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Article

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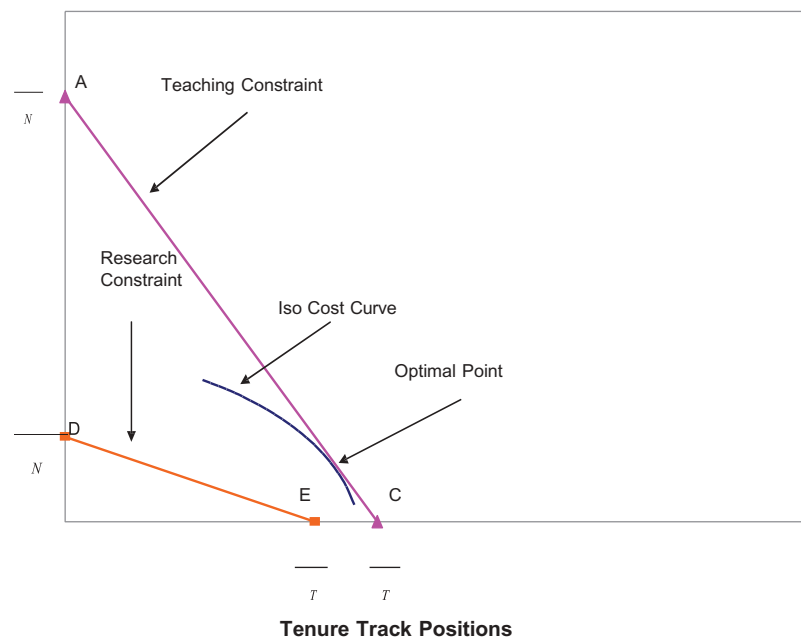


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Recruitment strategies in a university institution: a theoretical cost minimization approach

Iddrisu Awudu^{1*}, Saravanan Kuppasamy², Mario Norbis¹ and Matthew O'Connor³

Abstract: We study faculty recruitment issues in a university. We develop a cost minimization model that considers the decision-making process for the university administration by proposing a new approach of selecting tenure and non-tenure track faculty who are expected to achieve the institutional research and teaching goals. We explain the existence of tenure from an economic perspective. We propose a faculty tenure-granting process for a variety of institutions ranging from pure-teaching, teaching emphasis, research emphasis and pure-research institutions. We find that a teaching-emphasis or a pure-teaching institution (a research-emphasis or a pure-research institution) can increase the emphasis on research (teaching) without increasing costs. This paper makes important contributions to the university recruitment strategy by providing a set of guidelines on how to manage teaching and research incentives. The paper also contributes to the ongoing debate about tenure by providing a newer perspective and to the general theory of strategic university management.

Subjects: Economics, Finance, Business & Industry; Educational Research; Higher Education

Keywords: academic recruitment; tenure; economics; faculty appointments



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ABOUT THE AUTHOR

Mario Norbis is a Professor of Management Department at Quinnipiac University in Hamden, CT. He earned a B.S. in Chemical Engineering from the University of Uruguay, an M.S. in Industrial Engineering and Operations Research from University of Massachusetts and a Ph.D. from University of Massachusetts. His areas of expertise include mathematical modeling, production and operations analysis and supply chain management. Dr. Norbis has authored several publications in multidisciplinary areas including optimization models, production, business education and education administration. Dr. Norbis has a rich industry background having worked for Shell Oil Company and manufacturing companies. Professor Norbis and his co-authors work on research related to operations research, finance, supply chain optimization and logistics & transportation. The research in this paper relates to current decision making in academia and for that matter general recruitment strategies in academic settings.

PUBLIC INTEREST STATEMENT

Historically, tenure constitutes one of the pillars of academic life. However, the existence of tenure has been subjected to debate. The proponents and critics of tenure inside and outside the University, cite benefits and disadvantages. We contend that if tenure was as problematic as its critics claim, we expect university administrators to engage in a more coordinated and aggressive campaign to eliminate it. On the contrary, college administrators continue to hire faculty into tenure track positions and regularly award tenure to large numbers of faculty. Motivated by the above, we explore the economic factors that drive the faculty selection and tenure-granting process of a university administration. The result of our study shows that hiring a combination of tenure and non-tenure faculty can satisfy the goals of the institution at a minimum cost.

1. Introduction

Promoting inquiry and advancing human knowledge is one of the key purposes of an academic institution. Recruitment, promotion and the granting of tenure are the main components in the achievement of this purpose. However, the existence of tenure has been subjected to debate. The proponents of tenure cite a wide range of benefits, which includes academic freedom for faculty and imposition, maintenance, improvement of performance and collegiality standards for the university administration. On the other hand, critics contend that tenure offers protection for incompetent faculty and impedes innovation. If tenure was as problematic as its critics claim, we expect university administrators to engage in a more coordinated and aggressive campaign to eliminate it. On the contrary, college administrators continue to hire faculty into tenure track positions and regularly award tenure to large numbers of faculty. Motivated by the above, we explore the economic factors that drive the faculty selection and tenure-granting process of a university administration.

Typically, a university establishes strategic goals that can be translated into measurable research and teaching objectives. To achieve these objectives, the university must use its critical resource, faculty. In our model, the university administration considers two types of faculty: tenure and non-tenure track faculty. Although both types of faculty contribute to university objectives, they differ in the wages paid, job security, teaching and research productivity. For instance, tenure track faculty accepts increased job security in exchange for lower wages while non-tenure track faculty accepts reduced job security in exchange for higher wages, Faria, Loureiro, Mixon, and Sachsida (2013). Also, non-tenure track faculty is expected to have higher research productivity and lower teaching load than tenure track faculty. In addition, the university incurs search costs in administering the faculty hiring process. Therefore, it is important to analyze all these factors that influence the selection of tenure and non-tenure track faculty. To this purpose, we develop a quadratic optimization model to which a Lagrangian Relaxation is applied and Kuhn–Tucker conditions provide solutions to the resulting system of equations.

Our first contribution is in developing a model that enables an analysis of the underlying factors that influence the hiring process of a university administration. In this model, the key decision is to select a combination of tenure and non-tenure track faculty with the objective of minimizing the cost incurred to the university while achieving teaching and research goals. Our second contribution is characterizing the selection of faculty in terms of problem parameters such as the teaching and research goals, hiring costs, and wages. We find that emphasizing research goals increases the selection of non-tenure track faculty and on the other hand, emphasizing teaching goals increases the selection of tenure track faculty. Our third contribution is in extending the model to capture the operational characteristics of universities based on the research and teaching requirements. Carmichael (1988) shows that tenure is a rational hiring strategy for universities. We extend this line of research to develop an economic model of tenure that applies to a broader range of academic institutions, from pure teaching to pure research institutions. In addition, we provide university administrations with a set of guidelines on how to manage teaching and research incentives to achieve their goals. By taking tenure analysis out of the political and moral arenas and placing it squarely in the realm of economics, we believe our model contributes substantially to the literature and the overall debate regarding tenure. Our assumptions, some of them counterintuitive but realistic, set our approach aside from the more intuitive stream. For example, by “non-tenure” we do not mean “adjunct faculty” but rather specialized/researchers under contract. This type of hiring is observable in high research institutions like Columbia University or Yale University (Top Tier I research institutions).

The rest of this paper is organized as follows: Section 2 summarizes the relevant literature; Section 3 develops the model and presents the results; Section 4 analyzes the results and Section 5 concludes with a general discussion, managerial insights and an outlook on further research.

2. Literature review

Recruitment, promotion and the granting of tenure is a complex, multifaceted, socio-political practice and many papers have been devoted to understanding the existence of tenure from various perspectives, see Chait (2002) for a review. We broadly categorize these viewpoints into three groups: (i) historical – which traces the history and justification of tenure (see, Helms, Williams, & Nixon, 2001; Alchian, 1953), (ii) socio-political- which provides social and economic outlook of tenure for the faculty and academic institution (see, Antony & Raveling, 1998) and (iii) economical – which argues the benefits of tenure to an academic institution (see, Faria et al., 2013; Carmichael, 1988; Bleau, 1981; Zhang and Liu (2010)).

From the historical perspectives of tenure, Lewis (1980) argues the need to protect the academic freedom of both teacher and student while ensuring minimal performance standards and compatibility. Kuh and Whitt (1988) and Blackburn and Lawrence (1995) emphasize the historical importance of compatibility and collegiality to faculty. Brown (1997) analyzes the tenure problem and contends the university boards have a stake in the practice of tenure. Also, the author claims the university structure creates agency problems that administrators may exploit for personal gain; but, the tenure provides protection for faculty and reduces agency costs.

The socio-political gains for both faculty and institution have been discussed in the literature. Aigner (1993) suggests tenure protects underperforming faculty. Dnes and Seaton (2001) analyze the efficient management of universities with respect to tenure track. Also, the literature on post-tenure review has been growing. Trachtenberg (1996), Harris (1997), and Licata and Morreale (1997) question post-tenure performance evaluations. On the other hand, Goodman (1994) and O'Meara (2004) find positive outcomes from post-tenure review.

Recently, Zhang, Bao, and Sun (2016) analyze the relationship between various input factors (e.g. human resources, research expenditures, research equipment) and research production at research universities in China, by integrating insights from organizational theory and economics of higher education. Authors collect data from 72 institutions in every year between 2000 and 2010. Data elements included student enrollment, faculty employment, revenues and expenditures, and number of research articles published. Further, they disaggregate the data by science and engineering (SE) and non-science and engineering (non-SE). Authors find distinct patterns of research production between SE and non-SE fields. For instance, in SE, research equipment and expenditures are critical elements in addition to researchers, while the production of research in non-SE seems mainly dependent upon human resources.

As the tenure guarantees the job for faculty, it is argued that the protection offered by the tenure motivates faculty to undertake risky, innovative research. Brogaard, Engelberg, and Van Wesep (2018) study whether faculty respond to receiving tenure by attempting more innovative or ground-breaking research. They collect all academics who pass through economics or finance departments at top 50 US schools from 1996 through 2014. From the sample of over 2,000 faculty, authors consider two variables in the years before and after each academic receives tenure: the total number of publications and the number of ground-breaking publications. Authors find that the average number of annual publications and the number of ground-breaking publications fell significantly after tenure was granted. Authors conclude that by not sustaining the research effort after the tenure, the faculty from economics/finance did not appear to respond to the greater professional and intellectual freedom.

In the economic literature, Carmichael (1988), Sowell (1993) and Whicker (1997) has developed economic models of tenure from the perspectives of different stakeholders including faculty, the administration, students, and parent. They analyze incentive alignment within academic hiring practices. Faria et al. (2013) and Chatterjee and Marshall (2014) test models for tenure and promotion in different types of institutions. Our work is closely related to Carmichael (1988) and Faria et al. (2013) but we provide further perspectives on wider institutions. Carmichael (1988) provides

a modeling framework by considering an academic department as an internal labor market. Carmichael's analysis is consistent with other aspects of the academic environment including academic appointments; contract buy-outs, early retirement plans, and, the impact of budget crunch (e.g. elimination of an entire department). The results from Chen and Lee (2009) and Carmichael (1988) can be extended to other organizations in which members have an input into hiring process.

Our research is motivated by the multifaceted challenges of decision-making during hiring faculty in an academic setting. We model for a one-time period the decision-making process of four different types of institutions (pure research, research emphasis, teaching emphasis and pure teaching) when deciding how many faculties of two different types (tenure and non-tenure track) to hire in a given period of time. The objective is to minimize the total cost (hiring and wages) while providing students with needed courses and increasing the prestige of the institution through scholarship. Our study differs in the following ways from the previous literature: (i) we develop a conventional modeling framework which analyses underlying factors in the hiring process of a university administration, (ii) we address the hiring process within a broader range of institutional settings, and (iii) we provide the university administration a set of guidelines on how to manage teaching and research incentives (see Mesak & Jauch, 1991). In the next section, we provide the model assumptions and framework in terms of the type of institutions we analyze and the faculty the institution hires.

3. Model development

In this section, develop a model that considers the decision-making process of a university administration which includes a selection of tenure and non-tenure track faculty who are expected to achieve their research and teaching goals. We explore whether the decision to offer tenured positions is a rational economic choice on the part of the university administration. We impose no moral, legal, or bargaining restrictions on the university administration's ability to offer non-tenure track positions. We refer to *non-tenure track* as full-time faculty who are associated with research and yearly-renewal contracts; but, not as adjunct positions. We first list the model's assumptions and parameters. Note that this model can be extended to capture the operational characteristics of universities based on the research and teaching requirements (see, Section 4).

3.1. Assumptions and parameters

- We assume the strategic goals of a university can be translated into measurable research and teaching requirements. To meet these requirements, the university considers recruiting and using its critical resource, faculty. The faculty meets the university requirements with their teaching and research. We quantify faculty costs (including hiring and wages) as well as teaching and research requirements (Lee et al., 1987). Let, Θ and Γ be minimum university's research output required per period and minimum number of classes that must be taught per period, respectively.
- We differentiate teaching and research output for faculty categories: tenure and non-tenure track (Barnett, 1992). Let, Θ_N and Θ_T be average research output of a non-tenure track and a tenure track faculty per period, respectively. Also, let, Γ_N and Γ_T be the average number of classes taught by a non-tenure track and a tenure track faculty per period, respectively. Given a reasonable level of job security and compensation, typically, some faculty prefer to teach and be rewarded for teaching rather than to seek an increased pay in exchange for additional research productivity (Faria et al., 2013; Leslie, 2002). In addition, differences in research outputs suggest that tenure decreases faculty research productivity (Antony & Raveling, 1998). Further, *ceteris paribus*, tenure is more likely to be associated with teaching-oriented faculty rather than with research-oriented faculty. Therefore, in our model, we assume tenure track faculty has higher teaching loads and lower research requirements than non-tenure track faculty, i.e., $\Gamma_T > \Gamma_N$ and $\Theta_N > \Theta_T$. It follows, $\Gamma/\Gamma_T < \Gamma/\Gamma_N$ and $\Theta/\Theta_N < \Theta/\Theta_T$.
- Let W_N and W_T be wage rates of a non-tenure and tenure track faculty per period, respectively. We assume tenure track faculty accepts increased job security in exchange for lower wages while non-tenure track faculty accepts reduced job security in exchange for higher wages.

- We consider the search costs incurred by the university administration. The search costs are not linearly proportional to the number of faculty recruited due to the effort involved and administrative costs and it is reasonable to represent the effort involved by a quadratic function (Hamermesh, 1993; Hamermesh & Pfann, 1996). Let, K_N and K_T be adjustment costs for hiring a non-tenure track and tenure track faculty, respectively.

3.2. Decision variables and model formulation

Q_T = number of tenure track faculty hired

Q_N = number of non-tenure track faculty hired

$$\text{Min } C = Q_N W_N + Q_T W_T + \frac{K_N}{2} (Q_N)^2 + \frac{K_T}{2} (Q_T)^2 \tag{1}$$

$$\text{S.T. } Q_N \Theta_N + Q_T \Theta_T \geq \Theta \tag{2}$$

$$Q_N \Gamma_N + Q_T \Gamma_T \geq \Gamma \tag{3}$$

$$Q_N \geq 0 \tag{4}$$

$$Q_T \geq 0 \tag{5}$$

3.3. Methodology

In this section, we describe the methodology followed to solve the cost minimization model. The developed model is a parameterized quadratic optimization model consisting of a quadratic objective function, two decision variables, two linear constraints and two non-negativity constraints. So, as we apply a Lagrangian Relaxation to this model, we utilize four multipliers (λ) that with the two original decision variables ($Q_N, Q_T,$) result in six variables. We take the partials of the Lagrangian and equal each of them to zero, the optimality condition, ending up with a linear system of six equations and six variables. We apply the Kuhn–Tucker conditions. Typically, the solution involves assuming some of the constraints to be binding and the rest nonbinding and solve for $Q_N, Q_T,$ and λ 's. Seven solutions are developed for seven cases that follow and which optimal outcomes are summarized in Table 1.

Seven cases are generated that represent possible alternatives for the administration to fulfill its teaching and research requirement at minimum cost. Each one of these cases is represented graphically and variation of them are analyzed, for instance, alternatives to manage slack—teaching or research—resources. Finally, each case is discussed as of how much they represent

Table 1. Optimal solutions for the Lagrangian relaxation

Case	Binding Output Constraint	Binding Non-Negativity Constraint	Optimal Number of Non-Tenure track Faculty	Optimal Number of Tenure track Faculty
(i)	Teaching	Q_T	$Q_N^* = \frac{\Gamma}{\Gamma_N}$	$Q_T^* = 0$
(ii)	Teaching	Q_N	$Q_N^* = 0$	$Q_T^* = \frac{\Gamma}{\Gamma_T}$
(iii)	Research	Q_T	$Q_N^* = \frac{\Theta}{\Theta_N}$	$Q_T^* = 0$
(iv)	Research	Q_N	$Q_N^* = 0$	$Q_T^* = \frac{\Theta}{\Theta_T}$
(v)	Teaching	none	$Q_N^* = \frac{\Gamma K_T \Gamma_N + W_T \Gamma_T \Gamma_N - W_N \Gamma_T^2}{K_N \Gamma_T^2 + K_T \Gamma_N^2}$	$Q_T^* = \frac{\Gamma K_N \Gamma_T + W_N \Gamma_N \Gamma_T - W_T \Gamma_N^2}{K_N \Gamma_T^2 + K_T \Gamma_N^2}$
(vi)	Research	none	$Q_N^* = \frac{\Theta K_T \Theta_N + W_T \Theta_T \Theta_N - W_N \Theta_T^2}{K_N \Theta_T^2 + K_T \Theta_N^2}$	$Q_T^* = \frac{\Theta K_N \Theta_T + W_N \Theta_N \Theta_T - W_T \Theta_N^2}{K_N \Theta_T^2 + K_T \Theta_N^2}$
(vii)	Teaching & Research	none	$Q_N^* = \frac{\Theta \Gamma_T - \Gamma \Theta_T}{\Gamma_T \Theta_N - \Gamma_N \Theta_T}$	$Q_T^* = \frac{\Gamma \Theta_N - \Theta \Gamma_N}{\Gamma_T \Theta_N - \Gamma_N \Theta_T}$

observed situations in the four types of universities. A step by step algorithm to solve the developed model is provided below:

3.3.1. Algorithmic steps

- Step 1:** Set up the objective function and constraints, i.e. quadratic objective function and linear constraints
- Step 2:** Use the Lagrangian Relaxation to relax constraints (2) through (5) by using the Lagrangian Multipliers $\lambda_1, \lambda_2, \lambda_3$ and λ_4
- Step 3:** Determine the partial derivatives of the relaxed equations, which will lead to six equations, i.e. two original equations and four new equations containing the Lagrangian multipliers $\lambda_1, \lambda_2, \lambda_3$ and λ_4
- Step 4:** Equate the partial derivatives to zero and apply the Kuhn–Tucker conditions.
- Step 5:** In the Kuhn–Tucker conditions, we assume binding and non-binding constraints to solve the resulting problem
- Step 6:** We then determine the solutions from the equations which result in seven cases with optimal outcomes
- Step 7:** We apply the seven conditions to the four different types of institutions in consideration

3.4. Results

In this section, we discuss the results of the model by utilizing the Lagrangian Relaxation Methodology and considering the hiring options available to the university. We first define the *Lagrangian Relaxation* of the model presented in Section 3.2 relative to constraints (2), (3), non-negativity constraints (4), (5) and a non-negative vector λ to be,

$$\begin{aligned}
 J = & Q_N W_N + Q_T W_T + \frac{K_N}{2} (Q_N)^2 + \frac{K_T}{2} (Q_T)^2 \\
 & + \lambda_1 (\Theta - Q_N \Theta_N - Q_T \Theta_T) \\
 & + \lambda_2 (\Gamma - Q_N \Gamma_N - Q_T \Gamma_T) \\
 & + \lambda_3 (0 - Q_N) + \lambda_4 (0 - Q_T)
 \end{aligned} \tag{6}$$

The model has research, teaching and non-negativity constraints. It is possible that some of the constraints are binding (i.e., left-hand side of an equation is equal to the right-hand side of the same equation) and the rest of the constraints are nonbinding. The cases where constraints may or not be binding are often referred to as *Kuhn – Tucker conditions* (Ruszczynski, 2006). The following are Kuhn–Tucker conditions for the above Lagrangian relaxation:

$$L_{Q_N} = W_N + K_N Q_N - \lambda_1 \Theta_N - \lambda_2 \Gamma_N - \lambda_3 \leq 0; \quad Q_N \geq 0, \quad Q_N L_{Q_N} = 0 \tag{7}$$

$$L_{Q_T} = W_T + K_T Q_T - \lambda_1 \Theta_T - \lambda_2 \Gamma_T - \lambda_4 \leq 0; \quad Q_T \geq 0, \quad Q_T L_{Q_T} = 0 \tag{8}$$

$$L_{\lambda_1} = \Theta - Q_N \Theta_N - Q_T \Theta_T \leq 0; \quad \lambda_1 \geq 0; \quad \lambda_1 L_{\lambda_1} = 0 \tag{9}$$

$$L_{\lambda_2} = \Gamma - Q_N \Gamma_N - Q_T \Gamma_T \leq 0; \quad \lambda_2 \geq 0; \quad \lambda_2 L_{\lambda_2} = 0 \tag{10}$$

$$L_{\lambda_3} = Q_N \geq 0; \quad \lambda_3 \geq 0; \quad \lambda_3 L_{\lambda_3} = 0 \tag{11}$$

$$L_{\lambda_4} = Q_T \geq 0; \quad \lambda_4 \geq 0; \quad \lambda_4 L_{\lambda_4} = 0 \tag{12}$$

In the above set of conditions, there are six equations ($L_{Q_N}, L_{Q_T}, L_{\lambda_1}, L_{\lambda_2}, L_{\lambda_3}, L_{\lambda_4}$) and six unknowns ($Q_N, Q_T, \lambda_1, \lambda_2, \lambda_3, \lambda_4$). Typically, the solution involves assuming some of the constraints to be binding and the rest nonbinding and solve for Q_N, Q_T , and λ 's. Seven solutions are developed for seven cases that follow and which optimal outcomes are summarized in Table 1. Below, we provide a list of seven different cases for our solutions.

Case i. For this case, we assume that the non-negativity number of tenured faculty constraint (5) is binding,

$$Q_T^* = 0$$

i.e., $L\lambda_4 = 0$. Since $\lambda_4 \cdot L\lambda_4 = 0$, $\lambda_4 > 0$.

we also assume teaching output constraint (3) is binding,

$$Q_N\Gamma_N + Q_T\Gamma_T = \Gamma$$

i.e., $L\lambda_2 = 0$. Since $\lambda_2 \cdot L\lambda_2 = 0$, $\lambda_2 > 0$.

We also assume that research output constraint (2) and non-negativity number of non-tenured faculty constraint (4) are non-binding,

$$Q_N\Theta_N + Q_T\Theta_T \geq \Theta$$

i.e., $L\lambda_1 < 0$. Since $\lambda_1 \cdot L\lambda_1 = 0$, $\lambda_1 = 0$.

$$Q_N \geq 0$$

i.e., $L\lambda_3 < 0$. Since $\lambda_3 \cdot L\lambda_3 = 0$, $\lambda_3 = 0$.

Now, replacing $Q_T = 0$ in teaching output constraint (3) we obtain

$$Q_N\Gamma_N = \Gamma$$

from where

$$Q_N^* = \frac{\Gamma}{\Gamma_N}$$

Case ii. For this case, we assume that the non-negativity number of non-tenured faculty constraint (4) is binding,

$$Q_N^* = 0$$

i.e., $L\lambda_3 = 0$. Since $\lambda_3 \cdot L\lambda_3 = 0$, $\lambda_3 > 0$.

we also assume teaching output constraint (3) is binding,

$$Q_N\Gamma_N + Q_T\Gamma_T = \Gamma$$

i.e., $L\lambda_2 = 0$. Since $\lambda_2 \cdot L\lambda_2 = 0$, $\lambda_2 > 0$.

We also assume that research output constraint (2) and non-negativity number of tenured faculty constraint (5) are non-binding,

$$Q_N\Theta_N + Q_T\Theta_T \geq \Theta$$

i.e., $L\lambda_1 < 0$. Since $\lambda_1 \cdot L\lambda_1 = 0$, $\lambda_1 = 0$.

$$Q_T \geq 0$$

i.e., $L\lambda_4 < 0$. Since $\lambda_4 \cdot L\lambda_4 = 0$, $\lambda_4 = 0$.

Now, replacing $Q_N = 0$ in teaching output constraint (3) we obtain

$$Q_T\Gamma_T = \Gamma$$

from where

$$Q_T^* = \frac{\Gamma}{\Gamma_T}$$

Case iii. For this case, we assume that the non-negativity number of tenured faculty constraint (5) is binding,

$$Q_T^* = 0$$

i.e., $L\lambda_4 = 0$. Since $\lambda_4 \cdot L\lambda_4 = 0$, $\lambda_4 > 0$.

we also assume research output constraint (2) is binding,

$$Q_N\Theta_N + Q_T\Theta_T = \Theta$$

i.e., $L\lambda_1 = 0$. Since $\lambda_1 \cdot L\lambda_1 = 0$, $\lambda_1 > 0$.

We also assume that teaching output constraint (3) and non-negativity number of non-tenured faculty constraint (4) are non-binding,

$$Q_N\Gamma_N + Q_T\Gamma_T \geq \Gamma$$

i.e., $L\lambda_2 < 0$. Since $\lambda_2 \cdot L\lambda_2 = 0$, $\lambda_2 = 0$.

$$Q_N \geq 0$$

i.e., $L\lambda_3 < 0$. Since $\lambda_3 \cdot L\lambda_3 = 0$, $\lambda_3 = 0$.

Now, replacing $Q_T = 0$ in the research output constraint (2) we obtain

$$Q_N\Theta_N = \Theta$$

from where

$$Q_N^* = \frac{\Theta}{\Theta_N}$$

Case iv. For this case, we assume that the non-negativity number of non-tenured faculty constraint (4) is binding,

$$Q_N^* = 0$$

i.e., $L\lambda_3 = 0$. Since $\lambda_3 \cdot L\lambda_3 = 0$, $\lambda_3 > 0$.

we also assume research output constraint (2) is binding,

$$Q_N\Theta_N + Q_T\Theta_T = \Theta$$

i.e., $L\lambda_1 = 0$. Since $\lambda_1 \cdot L\lambda_1 = 0$, $\lambda_1 > 0$.

We also assume that teaching output constraint (3) and non-negativity number of tenured faculty constraint (5) are non-binding,

$$Q_N\Gamma_N + Q_T\Gamma_T \geq \Gamma$$

i.e., $L\lambda_2 < 0$. Since $\lambda_2 \cdot L\lambda_2 = 0$, $\lambda_2 = 0$.

$$Q_T \geq 0$$

i.e., $L\lambda_4 < 0$. Since $\lambda_4 \cdot L\lambda_4 = 0$, $\lambda_4 = 0$.

Now, replacing $Q_N = 0$ in the research output constraint (2) we obtain

$$Q_T\Theta_T = \Theta$$

from where

$$Q_T^* = \frac{\Theta}{\Theta_T}$$

Case v. For this case, we assume that the teaching output constraint (3) is binding,

$$Q_N \Gamma_N + Q_T \Gamma_T = \Gamma$$

i.e., $L\lambda_2 = 0$. Since $\lambda_2 \cdot L\lambda_2 = 0$, $\lambda_2 > 0$.

We also assume research output constraint (2) is nonbinding

$$Q_N \Theta_N + Q_T \Theta_T \geq \Theta$$

i.e., $L\lambda_1 < 0$. Since $\lambda_1 \cdot L\lambda_1 = 0$, $\lambda_1 = 0$.

We also assume the non-negativity number of tenured faculty, and non-tenured faculty constraints are nonbinding,

$$Q_N > 0$$

i.e., $L\lambda_3 < 0$. Since $\lambda_3 \cdot L\lambda_3 = 0$, $\lambda_3 = 0$; and

$$Q_T > 0;$$

i.e., $L\lambda_4 < 0$. Since $\lambda_4 \cdot L\lambda_4 = 0$, $\lambda_4 = 0$.

Substituting $\lambda_1 = \lambda_3 = \lambda_4 = 0$ in Kuhn-Tucker conditions yields,

$$Lq_N = W_N + K_N Q_N - \lambda_2 \Gamma_N = 0 \tag{13}$$

$$Lq_T = W_T + K_T Q_T - \lambda_2 \Gamma_T = 0 \tag{14}$$

$$L\lambda_2 = \Gamma - Q_N \Gamma_N - Q_T \Gamma_T = 0$$

Solving for λ_2 ,

$$\lambda_2 = \frac{W_N + K_N Q_N}{\Gamma_N} = \frac{W_T + K_T Q_T}{\Gamma_T}$$

and now, solving for Q_N

$$Q_N = \frac{\Gamma - Q_T \Gamma_T}{\Gamma_N}$$

Substituting Q_N and solving for Q_T

$$Q_T^* = \frac{W_N \Gamma_N \Gamma_T + K_N \Gamma \Gamma_T - W_T \Gamma_N^2}{(K_N \Gamma_T^2 + K_T \Gamma_N^2)}$$

Now, replacing Q_T^* and solving for Q_N

$$Q_N^* = \frac{W_T \Gamma_N \Gamma_T + K_T \Gamma \Gamma_N - W_N \Gamma_T^2}{(K_N \Gamma_T^2 + K_T \Gamma_N^2)}$$

Case vi. For this case, we assume research output constraint (2) is binding,

$$Q_N \Theta_N + Q_T \Theta_T = \Theta$$

i.e., $L\lambda_1 = 0$. Since $\lambda_1 \cdot L\lambda_1 = 0$, $\lambda_1 > 0$.

We also assume teaching output constraint (3) is nonbinding,

$$Q_N \Gamma_N + Q_T \Gamma_T > \Gamma$$

i.e., $L\lambda_2 < 0$. Since $\lambda_2 \cdot L\lambda_2 = 0$, $\lambda_2 = 0$.

We also assume the non-negativity number of tenured faculty and non-tenured faculty constraints are nonbinding,

$$Q_N > 0$$

i.e., $L\lambda_3 < 0$. Since $\lambda_3 \cdot L\lambda_3 = 0$, $\lambda_3 = 0$; and

$$Q_T > 0;$$

i.e., $L\lambda_4 < 0$. Since $\lambda_4 \cdot L\lambda_4 = 0$, $\lambda_4 = 0$

Substituting $\lambda_2 = \lambda_3 = \lambda_4 = 0$ in Kuhn-Tucker conditions yields,

$$Lq_N = W_N + K_N Q_N - \lambda_1 \Theta_N = 0 \tag{15}$$

$$Lq_T = W_T + K_T Q_T - \lambda_1 \Theta_T = 0 \tag{16}$$

$$L\lambda_1 = \Theta - Q_N \Theta_N - Q_T \Theta_T = 0 \tag{17}$$

Solving for λ_1 yields

$$\lambda_1 = \frac{W_N + K_N Q_N}{\Theta_N} = \frac{W_T + K_T Q_T}{\Theta_T} \tag{18}$$

And now, solving for Q_N ,

$$Q_N = \frac{\Theta - Q_T \Theta_T}{\Theta_N} \tag{19}$$

Substituting Q_N and solving for Q_T

$$Q_T^* = \frac{W_N \Theta_N \Theta_T + K_N \Theta \Theta_T - W_T \Theta_N^2}{(K_N \Theta_T^2 + K_T \Theta_N^2)} \tag{20}$$

Substituting Q_T and solving for Q_N ,

$$Q_N^* = \frac{W_T \Theta_N \Theta_T + K_T \Theta \Theta_N - W_N \Theta_T^2}{(K_N \Theta_T^2 + K_T \Theta_N^2)} \tag{21}$$

Case vii. For this case, we assume research output constraint (2) is binding.

$$Q_N \Theta_N + Q_T \Theta_T = \Theta$$

i.e., $L\lambda_1 = 0$. Since $\lambda_1 \cdot L\lambda_1 = 0$, $\lambda_1 > 0$.

We also assume teaching output constraint (3) is binding

$$Q_N \Gamma_N + Q_T \Gamma_T = \Gamma$$

i.e., $L\lambda_2 = 0$. Since $\lambda_2 \cdot L\lambda_2 = 0$, $\lambda_2 > 0$.

We also assume the non-negativity number of tenured faculty and non-tenured faculty constraints are nonbinding,

$$Q_N > 0$$

i.e., $L\lambda_3 < 0$. Since $\lambda_3 \cdot L\lambda_3 = 0$, $\lambda_3 = 0$; and

$$Q_T > 0;$$

i.e., $L\lambda_4 < 0$. Since $\lambda_4 \cdot L\lambda_4 = 0$, $\lambda_4 = 0$.

Substituting $\lambda_3 = \lambda_4 = 0$ in Kuhn-Tucker conditions yields,

$$L_{Q_N} = W_N + K_N Q_N - \lambda_1 \Theta_N - \lambda_2 \Gamma_N = 0$$

$$L_{Q_T} = W_T + K_T Q_T - \lambda_1 \Theta_T - \lambda_2 \Gamma_T = 0$$

$$L_{\lambda_1} = \Theta - Q_N \Theta_N - Q_T \Theta_T = 0$$

$$L_{\lambda_2} = \Gamma - Q_N \Gamma_N - Q_T \Gamma_T = 0$$

We conclude with the following equations:

$$Q_T^* = \frac{W_N \Theta_N \Theta_T + K_N \Theta \Theta_T - W_T \Theta_N^2}{(K_N \Theta_T^2 + K_T \Theta_N^2)} \quad (22)$$

$$Q_N^* = \frac{W_T \Theta_N \Theta_T + K_T \Theta \Theta_N - W_N \Theta_T^2}{(K_N \Theta_T^2 + K_T \Theta_N^2)} \quad (23)$$

Table 1 summarizes the optimal solutions for these seven cases.

The university administration has three options that minimize the total sum of the wages and the hiring cost of faculty: (a) hire tenure track faculty only (corresponds to optimal solutions (ii) and (iv)), (b) hire non-tenure track faculty only (corresponds to optimal solutions (i) and (iii)), (c) hire a combination of tenure and non-tenure track faculty (corresponds to optimal solutions (v), (vi) & (vii)). In this way, we demonstrate that hiring tenured faculty is economically justifiable for the university administration. Next, we use this model to analyze how hiring decisions vary by different institutions.

4. Analysis

In this section, we analyze and extend the model and the results presented in the previous section to understand the influence of problem parameters such as research and teaching thresholds, Θ and Γ , on the university administration's decision-making process in hiring faculty. Carmichael (1988) showed that tenure is a rational hiring strategy for research-oriented universities. Under our assumptions, we provide alternative views to understand the hiring strategies for a variety of institutions. Therefore, without limiting the general applicability of our model, we examine our model considering four stylized (but recognizable) types of academic institutions: the pure teaching institution, the teaching emphasis institution, the research emphasis institution, and the pure research institution. The categorization of institutions based on Θ and Γ follows: A pure teaching institution has a very high Γ , and $\Theta \approx 0$ which implies a very high Γ/Θ ratio; a pure research institution has a $\Gamma \approx 0$, and very high Θ which implies a very low Γ/Θ ratio; a teaching emphasis institution has high Γ , and low Θ which implies a high Γ/Θ ratio and a research emphasis institution has a low Γ , and high Θ which implies a low Γ/Θ ratio. Table 2 presents an overview of the mathematical relationships between teaching and research thresholds and the institutional classifications described above.

As a result of our analysis, we derive the following insight:

A teaching emphasis or a pure-teaching institution (a research emphasis or a pure-research institution) can increase the emphasis on research (teaching) without increasing costs.

Table 2. A categorization of institutions		
Institution Type	Γ/Θ ratio	Example
Pure Teaching	Very High	Gateway Community College
Pure Research	Very Low	Los Alamos National Laboratory
Teaching-Emphasis	High	Quinnipiac University
Research-Emphasis	Low	Yale University

In the next four sub-sections, we illustrate the above insight by exploring a university administration’s options of managing resources and providing incentives to achieve its teaching and research objectives at these types of institutions.

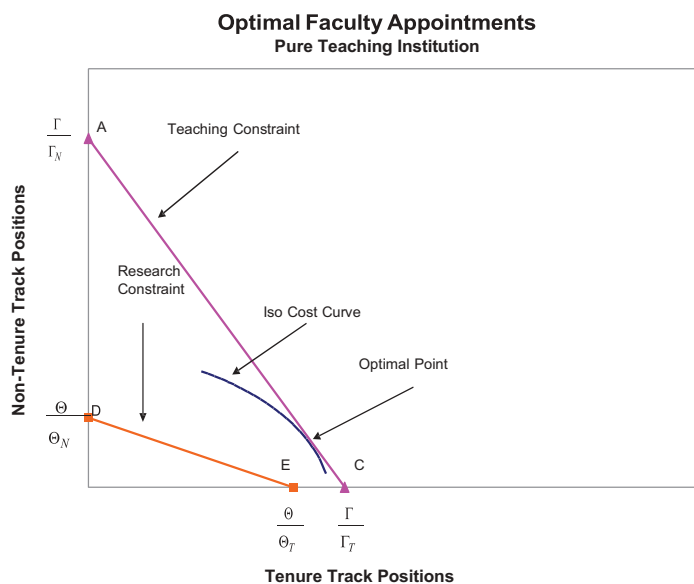
4.1. Pure teaching institution

In a pure teaching institution, the administration’s focus is entirely on teaching and the focus on the research goals is negligible to non-existent (e.g. a community college). In our model, we characterize this type of institution with a higher teaching requirement, Γ , and a very minimal research requirement, Θ , placed on both tenure and non-tenure track faculty. Note, Γ/Γ_T (Γ/Γ_N) represents the number of tenure track (non-tenure track) faculty, if only tenure track (non-tenure track) are hired to satisfy the teaching requirement, Γ . Similarly, Θ/Θ_T (Θ/Θ_N) represent the number of tenure track (non-tenure track) faculty, if only tenure track (non-tenure track) are hired to satisfy the research requirement, Θ . Given a very high Γ/Θ ratio, $\Gamma/\Gamma_T > \Theta/\Theta_T$ and $\Gamma/\Gamma_N > \Theta/\Theta_N$. We illustrate the decision-making process using the model presented in Section 3.2.

In Figure 1, the x-axis and y-axis represent the number of tenure and non-tenure track faculty hired, respectively. The research and teaching constraints, (2) and (3), are represented by line segments \overline{DE} and \overline{AC} respectively.

In this case, the pure teaching institution can achieve the teaching requirement with three options: (i) hire tenure track faculty only—which is represented by point C; (ii) hire non-tenure track faculty only—which is represented by point A; (iii) a combination of tenure and non-tenure track faculty—which is represented by a point on the line AC. On one hand, either when non-tenure track

Figure 1. Optimal solution—pure teaching.



faculty is getting paid much higher than tenure track faculty (i.e., a higher WN/WT ratio) or when the search costs for non-tenure track are higher than that for tenure track faculty (i.e., a higher KN/KT ratio), option (i) is the optimal solution for the university administration. On the other hand, when the aforementioned ratios are lower, option (ii) becomes the optimal solution. For example, option (ii) could be an optimal solution for a pure teaching institution operating in a large urban area where there is an excess supply of local PhDs and searching costs to hire a non-tenure track faculty are reasonably low. Lastly, when the ratios are in the middle, option (iii) becomes an optimal, which is represented by the intersection of the iso-cost curve and teaching constraint.

In what follows we analyze how to manage excessive research resources in a pure teaching institution. In a pure teaching institution, teaching constraint is active while research constraint is redundant, see Figure 1. In other words, an optimal mix of tenure and non-tenure track faculty is sufficient to satisfy the teaching requirement, Γ ; however, the same mix of faculty is excessive to satisfy the research requirement Θ . The institution has the following options to manage the excessive research resources: (I) increase minimum research output Θ and (II) decrease research output or expectations of both tenure and non-tenure track faculty, Θ_T and Θ_N , respectively. We illustrate the above options using Figure 2.

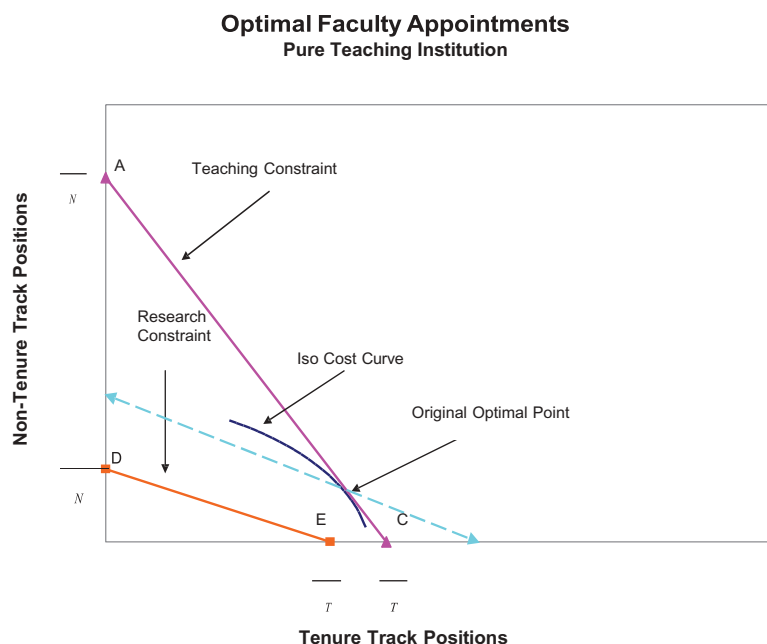
4.1.1. Option I

In this option, the university administration utilizes the excessive research resources by increasing the minimum research output, Θ . This example is typical in large state universities that are not research extensive but have high expectations for research. Also, prestige and the goodwill of the institution will increase with increased research expectations. Note, an increase in Θ , shifts the \overline{DE} segment parallel so that it becomes the dashed line, aligned with the iso-curve at the original optimal point, see Figure 2. However, when Θ increases and the dashed line shifts beyond the original optimal point indicated in Figure 2, the optimal solution changes and the hiring cost, i.e., objective function cost, increases. In other words, Θ has a restriction and cannot be increased infinitely without increasing the hiring costs.

4.1.2. Option II

In this option, the university administration reduces the research expectations of tenure and non-tenure track faculty, Θ_T and Θ_N , by redirecting their resources to teaching activities. For example,

Figure 2. Managing excessive research resources.



universities invite faculty to teach courses in summer which could reduce faculty’s potential to do summer research.

In summary, the university administration has options I and II to manage excessive research resources. While option I might improve the university’s perception or goodwill, it does not have a direct correlation with the objective function which is to minimize the overall cost. Also, redirecting resources from research to teaching does not seem to improve the bottom line.

4.2. Pure research institution

In a pure research institution, the teaching threshold, Γ , is dominated by the research focus (e.g. Los Alamos National Laboratory). In our model, we characterize this type of an institution with a higher minimum research output, Θ , and a very low minimum teaching output, Γ , for both tenure and non-tenure track faculty. Given a very low Γ/Θ , $\Gamma/T < \Theta/\Theta T$ and $\Gamma/TN < \Theta/\Theta N$

In this case, the institution can achieve the research requirement with three options: (i) hire tenure track faculty only-which is represented by point E in Figure 3; (ii) hire non-tenure track faculty only-which is represented by point D; (iii) a combination of tenure and non-tenure track faculty which is represented by a point on the line \overline{DE} . On one hand, when W_N/W_T or K_N/K_T are high, option (i) is the optimal solution for the university administration. Also, when the ratios are low, option (ii) becomes the optimal solution. Lastly, when the ratios are in between low and high, option (iii) becomes and optimal solution, which is represented by the intersection of the iso-curve and the research constraint.

In the next paragraph, we analyze how to manage excessive teaching resources in a pure research institution. In a pure research institution, research constraint is tight and teaching constraint is loose, see Figure 3. In other words, an optimal mix of tenure and non-tenure track faculty is sufficient to satisfy the minimum research output, Θ ; however, the same mix of the faculty is excessive to satisfy the minimum teaching output, Γ . In this case, the institution has the following options to manage excessive teaching resources: (i) increase minimum teaching output, Γ and (ii) decrease the number of classes taught by tenure and non-tenure track faculty, Γ_T and Γ_N . We illustrate the above options using Figure 4.

4.2.1. Option I

In this option, the university administration utilizes the excessive teaching resources by increasing the total number of classes taught, Γ . The administration can increase Γ by admitting more

Figure 3. Optimal solution—pure research.

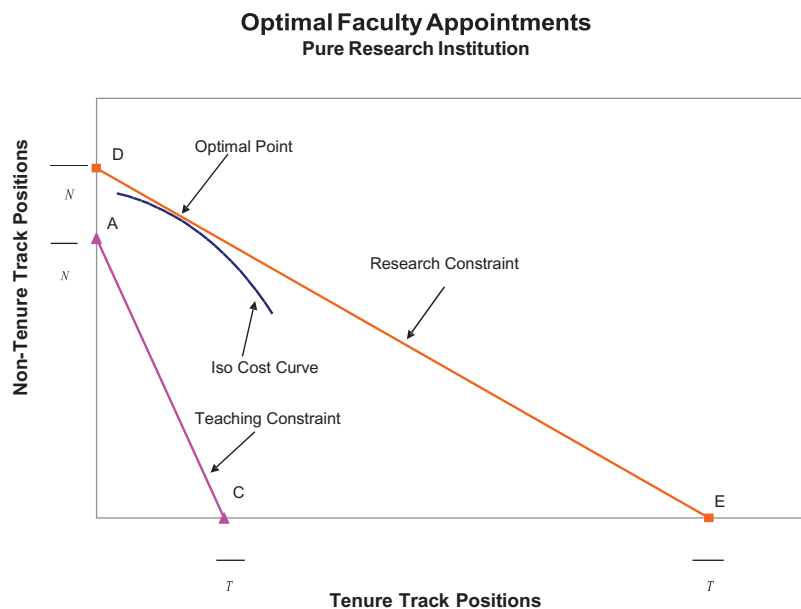
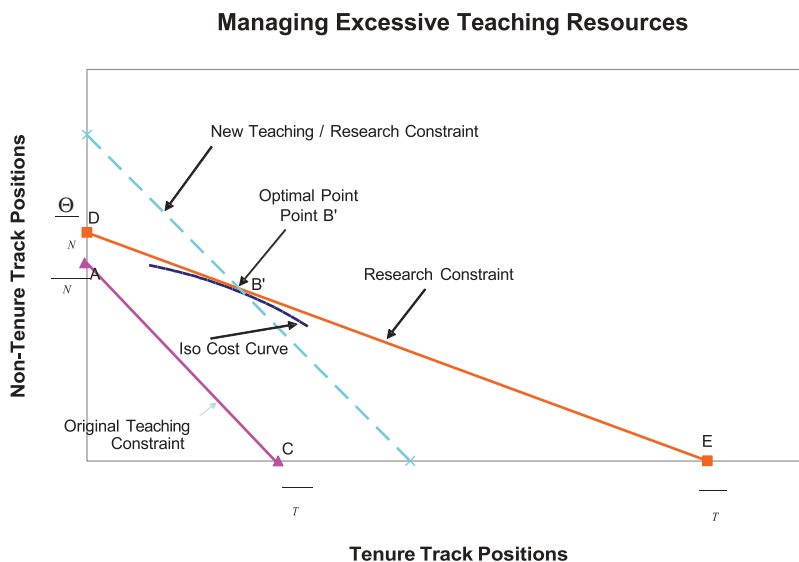


Figure 4. Managing excessive teaching resources.



students without increasing the average class size (e.g. a large state university increasing the student enrollment as public policies require to educate the population.) Also, the university administration can increase Γ by decreasing the average class size while keeping student enrollment constant (e.g. a private university reducing the class size to improve teaching quality or at least the perception of teaching quality as prospective students and their parents believe that smaller class sizes lead to better educational experiences.) Note, an increase in Γ shifts the line \overline{AC} parallel to the right, see Figure 4. However, when Γ increases and the dashed line shifts beyond the optimal point B' as indicated in Figure 4, the optimal solution changes and the cost, i.e. objective function cost, increases. In other words, Γ cannot be increased infinitely without increasing costs.

4.2.2. Option II

In this option, the university administration utilizes the excessive teaching resources by decreasing the number of classes taught by tenure and non-tenure track faculty, Γ_T and Γ_N . Note, Γ_T and Γ_N can be decreased such that B' in Figure 4 remains as the optimal solution, i.e., without increasing the hiring costs.

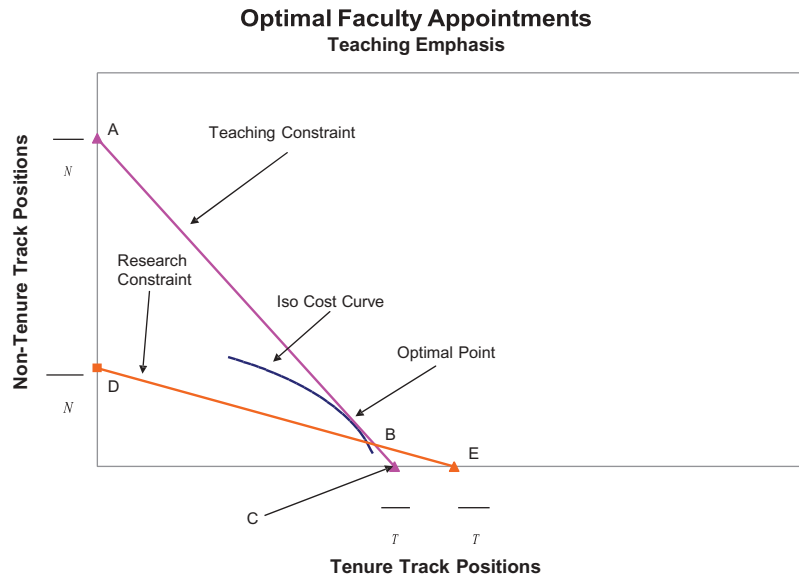
In summary, the university administration has options I and II to manage excessive teaching resources. While option II improves faculty welfare and moral since it reduces the class size taught by both tenure and non-tenure faculty, it does little to advance administration goals which is to minimize costs (or maximize profits). Therefore, it is reasonable to expect the administration to go with option I. Note, neither option incurs additional hiring costs for the university administration.

4.3. Teaching-emphasis institution

An institution with a teaching emphasis has a primary commitment to teaching but maintains a smaller, secondary commitment to research. In our model, we characterize this type of an institution with a high teaching requirement, Γ , and a low research requirement, Θ , for both tenure and non-tenure track faculty. A typical example is a small, four-year college, with predominantly or even exclusively undergraduate degrees (e.g. Quinnipiac University). A high Γ/Θ ratio, $\Gamma_T > \Gamma_N$ and $\Theta_N > \Theta_T$, implies the following: $\Gamma/\Gamma_T \geq \Theta/\Theta_T$ or $\leq \Theta/\Theta_T$ and $\Gamma/\Gamma_N > \Theta/\Theta_N$. Figure 5 illustrates the case when $\Gamma/\Gamma_T < \Theta/\Theta_T$. Note, when $\Gamma/\Gamma_T \geq \Theta/\Theta_T$ institutional emphasis becomes pure teaching (see, Section 4.1).

Similar to the case of pure teaching institution, if the ratios WN/WT and KN/KT are sufficiently large, only tenure track faculty will be hired, see point E in Figure 5. This is a very commonly observed hiring strategy for small teaching-oriented colleges. However, when the cost ratios fall, a combination of tenure and non-tenure track will be hired which is represented by the line

Figure 5. Optimal solution—teaching emphasis.

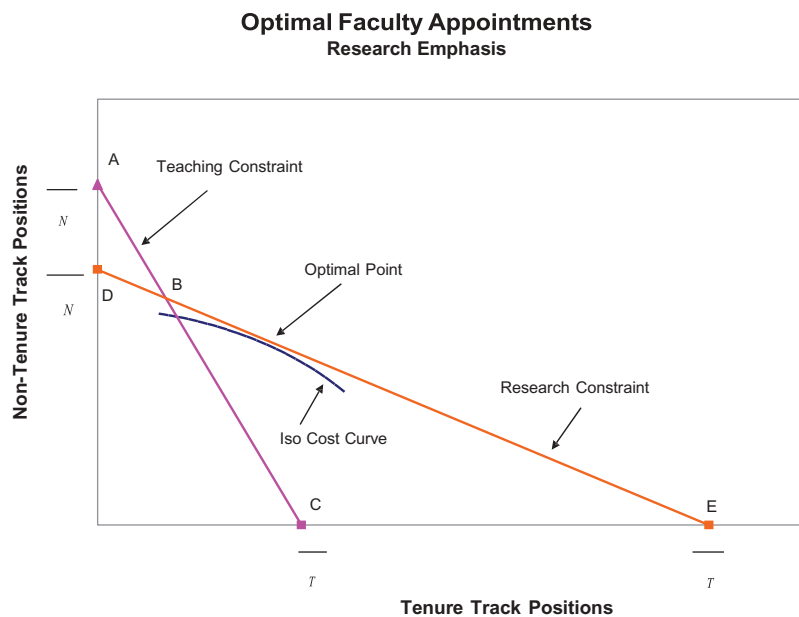


segment \overline{BE} and the lower portion of the line segment \overline{AB} . Note, if the institutional policies restrict the number of non-tenure faculty, the administration is coerced to hire more tenure track faculty which increases the cost incurred by the university.

4.4. Research-emphasis institution

An institution with a research emphasis has a primary commitment to research but maintains a smaller, secondary commitment to teaching (e.g. Yale University). In this institution, research is an integral component that is necessary for its accreditation and strategic commitment with teaching perceived as part of the institution’s cultural significance. In our model, we characterize this type of an institution with a high research requirement, Θ , and a low teaching requirement, Γ , placed on both tenure and non-tenure track faculty. A low Γ/Θ ratio, $\Gamma T > \Gamma N$ and $\Theta N > \Theta T$, implies the following: $\Gamma/\Gamma N \geq \Theta/\Theta N$ and $\Gamma/\Gamma T < \Theta/\Theta T$. Figure 6 illustrates the case when $\Gamma/\Gamma N > \Theta/\Theta N$. Note, when $\Gamma/\Gamma N \leq \Theta/\Theta N$ institutional emphasis becomes pure research (see, Section 4.2).

Figure 6. Optimal solution—research emphasis.



In both, teaching and research-emphasis institutions there may be research and teaching excessive resources, respectively. In both, teaching and research emphasis institutions, teaching and research constraints can be active. For instance, an optimal solution on \overline{BE} (see Figures 5 and 6) implies that the research constraint is active, and the teaching constraint is redundant; on the other hand, an optimal solution on \overline{AB} implies the vice-versa. Based on the location of the optimal solution, the options to manage the excessive resources will vary.

If the optimal solution is on \overline{BE} , the university administration has the same options as those of the pure-research institution, i.e. the administration can either increase the total number of classes taught, Γ , or decrease the number of classes taught by tenure and non-tenure track faculty, Γ_T and Γ_N (see options (i) and (ii) in section 4.2) in exchange for higher research output which is a typical method to incentivize faculty research. This seems to be a common tradeoff in professional schools seeking to increase research productivity in the pursuit of specialized accreditation. On the other hand, if the optimal solution is on \overline{AB} , the university administration has the same options as those of the pure-teaching institution, i.e. the administration can either increase the minimum research output required, Θ , or decrease the research output by tenure and non-tenure track faculty, Θ_T and Θ_N (see options (i) and (ii) in section 4.1).

5. Summary and conclusions

In this paper, we developed a model that considers the decision-making process of a university administration that includes a selection of tenure and non-tenure track faculty who are expected to achieve their research and teaching goals. We applied standard economic theory to develop a static, cost-minimizing model of faculty staffing practices. The model is preference free, relatively parsimonious, and applicable to a wide variety of institutional types, which include pure research, research-oriented, teaching-oriented and pure teaching institutions. We believe the parameterization (relative teaching and research outputs, wages, and search costs) of the model is supported in the literature as well as by casual observation.

Given the parameterizations of the model, we propose that cost-minimizing institutions will award tenure track positions but that the ratio of tenure track to non-tenure track decreases as the research threshold increases. In addition, regardless of research emphasis, we suggest that to the degree institutional policies restrict non-tenure track appointments, the efficiency of cost minimizing universities is impeded. We find that a teaching emphasis or a pure-teaching institution (a research emphasis or a pure-research institution) can increase the emphasis on research (teaching) without increasing costs.

The model is limited by its static nature. It also does not deal with faculty shirking, which to some may be the biggest detriment to tenure. However, we hope to address these issues in subsequent work.

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