THE FUTURE OF THE HIGHER EDUCATION ENTERPRISE: RESEARCH UNIVERSITIES TODAY AND TOMORROW, A COMPUTATIONAL APPROACH

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INTRODUCTION

Since at least the second world war, the top American research universities, both public and private, have enjoyed remarkable success, not only in capturing significant shares of the federal dollars available to support research but also in expanding their influence and significance within the context of American higher education. This success is reflected today in multiple ways from the growing undergraduate population seeking admission to these institutions to the prestige conferred by multiple ranking publications of varying methodological quality.

Yet over the past decades, as the financial circumstances of all colleges and universities have changed, with declining public tax-based support, increased tuition and fee structures, complex tuition discounting programs, sophisticated need-based financial aid mechanisms at the state and federal levels, accelerating costs of institutional operations, and competition for fee-paying international students, some worry that the research enterprises of these institutions may be at risk.

In addressing these issues, it is important to emphasize that American higher education is composed of quite distinct sectors. While they may have fuzzy boundaries, they are nonetheless substantially different in their organization, personnel composition, financial structures, opportunities, and expectations. Each of these sectors will respond to the current and likely future financial and demographic constraints by readjusting their operational models to meet changing public and private expectations in significantly different ways. Some will reconfigure their activities to acquire the efficiencies of sophisticated technologies and generate revenue by capturing currently under-served populations with low cost high volume enterprises. The traditional model of tenured professors defining the substance of the academic enterprise is already seriously modified at many institutions below the most prestigious and the ability of many universities to sustain a significant research presence will decline. Demographic trends will also have an impact although the National Center for Education Statistics (NCES, 2017) projects continued stability and growth in the college age population through 2025.

In any event, over time, the current higher education marketplace will continue to evolve into distinct operational sectors following different priorities (whatever their public relations rhetoric), with considerable turmoil at the boundaries. A wide range of quantitative indicators illustrate how much of that transformation is already well underway, even though the process is obscured by a media focus on elite institutions competing for small advantages among themselves.

THE CURRENT UNIVERSITY CONTEXT

Within this context, and over the past twenty years or so, the top American research universities have continued their dominance of the upper end of the higher education spectrum. The current model as described here is likely sustainable in the short term. Those already among the top 150 to 200 institutions, and especially those in the top 50 or so, will continue to prosper although those below the

top members of this group may find it increasingly difficult to continue to keep pace with the highest producers. The successful research institutions' faculty will remain highly tenured and predominately full-time although we may see various types of rolling term contracts for faculty in some fields. Moreover, it is possible that the context for major fund raising, a critical element in the financial structure of all major research universities, will encounter political difficulties as state and national legislators seek revenue by eliminating various tax deductions that have benefited research universities.

Although not the focus of this essay, another group of primarily public, comprehensive universities with some significant research presence will survive by diversifying into a wide range of occupational, masters, and technology enabled programs. They will have substantial undergraduate programs, extensive masters and certificate programs, and many professional programs. They will sponsor research in some areas but not at the intensity of the top universities. Their faculty will become more heavily contingent with the development of a variety of term contract faculty arrangements, in most cases developed through extensive negotiations with unions. We have modeled the future options for these and other institutional groups elsewhere. (Rouse, 2016)

A group of smaller public and private institutions will struggle to maintain sufficient enrollment to prosper. They will expand into masters and certificate programs, seek economies with extensive outsourcing of a wide range of university services, and continue the trend to increasingly contingent faculty. They will experiment with various tuition/fee arrangements with discounting and financial aid processes. Some private institutions in this group may fail and close or be absorbed by competitors, but the public institutions on the margin will more likely be consolidated into larger system entities rather than disappear, as they remain protected by the local political requirements of their states.

A special category of small prestigious and heavily endowed private colleges will continue to prosper with an emphasis on highly qualified tenured faculty, elaborate programs and facilities, and high demand from students. These elite institutions will also continue to compete with the top research universities (public and private) for the most qualified undergraduate students. Many will also develop masters programs in many areas to increase the yield from tuition dollars.

These categories will be very confusing at the boundaries, and many institutions will compete partially in one category and partially in another. However, in every case, the American higher education marketplace is likely to continue the trend that emphasizes the spread between elite institutions and non-elite institutions, between primarily academically and primarily occupationally centered institutions. Throughout, the controversies over elitism, diversity, inclusion, employability, and cost will remain a constant subtext in all discussions about the US higher education industry. The continued improvement in the quality and operational integrity of online educational systems will also siphon off a significant population and the revenue associated with the education of adult students, individuals seeking employment-related post baccalaureate skill certifications, and international students pursuing American content without the necessity of travel and residence abroad.

Most of our work on university behavior is based on two perspectives. The first uses historical data to identify long-standing trends in the performance of institutions, anticipating that past behavior will be the best predictor of future behavior. This has been the underlying perspective of the Center for Measuring University Performance (MUP) project and is reflected in the paper provided the Sackler Colloquium of the National Academy of Sciences (Lombardi, et al., *MUP*, 2000-2016; Lombardi, Craig, 2017) The second, recognizing recent trends in marketplace behavior, the shifts in institutional finance and staffing, and the critical commentary of many observers, projects dramatic transformations

that will radically restructure the academic marketplace over a period of no less than twenty years. This is the perspective of the dynamic mathematical models presented in Rouse (2016).

By connecting these perspectives within the same frame (a historical view contributing to the prospective mathematical model) we can offer a systematic exploration of the possible impact of changes in fundamental university behavior using a multivariable simulation that demonstrates the links between the various elements in the financial and operational model of universities. We can speculate about the impact of tuition increases, rising cost of pursuing first rank research faculty and the grants that sustain them, and other elements associated with the teaching and research activities of these institutions. With a multivariable model, we can test some of our assumptions about how universities can respond to the changes anticipated in the higher education marketplace and assess the consequences of one or another or many changes in the elements that drive the costs, revenue, and results of institutional activity. Elsewhere, we have developed this model in a generalized form to address the entire higher education marketplace from occupationally oriented institutions through research centric institutions and projected the likely results of a twenty-year forward look.

MODELING THE COMPETITION AMONG TOP RESEARCH UNIVERSITIES

Here, however, we focus on the top level of research universities, those institutions that in many ways establish the quality and prestige markers that define a university brand emulated in one form or another by other higher education enterprises. While there is always risk in projecting out twenty years, our historical perspective has demonstrated the remarkable stability of the current research university environment over the two decades, leading us to have some confidence that the elements that sustain the research university model are likely to remain more or less the same over time even if the rates of change in these elements and the impact of anticipated changes will surely vary.

To frame this exercise, we need to emphasize that today and twenty years from now, university research, and especially scientific research, with few exceptions, will remain an institutional loss leader. The revenue generated by research grants and contracts does not pay for the costs of producing the research. Indirect costs exceed any external reimbursement, and a wide variety of other research support provided by the university, whether for released time from teaching, unfunded facility, equipment and personnel costs, or institutionally supported research work, receives no external funding. In a resource-constrained environment, some observers worry that the financial model that has supported the current scale of America's dynamic and productive research university environment cannot continue.

However, even if the data may indicate that research generates an increasing net cost to institutions, it may not follow that all current research universities will reduce their commitment to research in pursuit of a more economically rational model of institutional finance. The most successful research universities, moreover, compete not to get rich but rather to generate the funds needed to accumulate the highest level of quality elements within their institutional boundaries as possible. This, in our model, translates into brand value. These institutions are relatively less interested in the external marketplace for their goods and services except as a venue for acquiring the resources to continue expanding their internal quality and sustaining their brand.

Indeed, this pursuit of brand value within the research university model deserves more attention than it usually receives. These institutions function as quality engines, that is they operate to capture the largest amount of nationally competitive quality elements within their institutional boundaries. These quality elements include students, faculty, staff, facilities, and programs, but above all they seek to

acquire research faculty and associated personnel. Research capable faculty bring with them or attract a wide range of other quality assets, whether graduate students, competitive grants, research publications, post-docs, or high-level scientific staff. Because these high performing faculty are in short supply relative to the demand from many research-competitive institutions for their services, they can command a significant university investment. This investment is less about salaries or individual faculty compensation and more about the facilities, the support personnel, the institutional research infrastructure, and the availability of related high quality faculty and programs. The prestige and significance, the brand value, of any research university is the result of the cumulative impact of these high performing people supported by the infrastructure and research-related personnel of the institution. (Lombardi et al., *MUP*, 2000-2016)

INDICATORS OF RESEARCH UNIVERSITY SUCCESS

For this reason, a primary indicator of research university success has generally been the annual federally sponsored science and engineering research expenditures. This number is useful for this purpose not because it reflects a monetary accounting unit but because it reflects the cumulative research activity funded through the national peer review process of the various federal funding agencies. Annual federal expenditure data is a particularly useful indicator, as opposed to federal research awards, because it reflects one year of direct and indirect billed activity on a federal research grant. It is also something of a general proxy for the scale of institutional investment required to sustain that level of federal research activity. This funding model for American research activity has some consequences for the way research institutions operate.

The model is based, in simplified terms, on a competition that pits individual faculty research proposals against each other in a peer reviewed context. These proposals are not institutional proposals but individual faculty proposals (although of course they all carry a substantial component of institutional support that underlies the quality and strength of the proposal). The awards when they come are primarily faculty awards, although they may have a wide range of linked institutional commitments. In practice of course, many individual proposals have multiple faculty participants, may well involve individuals from a number of institutions in a collaborative framework, and can include linkages to corporations or other outside entities. Nonetheless, the core competencies that drive the success of the research university are the high performing faculty whose records of achievement and whose reputations validate the likelihood of a successful research result from the funding proposed.

This model places a significant burden on the research university that must recruit and retain nationally significant faculty in order to build the capacity to compete successfully in the peer review process for the national grants that define research university success. The institution's investment is, in many cases, a high-risk investment because while it may be advantageous to recruit faculty who already have federally-funded research grants, the marketplace does not offer a sufficient number of these individuals to meet the demand, and as a result institutions must also recruit younger promising faculty whose work offers the expectation of a successful research career. Sometimes the promise is fulfilled, and sometimes it is not, so the institutional investment in promising high performing faculty carries a significant risk.

Research universities cover this risk in a number of ways. The most obvious is through the tenure process that attempts over a relatively short window of time to identify which newly hired faculty members will have the greatest likelihood of continued long-term future research success. Those that pass this review are deemed to be more likely to have a significant long-term competitive research career than those who do not pass. While this process lowers somewhat the risk associated with hiring

and supporting a particular faculty member, the time for decision is short, perhaps five years, so some significant risk remains. This risk is covered in a variety of ways by institutions, depending on their circumstances.

In institutions with substantial undergraduate populations, teaching and other functions associated with extensive undergraduate and masters or certificate programs provide a useful occupational niche for faculty whose research potential may not have reached or no longer can be sustained at the anticipated level of productivity. By shifting faculty effort from research to teaching and other institutional support activities, high quality faculty whose competitive research strengths are not quite up to the national level, remain productive and their cost compensated by the work done on behalf of the undergraduate, masters, or certificate programs. Moreover, once removed from the external research competition, the institutional research support costs associated with a former research faculty member now focused on teaching or some other task can be reallocated elsewhere.

This model is particularly relevant for the large public research universities whose research accomplishments have elevated many of them into the top levels of national and international competition. The size of the undergraduate student body and the growth of profitable masters and certificate programs serve public universities as a buffer against the risk associated with providing tenure to faculty candidates early in their research careers. Large undergraduate and pre-doctoral student populations in public universities also provide other advantages. While tuition and fee revenue for undergraduates generally do not pay for the full cost of their education, in most states, public funding tends to be driven by calculations closely related to student credit hours or their derivatives. In addition, since institutions rarely discount master's or certificate tuition and fees, these programs more than pay their own way. Some infrastructure and other operating costs of the institution, subsidized by the undergraduate and non-PhD graduate student economy, also subsidize research infrastructure, whether related to buildings, core support of energy costs, basic accounting and other business services, security, legal, technology, and the like. The larger the university budget from all sources, the better able the institution will be to support the special costs of sustaining highly competitive research faculty.

In short, the current research model seeks out all types of revenue to create a financial base capable of sustaining the substantial unfunded costs of highly competitive research faculty, staff, and facilities. This university quality engine, fueled by this financial base, seeks to acquire the highest level and volume of quality within its boundaries to define its brand value. It uses this brand to attract students, faculty, alumni, donors, granting agencies, foundations, and others to participate in and with the accumulated quality. These people engage primarily to participate in various ways with the quality assembled inside the boundaries of the institution. They individually receive various intellectual, social, or personal benefits derived from the institutional brand unique to each participant's needs and interests, and they use these primarily intangible benefits to enhance their own marketability or significance outside the university.

CONCENTRATION OF RESEARCH PERFORMANCE

Recognizing the many changes and much innovation taking place throughout American higher education, a retrospective review of the performance of highly competitive research universities nevertheless shows a remarkably stable profile. In our paper for the National Academy Modeling and Visualizing Science and Technology Developments (Lombardi, Craig, 2017) we identified 160 universities (public and private) with over $40 million in federal science and engineering expenditures in 2014. This group, represents about 19% of the academic institutions spending federal research funds and captures about 92**%** of the federal research expenditures reported by all these institutions (Table 1).

This relationship with minor variations has remained stable for over a decade and a half. However, it is important to recognize that this definition of the top institutions is broad, the elite in this sector, some 50 perhaps, would show even more concentrated performance characteristics.

Institutions Reporting Any Federal Research in Past Five Years	2014 (in 000s)	Percent Share	2010 (in 000s)	Percent Share	2006 (in 000s)	Percent Share	2002 (in 000s)	Percent Share
Total Federal Research	$36,882,439		$36,385,772		$29,971,148		$21,730,593	
Over $40M Group	$33,750,559	92%	$32,942,353	91%	$27,123,421	90%	$19,699,893	91%
Number of Institutions with Federal Research	856		735		658		623	
Over $40M Group	160	19%	158	21%	150	23%	125	20%

Note: Over $40M Group based on 2014 federal research expenditures.

Table 1. Federal Research

This stability is all the more remarkable given the many innovations and changes that have characterized the instructional and financial context of all of American higher education. Research universities constitute a special category among the many components of the American post-secondary marketplace. Their significance and visibility sometimes appears much greater than their participation levels in many parts of the higher education marketplace. For example, out of the 2,285 four-year higher education institutions (excluding for-profit enterprises), the top group of 160 research universities in our data used for this discussion constitutes only 7% of the institutions and enrolls roughly 3.5 million students, representing only about 18% of the 20.2 million students enrolled at all levels of public and private, nonprofit 4-year institutions. However, because they represent a highly visible and exceptionally prestigious cluster of universities, many capturing exceptional visibility through their intercollegiate sports programs, and because their doctoral programs produce a constant stream of instructors and faculty throughout the higher education industry, what takes place on these campuses often dominates the public conversation about higher education. (Lombardi, Craig, 2016)

There are many ways to highlight the historical stability of these research universities, and to recognize their long-standing significance within the postsecondary marketplace. The model of research university success that focuses on the capture of federal and other research dollars, the acquisition of highly qualified and productive faculty, and the development of other related assets, encouraged us to review the performance of the top research institutions over time to illustrate their success in maintaining their preeminence and brand value.

For this illustration we have taken our top group of academic research institutions in 2014 (defined by MUP as those with over $40M in annual federal research expenditures) and looked back in time to see if their dominant position remained stable over the last decade or so when much of the current conversation about institutional transformations and the restructuring of the academic marketplace has

taken place. We compare the performance of these 160 institutions, tracked back at intervals through 2002 on our measures, to the 968 institutions that spent any federal research funds within a five-year period between 2014 and 2010.

In our data we start with federal research expenditures as reported by NSF and adjusted by the MUP staff to ensure a single-campus comparison. In recent years, NSF guidelines have more closely matched our definition of single campus institutions for reporting purposes, thereby reducing the number of adjustments we needed to make.

Total research expenditures include both federal and non-federal funds (state and local and other sourced expenditures reported by institutions, some of which are peer reviewed and some of which are not). These resources reflect a larger pool of funds and their distribution offers a profile similar to the more competitive federal research expenditures. However, over time, the percent share of total research expenditures captured by the top institutions has declined from 25% in 2002 to 18% in 2014, likely the result in part of intense competition from less research-intensive institutions with good access to local and state funds and an increase in the number of institutions from which data are collected.

Because a strong institutional financial base is necessary for the support of highly competitive research universities, we have used endowment assets as a proxy for institutional wealth. This is of course only an indicator since a number for the true wealth of institutions is exceptionally difficult to acquire in any consistent or comparable fashion. Nonetheless, this indicator offers an illustration of the ability of these institutions to capture a strong position within the domain of private fund raising for endowment at a steady 75% of all endowment assets recorded for institutions that participate in the research marketplace despite making up only about one-fourth of the research university population (Table 2). Not surprisingly, the data on annual giving shows a similar pattern.

Institutions Reporting Any Federal Research in Past Five Years	2014 (in 000s)	Percent Share	2010 (in 000s)	Percent Share	2006 (in 000s)	Percent Share	2002 (in 000s)	Percent Share
Total Endowment	$483,957,113		$328,020,065		$318,622,750		$208,412,844	
Over $40M Group	$363,771,585	75%	$245,603,049	75%	$238,511,192	75%	$152,042,508	73%
Number of Institutions Reporting Endowment	697		687		661		644	
Over $40M Group	155	22%	155	23%	150	23%	152	24%
Total Annual Giving	$30,109,989		$22,665,967		$22,021,068		$18,736,552	
Over $40M Group	$23,274,769	77%	$16,940,366	75%	$16,014,245	73%	$13,875,345	74%
Number of Institutions Reporting Annual Giving	621		639		630		615	
Over $40M Group	153	25%	153	24%	144	23%	148	24%

Table 2. Endowment and Annual Giving

Faculty quality is another indicator of research university competitive success. While it is difficult to identify fully reliable measures of the achievements of university faculty in a comparative context, we have two indicators that serve to highlight the concentration of nationally recognized faculty in research institutions. One is the number of National Academy members in each institution. National Academy members are heavily concentrated in the top research group as we might expect. A steady proportion of 97% of the National Academy members are in the over $40M group, although only 69% of the institutions in this group have faculty with these distinctions. This is a reflection of the concentration of National Academy members in a small number of institutions. About half of these individuals are in the 14 institutions that have more than 100 National Academy members.

A second faculty indicator includes faculty who have received a variety of scholarly awards, outlined in detail on the MUP website and in the annual publication (Lombardi, et al., 2000-2016). These awards are for distinction in a wide range of fields, not just those in the sciences and engineering. Again, the over $40M institutions capture around 80% of the faculty awards even though they represent only 38% of all institutions having faculty with these awards. Of particular note here, 259 institutions not in the over $40M group nonetheless have high quality faculty who win these awards, an indicator of the common recognition of faculty quality as a brand value enhancer at all levels of university education.

These indicators of quality concentration within the top research institutions focus primarily on elements associated with what we could call the published research enterprise. That is, the activities of the university's people that end up as published books and articles contributing to the advancement of knowledge. Much of that is identified by the proxy of federal research and other elements associated with the faculty who are the primary drivers of this work. At the same time, however, these institutions sustain undergraduate enterprises, often of large size, and compete with other research institutions as well as liberal arts colleges for outstanding students. Again, data on the quality of students is elusive, but the selectivity of colleges is often linked to the scores on the SAT or its equivalent. While of course the SAT has many defects as an indicator of likely undergraduate student success it does serve as a surrogate indicator of institutional undergraduate selectivity, in its own way another reflection of brand value.

In our observation of research universities it appears likely that many high performing research faculty and staff not only seek institutions that can support their research ambitions but likely prefer to participate in the life of institutions with high quality students. A review of the differential attractiveness of research universities for high SAT students demonstrates that the research university brand advantage for recruiting high quality students is relatively less impressive, as many colleges with minimal research profiles but high brand value based on faculty quality and undergraduate elite characteristics nonetheless capture a significant number of high SAT applicants. The over $40M group has an SAT advantage of only 140 points over institutions outside this group, a premium of around 13%. Not all universities that fall into our group of research institutions require or provide SAT data, so these numbers should only be taken as general indicators.

Scale is an important element underlying research university success, in large part because sufficient scale helps spread the costs of research support and infrastructure over a larger number of projects, faculty, and research programs. Many research institutions have significant undergraduate student bodies whose numbers through tuition, fees, state support, and alumni commitment drive resources and support the teaching and other work associated with instruction that often provide an employment buffer for faculty whose research productivity may have declined but whose intellectual vitality remains strong. In many cases, as well, research faculty with highly successful programs and full funding nonetheless teach students at the undergraduate and graduate level, and offset some costs associated with their faculty salaries.

The top research universities have over a third of the undergraduate and graduate students enrolled in all the institutions with any federal research expenditures. These top institutions have a somewhat lower percentage of undergraduates than the entire group, but a higher percentage of graduate students. However, the top research universities have about three times the median size of undergraduate population and about four times the median size of graduate population than the group as a whole.

Reflecting this emphasis on graduate education, the top institutions in the over $40M group produce the smallest percentage of associate degrees, over a third of the bachelor's degrees, almost half the master's degrees, just over half the professional degrees, and over three quarters of the doctorate degrees. Since the over $40M group is just under one-fifth of the institutions included in this illustration, it is clear that they make a major impact on the degree production of all institutions with any participation in the federal research competition.

MODELING THE RESEARCH UNIVERSITY INTO THE FUTURE

These illustrations highlight the distinctiveness of the top American research universities within the context of the US higher education marketplace. They help us understand that general concerns about the trends and transformations affecting postsecondary schooling do not necessarily affect all institutions in the same way. Some vulnerabilities highlighted in the popular press do not apply to these institutions while other concerns have a much larger impact.

Major research institutions, while at little risk of failure, and operating stable competitive enterprises, struggle constantly with the challenge of maintaining the scale of their operations through continuous adjustments on the margin. They engage in constant innovation, pursue opportunities of every kind made available by expanding technological capabilities, seek economies in operation through outsourcing, pursue revenue opportunities wherever they can be found, and constantly adjust their undergraduate programs to continue to capture the best possible students while expanding the diversity of their student bodies.

Taken as productive organizations, research universities manage a wide range of product lines of dramatically varying profitability. Some generate net costs to the institution such as research and, for most institutions, intercollegiate sports. Some generate profits for the college such as undergraduate enrollment for public institutions with state funding and significant alumni support, stock market returns for public and private universities, and private fund raising for all institutions. Of the characteristics that define these institutions, their resiliency over the years in the face of financial challenges is perhaps one of the most interesting. A rational model of university operation that focused on return on investment or some other measurable utility function derived from commercial business enterprises would surely underestimate the value of the intangible products of the institutions that help explain their long-term behavior. This intangible element is captured by what we call brand value. It is possible that the stress of the current financial condition of American higher education will change the commitment to research that currently characterizes many institutions, but how these changes will produce a major re-framing of the American higher education marketplace is not yet clear.[1]

A COMPUTATIONAL MODEL FOR RESEARCH UNIVERSITIES

Even though we can be reasonably confident that our retrospective model of research university behavior and success is a stable and effective representation of the competitive context, no one is certain that what has worked so well for the past twenty years will continue, with only minor variations, for the next twenty years. To test some assumptions about the interrelationship of many elements in the research university model, we offer (summarized in Figure 1) a computation model for research universities elaborated in great detail in a recent book (Rouse, 2016).

This model is based on a thorough analysis of a wealth of data pertaining to the various aspects of a university enterprise. This includes sources of funding, alternative publication outlets, predictors of brand value (and hence rankings), workforce structure, administrative practices, and the like.

In this model, student applications are driven by tuition and brand value[2]. Accepted students who enroll, as well as continuing students, determine needs for classes and faculty members to teach these

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1 This discussion is based on a paper presented by Lombardi and Craig to the Sackler Colloquium of the National Academy of Sciences in 2017, which contains extensive notes and references related to these topics.
2 The various assertions in this section are fully supported by many sources cited and data compilations presented in Rouse (2016).

classes, which drives the costs of teaching. Tenure track (TT) faculty members need to pursue research to achieve tenure and promotion. They need to write proposals to attract funding for their research.

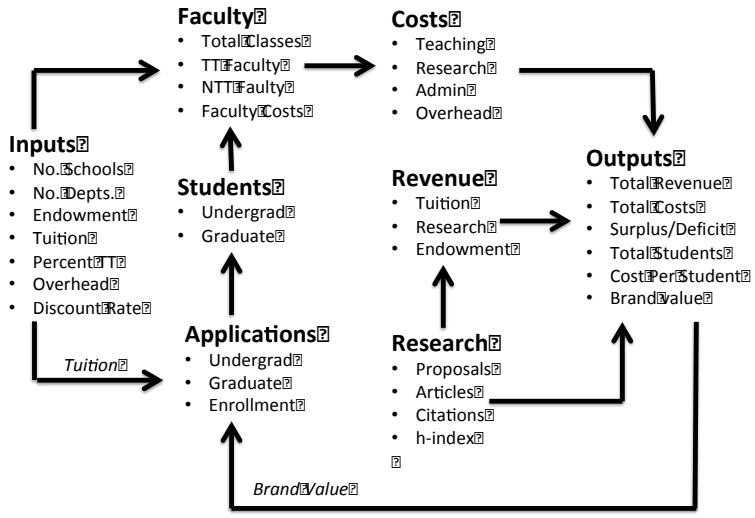

Figure 1. Computational Model of a Research University

The research activities of TT faculty members result in publishing research articles, which are eventually cited and, over time, increase faculty members' *h-index*, that is the number of articles cited at least *h* times. The combination of articles published, citations of these articles, and *h-index*, over time, provides an estimate of brand value, which correlates closely with an institution's rankings. This estimate is not a monetary value, but rather a composite performance indicator.

This is all complicated by several phenomena (Rouse, 2016). Research funding is increasingly competitive, with funding decreasing relative to a steadily increasing number of proposals. Publication is increasingly competitive, with opportunities very constrained relative to a steadily increasing number of submissions. The result is faculty members have to work harder to achieve less success.

The tsunami of competitors is willing to do almost anything to succeed. They will serve long appointments in poorly paid postdoctoral positions with a 15% chance of securing tenure track positions. They will work diligently to produce 10, 15 or 20 journal articles before applying for a tenure track position. In contrast, when the current senior generation was at that stage of their careers, they had few if any publications.

Revenue in this model comes from tuition, research grants, and endowment earnings. Costs include those for teaching, research, administration, and overhead. Projections of revenues and costs yield model outputs including various financial metrics plus number of students and brand value. Users of the model are interested in the impacts of various inputs on these model outputs.

Inputs include number of schools and departments per university, which have a strong impact on administrative costs. Endowments and tuition strongly affect revenues. Overhead rates affect the portion of grants that can be used for general expenses rather than direct support of research. The discount rate that reflects the cost of money affects projections of the net present value[3] (NPV) of the

projected surplus/deficit (S/D). Within this model, the goal is operate the model so that the NPV is driven to the point where the projected surplus or deficit is zero, that is, the institution breaks even.

Percent tenure track (TT) faculty has an enormous impact. Non-tenure track faculty members teach twice as many classes as tenure track faculty members, which substantially reduces costs, especially because they are usually paid much less. Tenure track faculty members spend half their time doing research, which may or may not be paid for from research grants. The publications resulting from this research strongly impacts brand value over time.

The tradeoff is very clear. Reducing percent TT lowers costs and, in principle at least, decreases tuition. Increasing percent TT increases costs and tuition, but enhances brand value. Prospective students seek lower net tuition and higher brand value. Leaders of research universities have to decide where to position themselves relative to this tradeoff.

There are many other parameters to the model beyond those shown in Figure 1. Endowment growth rate and tuition growth rate are also inputs on the "dashboard" for the model. Embedded variables include, for example, administrative salaries and growth rate; initial number of undergraduate and graduate students; growth rates of these populations; and class sizes for both types of students. Such variables are not included on the dashboard. Once they are set for a particular university, they are seldom varied.

There are several sub-models within the overall computational model. These sub-models relate to finance, administration, research, education, workforce, and brand. The research model projects proposals written, projects funded, articles submitted, and articles published. The workforce model projects decisions about hiring, promotion, tenure, and retirement. The overall model and all the sub-models are explained in detail in Rouse (2016).

SCENARIOS OF FUTURE PERFORMANCE

There are three forces of particular interest that work independently but have a combined effect on the results of the model:

- Scenario 1: Competition for federal dollars and publication in top journals is steadily increasing. The current success model at most research universities requires faculty members to work harder and harder to achieve less and less success, proposal writing consuming increasing time and publication preparation receiving decreasing attention
- Scenario 2: Foreign student enrollment in graduate programs has decreased in recent years due to competition from other countries and, more recently, concerns about US immigration policies. These professional masters degrees are typically "cash cows" for research universities, subsidizing many other aspects of the enterprise.
- Scenario 3: Highly polished, well-done MOOCs will increasingly succeed. Once the credentials associated with success in these online courses are acceptable to employers, it is easy to imagine a massive shift away from traditional classrooms for some categories of students, especially those seeking professional credentials and masters degrees where distance learning is already recognized and increasing common.

We have used the computational model to explore the implications of these forces for research universities. Well-resourced universities, such as the most successful among the top 160, perhaps the

3 Net present value is the current value of projected future cash flows, discounted by the interest rate one must forgo or pay due to cash flows being delayed.

top 50, will likely cope in different ways. Institutions almost totally dependent on tuition dollars, which likely fall outside the top group, will struggle and those who cannot keep tuition competitive while avoiding large deficits are likely to fail or require dramatic restructuring.

Using 2016 data from the Center for Measuring University Performance (MUP) (Lombardi, et al., 2000-2016), Table 3 was populated. The data in the first three columns were provided by the MUP project. The data in the remaining columns were gleaned from each university's website. We do not show the identity of each institution, but the model was explicitly fit to particular universities.

	Federal $ M	**Endowment $ M**	**State $ M**	**UG Students**	**UG Tuition**	**Grad Students**	**Grad Tuition**	**No. Colleges**	**Departments Per College**
Large Public	800	10,000	300	29000	15,000	15000	24,000	19	18
Large Private	700	20,000	0	7000	50,000	9000	50,000	7	16
Small Public	60	600	100	16000	15,000	5000	24,000	8	6
Small Private	50	900	0	4000	50,000	2000	50,000	4	6

Note: Large and small denote resources rather than numbers of students

Table 3. High Level Characteristics of Four Research Universities

Fitting the model to a particular university involved the following steps:

1. Input parameters from Table 3
2. Apply 50% discount for undergraduate tuition at private institutions or 20% for public institutions.
3. Adjust average award to match overall federal research $
4. Adjust class sizes to achieve near zero NPV of surplus/deficit, this is the break even assumption.
5. Revisit steps 3 and 4 as needed

The iterative nature of steps 3 and 4 was due to the faculty being automatically sized by the model to meet educational demands. When class sizes increase, faculty numbers decrease, fewer proposals are submitted, and fewer awards received. This requires increasing the average award size for the university to match the overall numbers in the first column of Table 3. Note that because graduate tuition is much higher, projections are more sensitive to sizes of graduate classes.

Table 4 shows the best-fit parameters that resulted from the fitting process. Common assumptions across all institutions included undergraduate population growth rate of 3%, undergraduate tuition growth rate of 3%, graduate population growth rate of 4%, graduate tuition growth rate of 5%, endowment growth rate of 6.5%, endowment earnings of 5%, and discount rate of 4%.

	State Funding Growth %	% Tenure Track Faculty	Overhead Rate on Funded Research	Average Undergrad Class Size	Average Graduate Class Size	Average Award Size[4]
Large Public	2%	70%	60%	80	28	$330K
Large Private	NA	80%	60%	16	8	$260K
Small Public	2%	30%	50%	65	45	$210K
Small Private	NA	70%	50%	40	29	$150K

Table 4. Model Parameters Fit to Four Institutions

UNDERSTANDING THE MODEL RESULTS

Three scenarios were explored:

- S1: Status Quo
- S2: Graduate Student Population Declines by 5% Annually
- S3: Graduate Tuition Declines to $10,000 Due to Online Offerings

The results are summarized in Table 5.

4 Note that the average award is adjusted so that federal monies received matches Table 3. The model assumes that only TT faculty generate proposals – obviously research staff members can and do generate proposals, but modeling the activities of research staff would really complicate things. The number of total faculty is driven by educational demands; number of TT faculty is determined by %TT in dashboard. The model also assumes one person-month per proposal, regardless of whether it is a $150K or $330K proposal, which does not seem unreasonable.

Large Public					
	S1: Current	S2: -5%	S3: $10,000	S3: 10X	S3; 1,000
Revenue 20	$8,003M	$4,197M	$6,885M	$4,438M	$4,242M
Brand 20	40,000	9,000	40,000	6,000	3,400
NPV (S/D)	$1,640M	$9,039M	($5,037M)	$17,683M	$19,501M
Large Private					
	S1: Current	S2: -5%	S3: $10,000	S3: 10X	S3; 1,000
Revenue 20	$8,586M	$4,780M	$6,670M	$4,653M	$4,446M
Brand 20	43,000	10,000	43,000	7,200	3,700
NPV (S/D)	$10,828M	$16,875M	($617M)	$22,605M	$24,979M
Small Public					
	S1: Current	S2: -5%	S3: $10,000	S3: 10X	S3; 1,000
Revenue 20	$1,751M	$1,031	$1,342M	$1,167M	$1,156
Brand 20	4,800	1,250	4,800	900	700
NPV (S/D)	$207M	$2,718M	($2,018M)	$5,627	$6,094M
Small Private					
	S1: Current	S2: -5%	S3: $10,000	S3: 10X	S3; 1,000
Revenue 20	$1,121M	$550M	$696M	$548M	$536M
Brand 20	6,000	1,500	6,000	1,100	800
NPV (S/D)	$33M	$621M	($2,510M)	$1,427	$1,730M

Revenue 20 and Brand 20 are projections for Year 20.

Table 5. Results for Four Institutions for Three Scenarios

Scenario 1: Status Quo

In this scenario, the number of proposals submitted grows exponentially, to compensate for declining success rate, which leads to number of articles submitted declining exponentially, due to lack of faculty time, which leads to a plateauing of brand value. More specifically, assuming a faculty member needs to secure an NSF award every other year, they need to submit 2 proposals in year 1 and 7 proposals in year 20. As proposals take precedence over publications, this faculty member will submit 4 articles in year 1, with 1 being accepted, and 0 in year 20, with of course none being accepted.

The consequence of these dynamics is increasing subsidization of the research enterprise, which has to come from other revenues. For private institutions with small endowments, this subsidy must come from tuition revenue. In the extreme at least, this translates into student debt being used to partially fund the research enterprise. These phenomena are illustrated in detail in Rouse (2016).

This scenario is, of course, not sustainable in an unmodified form. Institutions will need to reconfigure their faculty resources, so that the tasks of proposal preparation and article submission are distributed to different personnel, which is already the case in many research institutions with technical staff devoted to major proposal development and sub-faculty staff devoted to research activities that result in publication. More complex labor differentiation within the research environment, long evident in large laboratories focused on experimental physics with a significant number of non-TT faculty and other research support personnel leading to highly differentiated roles and responsibilities and much greater

efficiency in the process of proposal preparation and submission and article preparation and publication. It may be difficult for institutions with fewer resources to afford such organizational infrastructure.

Universities could also help themselves by broadening their success models beyond NIH and NSF. The idea that a junior faculty member has to secure a grant from one of these agencies to gain tenure results in their submitting large numbers of unsuccessful proposals to, hopefully, finally have one success. Intellectual outcomes are what really matter, not the source of the funds to create these outcomes. The model for brand value considers publications, citations, and *h-index*, not the sources of funding. Universities are paying dearly, in terms of increasing subsidies, by clinging to such outmoded thinking.

Beyond such changes within universities, research-sponsoring agencies could lower the cost of research by changing procurement processes. For example they could, and several do, require brief white papers with initial articulation of an idea. For ideas that have a high probability of being funded, investigators would be encouraged to submit proposals. This could substantially reduce the costs of preparing proposals with little chance of funding. These high "costs of sales" are not tracked, but are bundled with release time.

Agencies could broaden the proposal review process to include more than just academics. Current peer review processes at agencies such as NIH and NSF tend to reinforce reigning academic paradigms and discourage proposals outside the norm. Including reviewers who could judge the likely benefits of an idea, beyond refining and tuning the academic status quo, could foster increased innovation, especially when combined with the notion of screening ideas with initial white papers.

Scenario 2: Declining Graduate Enrollments

In this scenario, we see that declining enrollment results in declining size of faculty, which leads to fewer faculty members' research having to be subsidized, which leads to fewer publications and significantly decreased brand value. However, the key element for institutions of any size is not necessarily the total number of faculty but the number of research effective faculty. So an institution of small size with 200 research effective faculty and 50 teaching faculty can have the same research brand value as an institution of large size with 200 research faculty and 200 teaching faculty. Moreover, as the price of teaching faculty is less than research faculty, constructing the balance between enrollment, teaching faculty, and research faculty will become an increasing critical analytical issue for many institutions.

This scenario involved 5% annual decreases of graduate enrollments, reflecting an observed trend over the past few years, as well as recent turmoil over immigration. Realistically, the top players will not experience such decline, while the lower players will see greater declines. The top institutions will retain their abilities to pick the best foreign applicants. Fewer applicants overall will mean that the top institutions will consume a greater portion of the pool.

Scenario 3: Declining Graduate Tuitions

In this scenario, limits on graduate tuition, due to high-quality online offerings, results in substantial deficits, but brand value is sustained if class sizes are maintained at S1 levels. Deficits are highly affected by attempts to maintain the research enterprise. The utility of graduate and post-baccalaureate certificate tuition as a key support of tuition driven institutions and a profit center for all institutions will surely decline with the continued improvement in technology enabled instruction, although the

enhanced quality of technology driven solutions will not come cheap. Scale here will be critical as institutions increasingly outsource distance education offerings to professional organizations that can leverage the scale needed for cost effective operations. A key element in this and the other S3 alternatives will be the ability to brand distance programs with high value brands. This is an increasingly evident trend in the field as commercial providers offer institutionally branded course/degree/certificate programs on a common technology platform and most likely many other common elements.

A modification of scenario 3 that captures the effects of increasing graduate class sizes by 10X yields very positive results that differ across institutions due to baseline S1 class sizes; declining size of faculty, due to larger classes increases surplus but erodes brand value. Whether brand value will suffer as a result of changes in the scale of graduate education will depend much on the mix of programs. Some in the health related fields have key markers for quality linked to small class size. Others in business or technology fields may not have such issues with class size.

An additional modification to scenario 3 which estimates the impact of increasing graduate class sizes to 1,000 per class yields increasingly positive results, although the further decline of the size of faculty, due to yet larger classes, which increases the surplus, but further erodes brand value. A hybrid model would have such large classes for introductory course, but shrink class size to more traditional levels for advanced courses.

It is of particular note that the top institutions are driving all variations of scenario 3, with Coursera, edX and Udacity being prime examples. These institutions have the resources to enable large experiments. In addition, they can attract major commitments from industry to underwrite these experiments and seed enrollments. AT&T and Accenture's large commitment to Georgia Tech for high quality MS degrees is computer science and data analytics illustrates how $10,000 MS degrees can be possible. Lower level players, where tuitions from professional graduate degrees are their only "cash cow," are at substantial risk.

Assuming class sizes of 1,000 raises the prospect of there not being enough students to fill these classes. However, $10,000 professional MS degrees are likely to spur dramatic increases in demand, in part because this price point will easily fit within many large corporations' education budgets. Nevertheless, the higher brand value institutions may dominate this market, to the significant detriment of the lower brand value institutions.

Overall, all these scenarios result in decreased research productivity due to diminishing returns for S1, and declining faculty sizes for S2 and S3. All four institutions that illustrate these scenarios benefit financially by decreasing subsidies of research, but the dramatic decrease of research output is certainly a national concern. Using student debt, at least in part, to subsidize the research enterprises is not in the national interest. Some rethinking seems definitely warranted.

CONCLUSION

This paper has brought together many of the pieces of the puzzle associated with the higher education challenges. The elements of the education and research enterprise have been integrated to enable projecting the likely consequences of several scenarios for the future of the academic enterprise. We cannot predict what mix of these scenarios will actually emerge. However, universities need strategies and investments that enable robust responses to whatever mix emerges. Tools such as the one

illustrated here and more fully explored in Rouse (2016) provide institutional leaders a method of testing the impact of various policy changes within their institutions, as well as the results of changes in the external environment.

Fundamental change is in the offing. Higher education cannot sustain its current cost structures. The limits of revenue increases will inevitably be reached, significantly facilitated by increasingly powerful and sophisticated technology platforms, likely offered by institutions with high brand values. Many educational institutions will need to reconfigure their operations, restructure their financial models, or disappear amidst what can be called "creative destruction" (Schumpeter, 1942).

Nevertheless, we need a healthy, educated and productive population that is competitive in the global marketplace. If the population is not educated, it will not be healthy. If the population is not productive, it will not be competitive. The pieces all fit together. We have to foster the right portfolio of investments in the hedges that will assure success despite the inevitable restructuring of higher education finance illustrated by the examples in this paper and documented elsewhere.

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