not necessarily delivery) of research, teaching and administration, and their salary would reflect this expectation. Moreover, any promotions should in principle have been on the basis of research, again in expectation rather than in practice. Where then delivery say of research exceeds expectation that could lead to salary rise through promotion but the model would see that as stable cost efficiency as input (salary) would be rising in response to output (research). The model would then capture as inefficiency where salary cost is not in keeping with the best 'ratio' of research output to salary, e.g. because promotion was on criteria other than research. Where promotion might have been on excellence in teaching or outreach to community (relatively rare to date) that data would not be suitable to use in our model. Where, however promotion might have been on what officially the institution or state would not sanction (e.g. recruitment or promotion despite insufficient research output) then the model would reflect that as cost inefficiency of recruitment and promotion practices.

Figure 1 shows the proportion of the overall salary of each academic that would have been saved if their initial and subsequent salary levels were compatible with the duration and the quantity and quality of the research outputs of the benchmark individuals. The latter are the 12 individuals in Figure 1 for whom no scope is found for reducing the salary expenditure of their research outputs. For the median person, some 12% of their salary might have been saved if their research performance had matched that of the benchmark individuals. In aggregate the potential savings are 17.45% of the salary bill. It is worth noting that in this particular case the results were not very sensitive to the subjective choice that a paper in an A ranked journal is worth 2 papers in B ranked journals. When the model was rerun assuming one A paper (before or after appointment) is worth 10 corresponding B

papers) the aggregate savings rose from 17.45% to 19.11% of total salary and two previously benchmark individuals were no longer so. Thus, though the assessment now valued so much more extremely papers in journals ranked A compared to B, the findings for at institution level and therefore the derived views on the recruitment and promotion practices did not alter substantially. The effects would have been even less pronounced with a more median trade-off between papers in A and B ranked journals.

Figure 1: Savings on salary research component as % of total salary cost



From the institutional perspective, it is worth investigating if there are patterns in the qualifications benchmark individuals offered on recruitment and in their subsequent promotions pattern and contrast them with those of 12 individuals at the other end of the spectrum, showing the largest proportions of potential salary savings. This second set of 12 individuals is estimated on average to be able to save about 26.66% of their salary if they matched the benchmark individuals on rate, quantity and quality of publications. Table 2 contrasts the two sets of individuals by showing the data for the 12 non-benchmark individuals as percentage of the corresponding data for the benchmark individuals.

Table 2: Mean values of 12 non-benchmark individuals expressed as % of those for 12 benchmark individuals

	Years in post	Salary on appointment	Salary from year 2 on	A+ Before	B Before	A+ after	B after	Citations
12 non-benchmark mean as % of 12 benchmark mean	191.16	94.41	113.21	29.32	24.60	58.41 (adj 30.55)	91.99 (adj 48.12)	35.72

Though the sample of 38 individuals is too small from which to draw firm conclusions, and the assessment has rested on a number of subjective assumptions, to the extent our data are realistic Table 2 can be used to illustrate how findings of assessments of the type developed in this paper can be used by an institution. For example, one notable difference between the two sets of individuals is the duration in post. Benchmark individuals have on average been half as long in post as the non-benchmark individuals with the highest scope for savings. However, research output prior to appointment of the non-benchmark individuals relative to that of the benchmark individuals is only 29.32% and 24.6% in A^+ and B ranked journals respectively. So, on the face of it there has been a considerable improvement over time in terms of publications offered by those being recruited and this seems to have led to more productive individuals in terms of research as the lack of scope to save on research component of salary shows.

In terms of A^+ and B publications after appointment the 12 non-benchmarks have a mean which is 58.41% and almost 92% respectively of that of the benchmark individuals before adjusting for duration in post. After adjusting for 191.16% duration in post of non-benchmark individuals A^+ and B ranked publications fall to 30.55% and 48.12% respectively of those of the 12 benchmark individuals. Finally, citations of benchmark individuals are about 3 times those of the non-benchmark individuals under discussion. This difference is even more in favour of the benchmark individuals when we reflect on the fact the non-benchmark individuals have had a longer period to build up the citations compared to the benchmarks.

Mean salary on appointment is marginally lower for non-benchmark individuals at 94.41% of that of the benchmark individuals. This is in the right direction given the lower research profile of non-benchmark individuals at the time of appointment. However, the differential is not significantly large given the much wider difference in research publications offered pre-appointment by the two groups.

Here is the first policy issue that comes into sharp relief: the salary on appointment does NOT on the face of it discriminate sufficiently on promise of research. The individuals in the two Groups differ by about 6% in favour of benchmark individuals who, however, offer substantially better research profile on appointment compared to the non-benchmark individuals. Thus, on the basis of this admittedly limited sample, the Institution is offering in an inconsistent manner ‘advance payment’ on the promise of research rewarding the same way those with less and those with more promise of research output.

The next question is the promotions policy and whether it is compatible with research output by individuals. The promotions of individuals are reflected in their mean annual salary, post year 1. Here

we have a relatively large advantage in favour of the 12 non-benchmarks. Their mean annual salary post year 1 is 13% higher than that of the benchmarks. Given the superiority of the benchmarks on research both pre- and post-appointment the salary differential in favour of non-benchmarks is not justified, at least where research is concerned. If an institution did have findings of the type depicted in Table 2 it would be incumbent upon it to check whether its promotion policy is in tune with research output rate, as the indications would be that it is not. For example, Table 2 suggests that promotions are a reward for longevity in post rather than for achieved research output. It is true that research may be seen as less important in career terms by those already established in post for considerable time, or after they have achieved the promotion they sought. However, while this phenomenon may be understandable from a practical perspective, it is not compatible with promotion on merit, where merit is earned through research output. The model identifies where salary increases are not justifiable on research terms, at least not relative to benchmark individuals. It would be for the institution to decide whether it wishes to condone 'slackening' on research output by individuals and thus not deem it as an unintended consequence of recruitment and promotion practices where those individuals are concerned. The analysis brings to the fore the need for the institution to clarify its criteria for promotion when research does not appear to be the main one in practice.

A further additional consideration from the institutional perspective is whether recruitment and promotion decisions have been deficient in identifying potential for rate of research going forward or have been too generous in salary terms, given research output. Figure 2 shows the optimal values of θ_2, γ_1 and γ_2 in Model 3. Individuals are ordered by the value of θ_2.

It is clear from Figure 2 that the biggest range of optimal values is shown by θ_2, ranging from under 0.2 to 1. This means there is great variability in rate of research output as the lower the value of θ_2 the shorter the time justified by the person's research output and so their rate of output should have been higher. The median value of θ_2 is 0.736, which in effect means the median person has spent about 26% of their time for research unproductively. As we can see, however, in Figure 2 there is great variability at individual person level. For the benchmark individuals, setting the standard for salary and output profiles, we have $\theta_2, = \gamma_1 = \gamma_2$ =1. In contrast at the other extreme some individuals have wasted about 80% of their time for research (we have optimal $\theta_2 = 0.2$) and even then, they would only justify about 70% of their mean career salary (γ_2 =0.7). This can be seen clearly at the person level bars, on the left end of Figure 2.

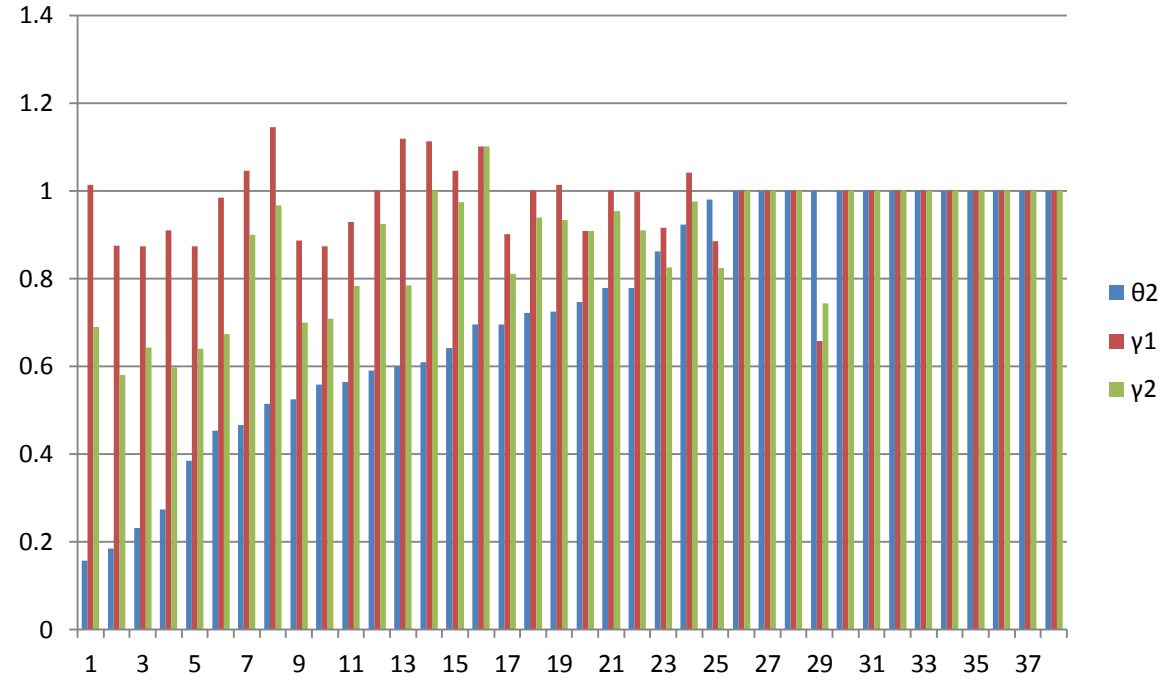
In contrast to θ_2 the values of γ_1 (appointment salary) show little variation around 1. Thus, not much can be achieved where savings are concerned by varying appointment salary. This of course in large measure reflects the legal minimum salary that must be offered. Nevertheless, some optimal γ_1 values are above 1 suggesting certain individuals should have been offered better initial salaries albeit at the expense normally of their subsequent annual salary. In one case however, the model suggests that savings can be achieved through raising both the appointment and subsequent salary of an individual if they could produce their research outputs faster. Finally, the values of γ_2 range from about 0.6 to 1.1 with a median value of 0.936. As can be seen in Figure 2 for most individuals the optimal value of γ_2 is below 1. Had this been the finding for an institution it would be suggesting there is scope for downward salary adjustment, which in effect means slower pace of promotion.

The policy implications of the findings above can be summarised as follows:

- There is little scope for savings in terms of salary offered at appointment. Indeed, in a number of cases they should have been offered higher initial salaries than materialised.

- There is scope for savings by making promotions more compatible with research output. There appears significant correlation between duration in post and career mean annual salary and yet not matched by research output;
- The largest scope for savings is available through a faster pace of research output. The median research output profile appears to justify only about 74% of the time they have actually taken to deliver the research and in some cases a lot less.

Figure 2: Potential proportional change in recruitment salary (γ_1), mean post year 1 annual salary (γ_2) and duration in post year 2 (θ_2) for research



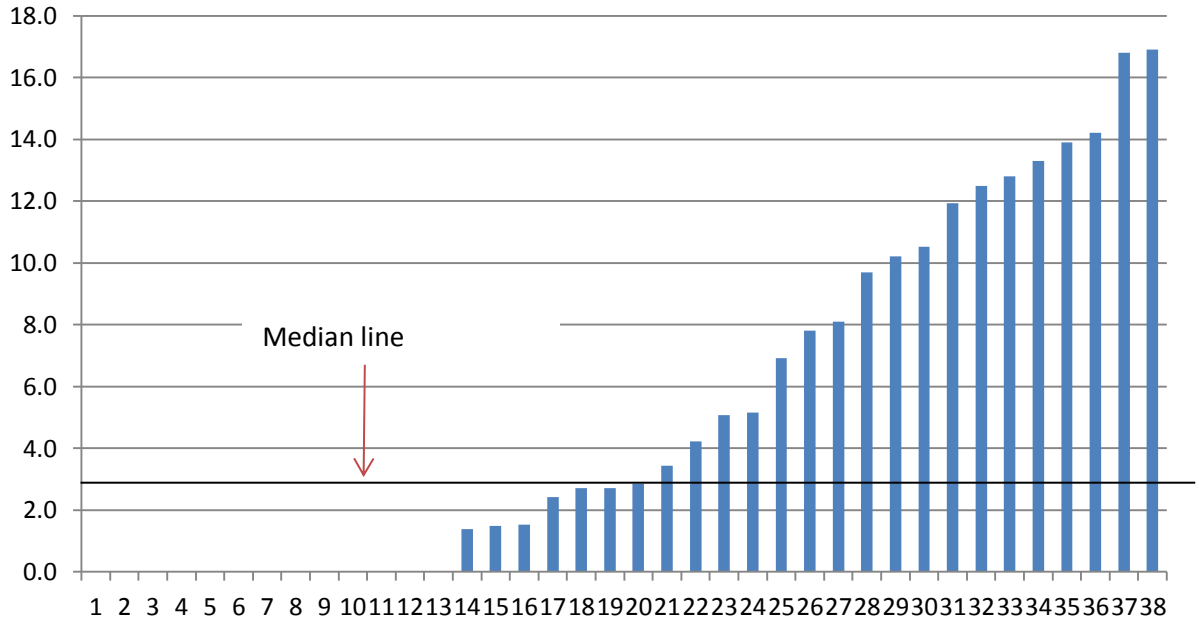
It should be noted that in interpreting the results depicted in Figure 1 and Figure 2 in terms of the institution's recruitment and promotion policies we have not gone further to see whether the optimal values of θ_2, γ_1 and γ_2 in Model 3 are associated in some way with year of appointment and/or year of promotion. If such an association were to be found, e.g. on average lower θ_2 optimal values for those appointed say 15 years ago compared to those appointed 5 years ago, it would suggest policy in terms of recruiting those with a better rate of research output had improved over time. As we wish findings to be comparable across time we can run the assessment using all time periods but we can then examine optimal values by time period as desired, e.g. to assess the impact of some policy change that was implemented at some given point in time. We next consider the particular changes an institution might adopt to make salaries more in line with research output.

4.2 Assessing the scope for savings through optimising only recruitment and promotion practices

The preceding section identified potential savings in aggregate through both salary adjustments and optimising the rate of research output. In this section, we isolate the scope an institution would have had to control the cost of its research when the sole instrument at its disposal is the salary it offers its staff. Arguably an institution has more immediate control of this instrument rather than influencing the pace at which its academic staff deliver research outputs.

We can isolate the scope for savings through salary adjustments alone by solving a modified version of Model 3 where we set $\theta_1 = \theta_2 = 1$. Model 3 remains otherwise as stated above so that γ_1 and γ_2 are permitted to vary. Thus, the model seeks to minimise the cost of the research outputs of an academic person solely by assessing whether his/her salary at appointment and/or the career mean annual salary could have been different but not below the legal minimum. Figure 3 shows the findings at person level.

Figure 3: Potential saving as percent of career salary solely through salary adjustments



The median saving is just under 3% while the aggregate savings are 7.63% of the career total pay of the individuals. These figures contrast with median potential savings of 12% and aggregate savings of 17.45% of the total salary bill when rate of research output is also optimised. Clearly therefore the bulk of the savings possible, as already established through Figure 2, is if rate of research output is optimised. Put another way, the cost per unit of research output can primarily be reduced through increasing the rate at which research outputs are produced rather than by manipulating the salaries of the academics. Indeed, behaviourally rewarding with higher salaries may be more effective in raising the rate of research output rather than the other way around.

Figure 3 suggests that there is significant scope for savings only in the case of a minority of individuals, perhaps those where estimated savings are above 10% of career salary. Such individuals constitute about 25% of the sample of individuals. The aggregate potential saving of 7.63% can be

taken as an index of the effectiveness of the recruitment and promotion practices of the institution when we accept that duration in post, once a person has been appointed, is in large measure outside the control of the institution (e.g. because of the legal framework on hiring and firing staff). The practices relate to decisions made at the time an individual is recruited and at the time or times that individual is promoted.

Taking first the issue of salary at appointment we can investigate how its levels relate to publications prior to appointment and performance in research post appointment. Table 3 shows the mean values of publications before and after appointment and the scope for savings of full salary through salary adjustments alone. The data is arranged by quartile on recruitment salary level. Publications after appointment also show adjusted normalised data for duration in post.

We would expect that salary at appointment would have a strong correlation with publications prior to appointment as one key criterion on which academic appointments are normally made. However, while the relationship revealed in Table 3 is in the right direction it is perhaps weaker than we would expect. This is especially so in going from quartile 1 to quartile 2 where mean appointment salary

Table 3: Mean values by quartile of salary at appointment, standardised on quartile 1=100

Quartiles on recruitme-nt salary	Salary at appoint-ment	Years in post	Mean annual salary	A+ (before)	B (before)	A+ (after)	B (after)	Citations	Savings case 2 as % of full salary
Q1	100	100	100	100	100	100	100	100	100
Q2	103.27	113.67	111.02	140.43	154.37	130.56 (adj 114.86)	289.12 (adj 254.35)	161.99	147.76
Q3	114.60	124.13	123.05	191.49	193.20	104.17 (adj 83.92)	208.84 (adj 168.24)	145.46	244.40
Q4	128.74	87.37	127.50	278.72	180.58	61.11 (adj 69.94)	144.90 (adj 165.85)	135.11	271.27

rises by only 3.37% yet A^+ publications before appointment rise by 40.43% and B publications by 54.37%. A more pronounced lack of proportionality between salary at appointment and publications before appointment exists between quartile 1 and quartile 3. Salary rises by about 14.6% while publications before appointment are nearly double both for A^+ and B ranked journals. It is true of course that we would not expect a constant returns-to-scale type proportionality between salary at appointment and level of publications prior to appointment but here there is relatively little reward at appointment time for publications offered. Another way to view the situation is that it has become tougher to enter the profession and ever higher level of publication is required for being offered a post while salaries are low and differ little between different grades. Appointments do not appear to be made at senior level unless of course salary differentials between senior and entry level grades are no more than about 30% of starting salary.

Turning to the relationship between appointment salary and pre-appointment research profile on the one hand and post appointment research performance on the other, the picture is mixed. Publications post appointment in B ranked or equivalent journals rise on the whole both with appointment salary and with pre-appointment publications. The rise is not so pronounced however where publications in A^+ journals are concerned and in fact adjusted for duration in post publications fall. More

significantly, as salary at appointment rises so does scope for savings as can be seen in the right most column of Table 3. E.g. those appointed with a mean annual salary in the fourth quartile have nearly 3 times (271.27%) the scope of savings of those appointed with a salary in the first quartile. This means post appointment there is a slackening of research output and a drift towards B from A journals and the higher the salary at appointment the more pronounced the slackening and the drift. As noted earlier, such slackening in output post appointment and/or promotion may be understandable at a practical level. However, the model identifies it as it may be seen as out of line with the institution's own formal expectations of STRA academics and thus a potential defect in its recruitment and promotion criteria.

In summary, had the findings in Table 3 been based on accurate real data they would call into question the relationship between the salary structure and research output post appointment. The emerging picture is that salary at appointment up to and including quartile 3 shows little variation in absolute values yet publications offered at the time of appointment are significantly higher. Salary in quartile 4 is somewhat better in line with publications pre-appointment. Post appointment publications tend to veer towards B journals but keep to some extent pace with publications offered at appointment, at least for quartiles 2 and 3 on appointment salary. The quantity and quality overall however, of publications and citations post appointment is not commensurate with expectation relative to benchmark individuals as can be deduced from the significant scope for savings (right most column of Table 3). Table 3 shows that the higher the appointment salary the higher the mean career salary, as we might expect. In fact, up to and including quartile 3 the mean annual salaries move almost in unison with mean number of years in post. Only for those appointed at the higher quartile 4 salaries does the duration in post not run in line with mean annual salary, suggesting they might have been appointed more recently to senior posts. However, in all cases as mean annual salary rises so does the scope for savings. This suggests promotions and initial appointment salary while they lead to improvement in number of publications, those are not in as highly ranked journals and in any case not commensurate with those of benchmark individuals and hence the significant scope for savings.

4.3 Assessing the scope for savings through optimising only promotion practices

We conclude this section by exploring potential savings on the cost of research outputs through better alignment of the promotions practices, given the salary at which each person has been appointed and their duration in post. This is achieved by solving Model 3 in a modified form in which $\theta_1=\theta_2=1$ and a in constraint *C1.17* is set equal to the actual salary at appointment of the individual, denoted p_{10}. Thus, the model can only now minimise the cost of research output through varying the mean career salary given duration in post is fixed and appointment salary could not have been lower than what transpired at the point of recruitment. Figure 4 shows the potential savings in ascending order. Percentages are of full salary cost.

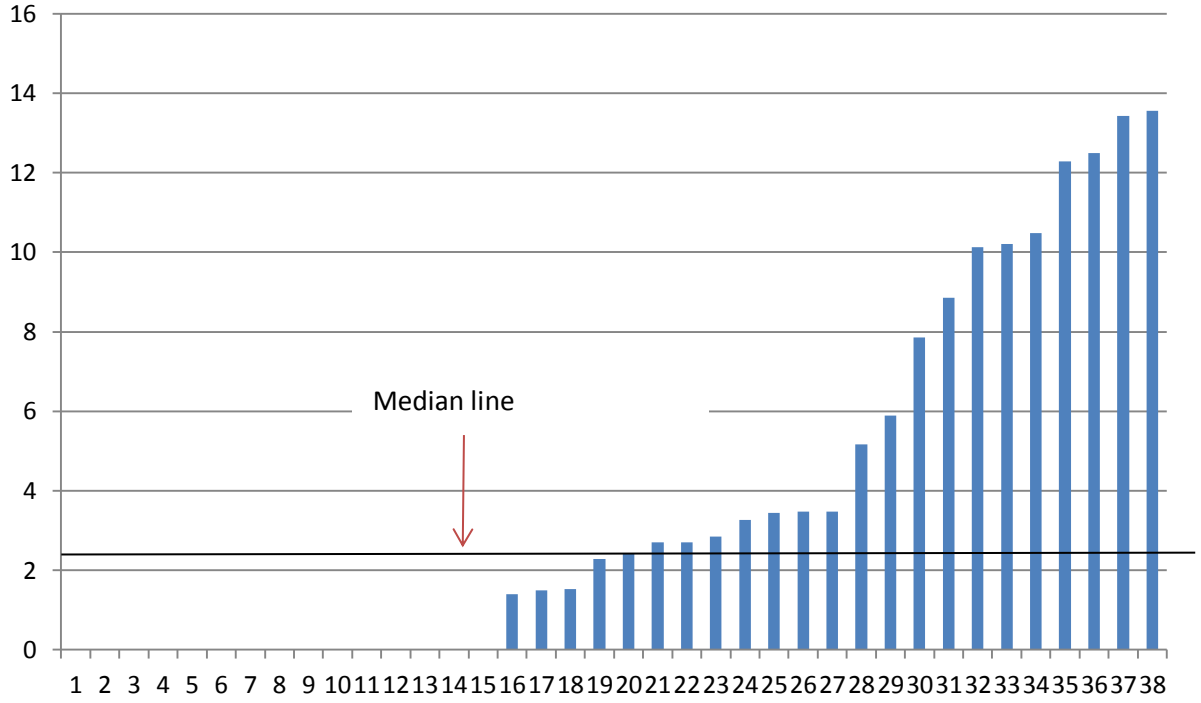
The median saving when promotions policy is in effect the sole instrument for minimising the cost of research outputs is 2.35%. This compares to just under 3% and 12% when ability to reduce appointment salary and ability to 'control' the pace of research output is added respectively. The aggregate savings are 5.83% compared to 7.63% and 17.45% of the career total pay of the individuals when ability to reduce appointment salary and to 'control' the pace of research output is added respectively. Clearly once we discount the ability to control the pace of research output, once a person has been appointed at a certain salary then realistically the sole instrument for the institution to minimise the cost of research outputs is the promotions policy as it influences the person's mean

annual salary. This, as seen above, offers only a modest scope of saving only about 6% of the total salary bill.

In order to investigate any link between promotions and performance in research before and after appointment we have divided mean career salary by salary at appointment, to which we shall refer as the '*promotions ratio*'. The higher the promotions ratio the more likely it is the individual has had one or more promotions. Table 4 shows mean values of the variables listed, including estimated potential for saving by quartile of promotions ratio. The values as usual are standardised on quartile 1=100 and publications after appointment are adjusted for duration in post.

We should expect promotions ratio and years in post to move in the same direction if we assume a person's research output is uniform in rate over their career and that promotion is largely based on research outputs. This expected relationship does not hold in Table 4. As we move from quartile 1 to quartile 2 we have a promotion ratio rise of about 6% while in round figures publications in B journals post appointment rise by 58% (adjusted for duration in post) but those in A^+ journals fall by 17%. As we move further to quartiles 3 and 4 by promotion ratio, publications in A^+ and B ranked journals post appointment fall and only citations exceed significantly those prior to promotion.

Figure 4: Potential saving as percent of career salary solely through mean annual salary adjustments



The rise in mean annual salary being out of synch with research output is strongly reflected in the significant rise in potential to save in salary, captured in the right most column of Table 4. Here we see that while quartile 4 individuals have a mean salary 41% higher than at the time of their appointment their savings feasible are 25 times those available for individuals in quartile 1, who in general have not yet had a promotion. This high factor is an artefact of the division by a very small number as those who have not yet had a promotion (quartile 1) have not got a high scope for savings. It is interesting that there is a general agreement between promotions ratio and publications in B

journals prior to appointment. It is as if individuals are getting repeat credit by way of promotion for publications prior to appointment and those have tended to be in B ranked journals.

Table 4: Mean values by quartile of promotions ratio, standardised on quartile 1=100

Quartile on Promotion	Promotions ratio	Years in post	Initial Sal	Career Mean	A+ (before)	B (before)	A+ (after)	B (after)	Citations	Savings case 2 as % of full salary
Q1	100	100	100	100	100	100	100	100	100	100
Q2	106.05	78.02	109.50	103.3	85.19	403.48	64.88 (adj 83.16)	122.48 (adj 158)	188.39	538.01
Q3	117.88	99.54	101.49	100.43	27.74	178.01	32.14 (adj 32.29)	78.89 (adj 79.25)	119.34	971.40
Q4	141	91.34	105.20	102.27	80.91	356.00	49.14 (adj 53.80)	76.22 (adj 83.45)	149.96	2515.33

5. Policy implications of the findings

A key aim of the approach outlined in this paper is to help institutions improve their recruitment and promotions policies of academic faculty from the perspective of the payments they make for research output. A key notion is that an institution pays for research in prospect rather than in retrospect in the sense that salary level is set on the research output prospect, albeit the prospect is largely based on actual research outcomes to date. Once an appointment or promotion has been made, an expenditure stream is set to follow going forward, and the duration of this can be independent of research outcomes for a considerable period of time, depending on managerial styles, institutional conventions and legal frameworks. The main aim of the approach developed in this paper is to aid institutions in taking timely retrospective review of policies and practices on recruitment and promotion with a view to making them more effective from the cost perspective going forward. A secondary possibility, whether or not an aim, would be to aid institutions in managing the research performance of academics who are still within the institution. This becomes possible as the review of the effectiveness of past recruitment and promotion policies regarding cost effectiveness of research is through a review of individual academics from the cost effectiveness of research at person level. The individuals whose data is analysed need not all be current members of faculty. The data of any faculty that have left the institution within the period of time analysed are still legitimate to analyse in terms of conveying evidence on the efficacy of the recruitment and promotions policies of the institution.

From the institutional perspective at the level of policy review the following issues can be investigated through the analysis carried out in this paper:

a) Have research profiles at recruitment proven good predictors of performance on research in post?
b) Are there research profiles at recruitment which are associated with good post recruitment performance in research?

We shall investigate these questions using the basic Model 3 so we capture the full potential flexibility of action on the part of an institution, including affecting the rate of research output.

5.1 Did research profile at recruitment prove a good predictor of ultimate performance in research?

In order to capture the research profile of an individual we aggregate their pre-recruitment A+ and B papers using $A^{+}=2B$. We are unable to allocate citations to pre- or post-appointment papers but it is safe to assume most citations will have occurred post appointment given the generally long periods in post of the individuals whose estimated data is being analysed. Table 5 shows the data by quartile on publications before appointment, standardised on Q1=100. Publications after appointment are also shown adjusted for duration in post.

Table 5: Publications and citations after appointment by quartile on papers prior to appointment

Quartile on Pre-appointment publications	A^{+} Before	Years in post	A^{+} after	B after	Citations	Potential savings as % of total salary cost
Q1	100	100	100	100	100	100
Q2	328.56	46.46	43.33 (adj. 93.26)	58.97 (adj. 128.86)	57.94	67.90
Q3	643.16	56.64	83.05 (adj. 146.63)	94.86 (adj. 167.47)	122.57	38.88
Q4	1798.62	58.14	66.27 (adj. 113.98)	84.76 (adj. 147.78)	168.30	27.42

There is an interesting non-uniform association between publications pre- and post- appointment. As we move from quartile 1 to 2 on pre-appointment publications, pre-appointment publications more than triple reflecting a very low level of publications by the bottom quartile. Looking at adjusted for duration in post publications post appointment they generally rise, especially so for publications in B ranked journals. The rise is not, however by the same factor by quartile as is for pre-appointment publications. Citations rise too, as we might expect. There is a hint from A+ publications after appointment that there is some threshold of publications prior to appointment so that only those offering pre-appointment publications above the threshold do proceed to offer a level of research output post appointment which is somewhat consistent with their research output pre-appointment. The threshold appears to be at the median level of publications pre-appointment. The more interesting finding appearing in Table 5 is that in the right most column. Potential savings in cost of research output drop consistently as publications before appointment rise. This would be in line with intuition, i.e. the stronger the record in research at appointment the better the subsequent research output, not leaving much scope for savings in cost per unit research output. One very prominent feature in Table 5 is that those in Quartile 1 who offer the lowest level of publications at recruitment, have been the longest in post. They have been on average twice as long in post as the remaining 75% of academics. This suggests as also noted earlier that in general over time the institution started to recruit academics with better qualifications. This, did lead to better cost efficiency of research overall.

So, one clear implication, had these findings been based on real rather than realistic data, is that the institution has been moving in the right direction in terms of lowering the cost per unit of research output produced. This has been dropping as the institution has been recruiting persons with better research output profiles over time. However, the institution could do even better by improving still further the pace of research output, as we saw in Table 1.

5.2 Identifying benchmark individuals as case studies where recruitment and promotions have led to good cost efficiency of research in post.

One additional use of the analysis undertaken would be to identify appointments which have turned out well in terms of cost of research in order to identify decision points and relevant decisions that were made at the time which could inform future policy on recruitment and promotions.

Table 6 shows the key 6 benchmark individuals identified. These are individuals who each was used at least once as a comparator for setting targets for someone else. The three columns listed under 'Benchmark Index' show the sum of the optimal λ or z values for each benchmark individual as Model 3 was solved over the 38 academics in the assessment sample. Thus, the integer part of the index (plus 1 for any decimal part) shows respectively at least the number of times the person concerned was used as a benchmark for research output quality and rate, for initial salary and for mean annual salary. For all these individuals, we identify no scope to lower their cost per unit of research output. The table also shows the publications before and after recruitment of the individual, having converted them to A+ equivalent using 2 B publications as equivalent to 1 A^+ publication. Salary data though estimated within the analysis have here been further scaled for reasons of confidentiality. The same scaling constant was used for initial and annual mean salary to enable comparison of the two. Citations are in units of 10. The adjusted publications post-appointment have been normalised on a confidential duration in post.

Table 6: Benchmark individuals and their performance in research pre-and post-appointment

	Benchmark index							
	Res output rate and quality	Initial salary	Mean annual salary	A^+ Equiv before	A^+ Equiv after (adj)	Citations	Initial Salary (scaled)	Mean annual salary (scaled)
Person 1	11.99	7.49	16.48	1.23	0.7	13.10	3.57	3.57
Person 2	8.38	10.79	5.97	1.80	3.8	40.40	3.57	3.83
Person 3	3.38	5.12	1.64	6.67	4.35	95.10	4.09	5.81
Person 4	2.91	3.46	2.35	1.71	3.76	26.30	4.09	5.33
Person 5	2.37	3.05	1.70	2.89	0.11	13.70	4.09	4.39
Person 6	2.33	1.02	3.63	1.84	2	23.70	4.09	4.09

Person 1, used most frequently (12 times on research output and even more on mean annual salary) is perhaps not an obvious benchmark. His/her publications record declines after appointment. However, his/her use as a benchmark may be the result of having one of the lowest pre- and post-recruitment salaries and a fair profile if pre- and post-appointment research is set against a short duration in post. Person 2 has closer to a profile we would expect for a benchmark. In post, he/she has improved their research output while their salary rise has been only 7.3%. Person 3 has a stable pre- and post-recruitment research output. He/she is a good example of output and initial salary but not so for promotion (used only about twice as benchmark on post appointment salary). This is because his/her salary has risen by 42% post appointment. The person offers by far the best citations record. Person 4 has a significant improvement in their research post appointment. Their mean annual salary shows a corresponding significant increase. The last 2 persons show a deterioration in research output over time but their duration in post is relatively short. They are needed it would appear as benchmarks for initial and mean annual salary respectively.

In summary, the six individuals with the highest benchmark indices, are used either to benchmark the research output of others or to benchmark their salary. The method trades off research output with salary to minimise the cost of research. In a real-life context, internal review of the benchmarks would be much more meaningful without the constraint of confidentiality. The institution would be able to review the cases to identify what were good and what not so good about the decisions made at the time of their appointment so far as financial considerations are concerned. For example, person 6 might have come in at a higher than need have been the case salary while person 3 might have been promoted too soon and hence their mean annual salary is not attractive as a benchmark for others.

6. Conclusion

This paper has developed an approach which universities can use to assess retrospectively the efficacy of their recruitment and promotion practices for those where the key criterion for recruitment and promotion is anticipated performance in research. There is generally a long lead time between the conduct of research and its appearance in the form of published output. Thus, academic institutions at the recruitment stage offer salary levels on the prospect of quantity and quality of research output they perceive the academic concerned will deliver in post. The economic efficiency of the judgments made can only be ascertained in retrospect after those recruited have had a period of time in post to deliver the research expected of them. This paper has developed an instrument for this purpose and illustrates its use on realistic data (for confidentiality reasons) from a University in Greece.

The DEA model developed is applied at person level. Ideally it should set the salary component that relates to the research outputs of the person concerned against the quantity and quality of that research. However, as research specific components of salary are typically not available for academics, a uniform proportion of the salary of each academic can be used without detriment to the findings of the model provided contractually the persons being compared are required to deliver on research in the same manner across their full portfolio of duties. Research outputs by the individual are treated differently depending on whether they had appeared prior to recruitment at the institution or after. The latter are deemed more valuable in terms of promoting the prestige of the home institution. Further, research outputs are divided for quality. There is no consensus on how to judge quality of research. The paper adopts the practice of using the ranking of the journals where research has appeared as a proxy for its quality. However, an institution can use its own measures of quantity and quality of research outputs within the broader type of model developed here. The DEA model constructed is non-linear minimising the cost in the form of aggregate product of salary and time taken to deliver the research.

The use of the model is illustrated using data on 38 academics who had spent a minimum of 3 years in an academic department of a Greek University. The data for reasons of confidentiality are realistic rather than actual. The paper illustrates how the institution can estimate retrospectively the scope for savings of the attained research outputs and thereby draw lessons from the recruitment and promotions policies practiced hitherto. Such lessons are not so much for making economies going forward. Rather, the financial information is a proxy for the mismatch, if any, between expectations of research output and research actually delivered, consequent on the recruitment and promotion policies practiced. Such information can be used to streamline recruitment and promotion policies going forward better with the institution's objectives on research output by its academic staff.

In the case of the illustrative data analysed some of the key findings are:

- The institution is recruiting progressively better qualified staff in terms of research offered at appointment and subsequent research delivered. However, salary offered at appointment does not reflect the significant differential in research between the better qualified staff at recruitment who go on to deliver better research in post. This could be demotivating for staff able to deliver good research outputs.
- Promotions appear to match longevity in post better than they do research output. As in the case of salary at appointment there is clear mismatch between research delivered in post and promotions as reflected in mean annual salary post appointment. This again can prove counter-productive for the research culture of the institution.
- The key reason a mismatch is found between research outputs and financial rewards is not the level of salary at appointment or indeed at promotion. Rather it is the rate of research output. This has implications for recruitment and for promotion policies in terms of motivating staff to a higher rate of research output.
- Publications prior to appointment do tend to be associated with a better publications record post appointment but only where pre-appointment publications pass a certain threshold. The identification of the threshold could help make more productive appointments where research is concerned.

The approach developed in the paper can be applied by an academic institution where research is a key criterion for recruitment, to monitor the effectiveness of its recruitment and promotion policies as they evolve. The model developed is a generic one. It can be adapted to the legal framework where the institution is located (e.g. restricting the γ values so as not to permit salary below the legal minimum for each level of post, or by not permitting salary reduction overtime), or constraining the θ values so as to allow for a minimum duration, consistent for example for any probationary period for new staff. Moreover, the institution may wish to judge its staff against absolute attainment levels rather than relative ones. For example, it can include within the observations 'ideal' staff who would have produced research output of quality and quantity and within a time frame it would deem ideal. Where these ideal targets exceed observed data, they would be used as benchmark within the framework of the DEA model and the findings will then reflect how effective the institution's recruitment and promotion policies are relative to the ideal targets. This of course means the ideal targets would need to be carefully crafted to be realistic and attainable and within the legal context of the institution.

Another refinement of the generic model would be to set the standard below that of the very top performers in research when assessing recruitment and promotion practices. For example, the 12 benchmark individuals depicted in Figure 1 can each be assessed in turn relative to the rest of the sample but without permitting the individual being assessed to also be a potential benchmark. This is the spirit of the so-called "super-efficiency" model of Andersen and Petersen (1993) adapted to the framework of Model 3. The model would need to allow for θ_2 to exceed 1 in C3.15 so that the cost of the academic concerned could exceed their observed salary cost in post, reflecting the potential for such person to earn a salary in excess of what they were in fact paid. Subjectively then a proportion (e.g. 5%) of the cohort showing the highest potential salary in this manner could be excluded from being benchmark so that potential savings for all the rest are estimated relative to the remaining STRA staff in the sample. (For an illustration of using super-efficiency models to lower targets for school pupils in this manner see Thanassoulis, 1999). We have not gone down this avenue but it is clearly an option in the implementation of Model 3. This avenue could be pursued for example if it is deemed some exceptional performers in research, perhaps who were not paid as much as they might

have deserved, should not be used to set standards by which to judge the financial efficacy of institution's recruitment and promotion practices.

Once the regal and institutional framework has been integrated along with any ideal targets within the model, it can be run using data on existing and past academic staff in order to explore the implications of past recruitment and promotion policies and draw lessons for the future.

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