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Research Article

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Posted Date: November 20th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11789580/v1

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Additional Declarations: The authors declare no competing interests.

Do Universities Scale Like Cities? Patent Production and Institutional Size

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Abstract

Urban scaling research has shown that cities generate disproportionately more patents than smaller cities because they concentrate larger numbers of inventors, researchers, entrepreneurs, and other knowledge workers, increasing opportunities for innovative collaboration. We test whether the urban scaling framework for innovation extends to research universities, which plausibly represent similarly dense concentrations of such people, across multiple university size metrics. Across all candidate measures of institutional size—including institutional population, faculty, graduate enrollment, undergraduate enrollment, and total enrollment—patent production scaled linearly to sublinearly, with no compelling evidence of the superlinear relationships observed in cities. Instead, research and development (R&D) expenditures were the strongest predictor of patent output ($\beta = 0.75$, $R^2 = 0.60$.) Stepwise regression models explained 72-75% of variance in patent production using only three predictors: R&D expenditures, presence of an engineering school, and graduate enrollment (Model A) or technology transfer office staffing (Model B). Finally, we examined R&D expenditures over time, finding institutional spending to be quite stable over three decades ($r = 0.942$-0.988). Patent production over time was similarly correlated ($r = 0.728$-010.921), consistent with the Matthew effect, showing that early research advantages compound over time. Together, these findings suggest that universities do not exhibit the superlinear innovation scaling characteristic of cities. Instead, patent production is shaped primarily by research investment and organizational capacity, indicating that universities behave less like emergent urban systems and more like structured organizations whose innovation depends on the allocation of resources.

Keywords: Urban scaling | University innovation | Patenting | Tech transfer | Research and development

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Disclosure Statement:
The authors have no relevant conflicts of interest to disclose, financial or otherwise.

Introduction

Scaling laws describe remarkably consistent relationships between size and function across biological systems. Many biological phenomena, be they the metabolic rates of mammals (Savage et al., 2007), the flying speeds of birds (Alerstam et al., 2007), or the length of vascular systems, scale with body size. For example, in comparisons among mammal bodies, metabolism scales inversely with body mass; big mammals have predictably slower metabolisms than do smaller mammals. The decrease in metabolism with body mass has a predictable slope (0.75 when data are log transformed) and occurs because of efficiencies in resource use that occur as organisms become larger. Scaling rules reflect evolution's optimization of the workings of bodies in relation to size.

As so-called "metabolic engines," the bodies of organisms "have a clear counterpart in social systems," as Bettencourt et al. (2007a) pointed out, where cities are the engines of societies. Building on this metaphor, Bettencourt et al. (2007a) and others have shown that innovation scales with city size via a relationship characterized by increasing returns (also called superlinear scaling). Bigger cities have more innovation, as typically measured via patents, per capita than do smaller cities. This relationship is true within the United States where it has been best studied, but also globally (Lobo et al., 2013). Very little has been done to apply scaling frameworks to universities, which may represent densely populated innovation hubs similar to cities. One notable exception is Taylor et al. (2021), who found that different sectors of higher education (public/private, community colleges, etc.) followed distinct scaling laws across institutional outcomes. Here, we extend this line of inquiry by examining the scaling of university patent production.

Universities share many features with cities (indeed, many are run as small cities). Most importantly for theories of urban scaling and innovation, universities represent uniquely dense concentrations of scientists, engineers, inventors, and researchers. Urban scaling research suggests that larger cities generate disproportionately greater innovation because they bring together increasing numbers of highly skilled knowledge producers, creating more opportunities for collaboration, idea exchange, and the recombination of knowledge (Bettencourt et al., 2007b; Glaeser, 1994; Florida, 2005, 2014). If these mechanisms are responsible for the superlinear scaling of innovation observed in cities, research universities should provide an especially strong test of the theory. However, universities differ from cities in crucial ways. Universities are formal institutions rather than emergent social systems, and to a much greater extent than cities, their budgets, sizes, and organization structures are under the control of relatively few individuals. Research on form size and innovation has generally emphasized organizational dynamics and innovation productivity rather than explicit scaling relationships, with patterns that differ from the superlinear innovation observed in cities (e.g., West, 2017). These differences raise the possibility that universities may likewise diverge from urban scaling expectations.

We examine three related indicators of university technology transfer associated with innovation: invention disclosures, licenses executed, and patents issued. We acknowledge that universities can "game the system" with these variables in ways that are decoupled from true benefit to inventors, universities, or society, but hypothesize that across large numbers of universities, this "gaming" comes out in the wash. More practically, patents have been the primary measure of innovation in the urban scaling literature (Bettencourt et al., 2007a, 2007b; Lobo et al., 2013), making them the most natural point of comparison with existing work. We first consider the correlations among these dependent variables and whether they justify separate consideration. Because these variables are all highly intercorrelated (r^2 = 0.738-0.876, $p <$ 0.001), we focus on patent number as the primary outcome.

In the present study, we employ a framework from Bettencourt and colleagues (2007a, 2007b), who established basic scaling principles related to a swath of urban outcomes to city population size, and by Lobo and colleagues (2013), who extended that framework specifically to patenting in global urban areas. Contrasting perspectives from urban scaling and firm innovation research generate competing expectations for universities. If innovation is primarily driven by the agglomeration of knowledge producers, universities should resemble cities and exhibit superlinear patent scaling. By contrast, firm innovation research has largely focused on organizational dynamics, innovation productivity, and R&D

efficiency (as opposed to explicit scaling relationships), generally finding diminishing returns in patent productivity or innovation output in accordance with increasing firm size and R&D investment (e.g., Bound et al., 1982; Acs & Audretsch, 1988; Chakrabarti & Halperin, 1990; Breitzman & Hicks, 2008). If organizational structure and resource allocation instead play the dominant role, universities may resemble firms and exhibit weaker scaling relationships. On the other hand, if universities function more like cities as dense areas of knowledge exchange, they would be expected to have stronger, superlinear patent-size relationships.

A key question raised by bringing scaling to universities is the meaning of size or, fully extending the metaphor, body size. Bettencourt et al. (2007a, 2007b) used "total population" as the primary size metric for cities. Lobo et al. (2013) offered a useful precedent for questioning this metric as the assumed correct predictor, comparing population and GDP as predictors of urban patenting (using just the U.S. subset of his global sample), and finding that population has the stronger relationship ($\beta = 1.39$, $R^2 = 0.72$) while GDP was sublinear and much less explanatory ($\beta = 0.77$, $R^2 = 0.39$). We take a multifactor approach. For population, we consider different components of the total populations separately. Different members of a university community are unlikely to contribute equally to measurable innovation outputs, including students, staff and faculty with distinct relationships to innovation Undergraduate students, for example, may not equally contribute to the institution's knowledge economy, particularly at large research-centric universities where research and teaching missions can become decoupled (Tight, 2016; Robertson, 2007). We therefore examine multiple metrics of population size with regard to population: total institutional population, faculty alone, students alone, graduate students, undergraduate students, and tech transfer office (TTO) staffing. In keeping with Lobo et al. (2013) we also consider a financial metric of university size in relation to innovation. As a metric of the financial size of an institution, we measure R&D expenditures.

Ultimately, this study addresses three related questions. First, do universities exhibit the superlinear patent scaling characteristic of cities or sublinear patent scaling characteristic of firms? Second, which measure of institutional size best captures any scaling relationship? Third, beyond institutional size, which institutional characteristics best explain patent production? Based on urban scaling theory, we predicted that universities would capitalize on the same feature that drives superlinear patent output in cities, agglomeration of inventors (Bettencourt 2007b), and might exhibit a similar pattern.

Methods and Data

Data

The analytic dataset was constructed by integrating the 2024 results or records from four primary sources: the AUTM Licensing Activity Survey (LAS), accessed through the AUTM Statistics Access for Technology Transfer (STATT); the Higher Education Research and Development (HERD) survey; the Integrated Postsecondary Education Data System (IPEDS); and the National Academy of Inventors (NAI) Top Universities list. The final analytic sample reflects the intersection of institutions appearing across all relevant sources (see Table 1).

Patent counts, the primary outcome variable, were drawn from two sources to improve coverage of patent-active institutions: AUTM LAS and the NAI Top Universities list. The 2024 AUTM LAS, which includes 185 U.S. reporting institutions, served as the primary source. The 2024 NAI Top Universities list, which identified 123 institutions based on The United States Patent and Trademark Office patent activity, was used as a secondary source for patent counts. Most NAI institutions were already present in the LAS data; after matching, the NAI list contributed patent counts for 36 additional institutions to the analytic dataset.

Additional technology transfer variables were drawn from LAS. These variables included invention disclosures, patent applications, licenses executed, and TTO staffing. The measures related to

commercialization were used in preliminary analyses to examine intercorrelations and inform outcome variable selection.

R&D expenditures and the medical school indicator were drawn from the 2024 HERD survey, administered by the National Science Foundation. HERD defines a medical school as an institution granting an MD or OD degree. This definition is more restrictive than IPEDS, which includes schools of veterinary medicine, pharmacy, and dentistry. The narrower HERD definition was preferred to intentionally distinguish institutions granting MD and OD degrees. HERD's 2024 dataset includes 925 U.S. institutions.

Engineering school status was coded using institutional website data, with institutions classified as having a dedicated engineering school if they house an administratively distinct school, college, or department of engineering. Other institutional characteristics – total enrollment, graduate enrollment, undergraduate enrollment, faculty and staff counts, and geographic identifiers – were drawn from IPEDS.

City-level population data were obtained from the U.S. Census Bureau's 2024 population estimates, matched to each institution using Core Based Statistical Area (CBSA) codes available in IPEDS. This allowed direct linkage between each university and the metropolitan or micropolitan statistical area in which it is located.

Sample Construction

Matching institutions across LAS, NAI, HERD, and IPEDS produced a final analytic sample of 158 universities. This represents a subset of the approximately 5,800 degree-granting postsecondary institutions included in the IPEDS data, which reflects the full breadth of U.S. higher education, including community colleges, for-profit institutions, and specialized schools with no meaningful research activity, such as schools of cosmetology and other technical colleges. The relevant population for this study is considerably narrower: research-active universities that report patent activity and report at least $150,000 in R&D expenditures, leading them to appear in the HERD data.[1] Mismatches across data sources arose for several often-overlapping reasons, which included: (1) some AUTM or HERD reporting occurs at the institutional system level while IPEDS reports individual campuses separately; and (2) some LAS respondents are not universities at all but independent research organizations. Sample sizes vary across specific analyses due to incomplete data on certain variables. TTO staffing in particular was reported by substantially fewer institutions than other measures, resulting in a smaller effective sample for models that include TTO staffing (n=112).

Scaling Analysis

The scaling analysis presented here follows the general framework used by Bettencourt and colleagues (2007a, 2007b), in which Y represents a quantity of interest that is modeled by a power law function of a size metric, N. This takes the form $Y(N) = Y_0N^{\beta}$. In a log-log space, this relationship linearizes and becomes comparable to other logged pairs. The scaling exponent (β) becomes interpretable as the slope of the regression line, showing the percent change in Y associated with a 1% change in N.

Bettencourt et al. (2007a, 2007b) treated city population as the fixed measure of size and asked what scaled with that measure of size, examining a wide range of urban outcomes. We invert that question, fixing patenting activity as our outcome of interest, and asking what it scales with, that is, what measure of "size" serves as the most meaningful analogue to city population in the urban scaling literature. Each of our candidate size metrics is examined in an individual bivariate log-log regression with log-patents as the dependent variable. All variables were natural-log transformed using ln(x + 1). Candidate size metrics are in Table 1 below.

[1] Indeed, 83% of our final sample are designated as R1 universities; an additional 15% are R2. Only 2% of institutions in our sample fail to meet the R2 threshold.

Table 1 Analytic variables used in scaling and regression analysis

Measure	Description	Source (all 2024)
Patents	Total number of patents issued to the institution in the survey year, serving as the primary outcome variable in all scaling analyses.	AUTM Licensing Activity Survey (LAS), National Academy of Inventors (NAI) Top Institutions List
Institution population	Total number of individuals affiliated with the institution, including students, faculty, and staff; intended to capture the closest university analogue to city population as used in urban scaling research.	National Center for Education Statistics (NCES) IPEDS
Faculty	Total number of instructional and research faculty reported by the institution, representing the subset of the university population most directly engaged in research and knowledge production.[2]	NCES IPEDS
Technology Transfer Office (TTO) staff	Total number of full-time equivalent staff employed by the institution's technology transfer office, representing the administrative infrastructure dedicated to commercialization activity.	AUTM LAS
Student enrollment	Total number of enrolled undergraduate students, graduate students, and then combined, representing the broadest measure of the student population.	NCES IPEDS
R&D expenditures	Total research and development expenditures as reported to the NSF, representing the financial resources dedicated to research activity and serving as an economic analogue to city GDP in urban scaling research.	NSF HERD
MSA population	U.S. Census population data estimates for micro- or metropolitan areas, matched via institutional CBSA code	U.S. Census Bureau Population Estimates
Medical school indicator	A binary variable indicating whether the institution offers MD or OD degree	NSF HERD
Engineering school indicator	A binary variable indicating whether the institution includes a standalone engineering school	Institutional websites

Models are then compared on two dimensions: the scaling exponent β, which indicates whether the relationship is sublinear ($\beta < 1$), approximately linear ($\beta = 1$), or superlinear ($\beta > 1$); and also adjusted R^2, which reflects how much variance in patenting activity each size measure can account for. Because

[2] Research-only faculty were not examined separately because institutions do not consistently distinguish research and instructional faculty in publicly available datasets, and many faculty members perform both research and teaching roles.

the dependent variable is identical across all models, R^2 comparisons are interpretable. Taken together, these two dimensions allow us to assess both the nature and strength of the scaling relationship.

Stepwise Multiple Regression Analysis

Whereas the scaling analyses examined each candidate measure of institutional size independently, the multiple regression models evaluated the independent contribution of multiple institutional characteristics considered simultaneously. To complement the scaling analysis, we estimated two stepwise multiple regression models to predict log-transformed patent counts. Stepwise selection (SPSS Stepwise method) was used to identify a parsimonious set of institutional characteristics that independently explained variation in patent output. Candidate predictors included log-transformed R&D expenditures, graduate student enrollment, and faculty counts, along with indicator variables for engineering school and medical school presence. A second model included logged TTO staffing. Because TTO staffing data were missing for a substantial number of cases, the second model was estimated on a reduced sample.

Results and Discussion

Universities scale more like firms than cities

University patent output scales with institutional size, but not in the way that patent output scales with city size. Across every candidate measure of university size we examined, scaling exponents were sublinear to linear (Table 2). None approached the superlinear coefficients reported by Bettencourt et al. (2007a) ($\beta = 1.27$) or Lobo (2013) ($\beta = 1.39$). Universities, unlike cities, do not generate disproportionately more patent output as they grow. Bigger universities produce more patents, but not more patents per capita. This raises the question of whether additional innovation is latent in university systems but under-realized (for further discussion, see Wang, 2024).

Table 2 Scaling exponents for institutional indicators vs. patent production

Metric	β	95% CI	R^2 Adj	Observations
Institutional population	0.89	[0.65, 1.13]	0.26	153
Faculty	1.13	[0.94, 1.31]	0.49	153
All students	0.47	[0.26, 0.68]	0.11	153
Graduate students	0.96	[0.77, 1.16]	0.38	153
Undergrad students	0.29	[0.11, 0.48]	0.06	148

Candidate metric comparisons

The scaling relationships across different metrics of university size are telling. Of population-based metrics, the number of faculty at a university shows the strongest scaling relationship with patent number ($\beta = 1.13$, 95% CI [0.94, 1.31], $R^2 = 0.49$). The confidence interval is sufficiently wide so as to allow for the possibility that this relationship is superlinear, or at least linear. Graduate students follow closely ($\beta = 0.96$, 95% CI [0.77, 1.16], $R^2 = 0.26$). The relationship between total institutional population and patenting is weak ($\beta = 0.89$, 95% CI [0.65, 1.13], $R^2 = 0.26$), with a notably wide confidence interval. Total student enrollment, a measure that is the sum of undergraduate and graduate students, was sublinear ($\beta = 0.47$, 95% CI [0.26, 0.68], $R^2 = 0.11$) and undergraduate student enrollment was highly sublinear ($\beta = 0.29$, CI [0.11, 0.48], $R^2 = 0.06$) with such low explanatory power that it's not unreasonable to suggest a total uncoupling of undergraduate students from a university's innovation economy.

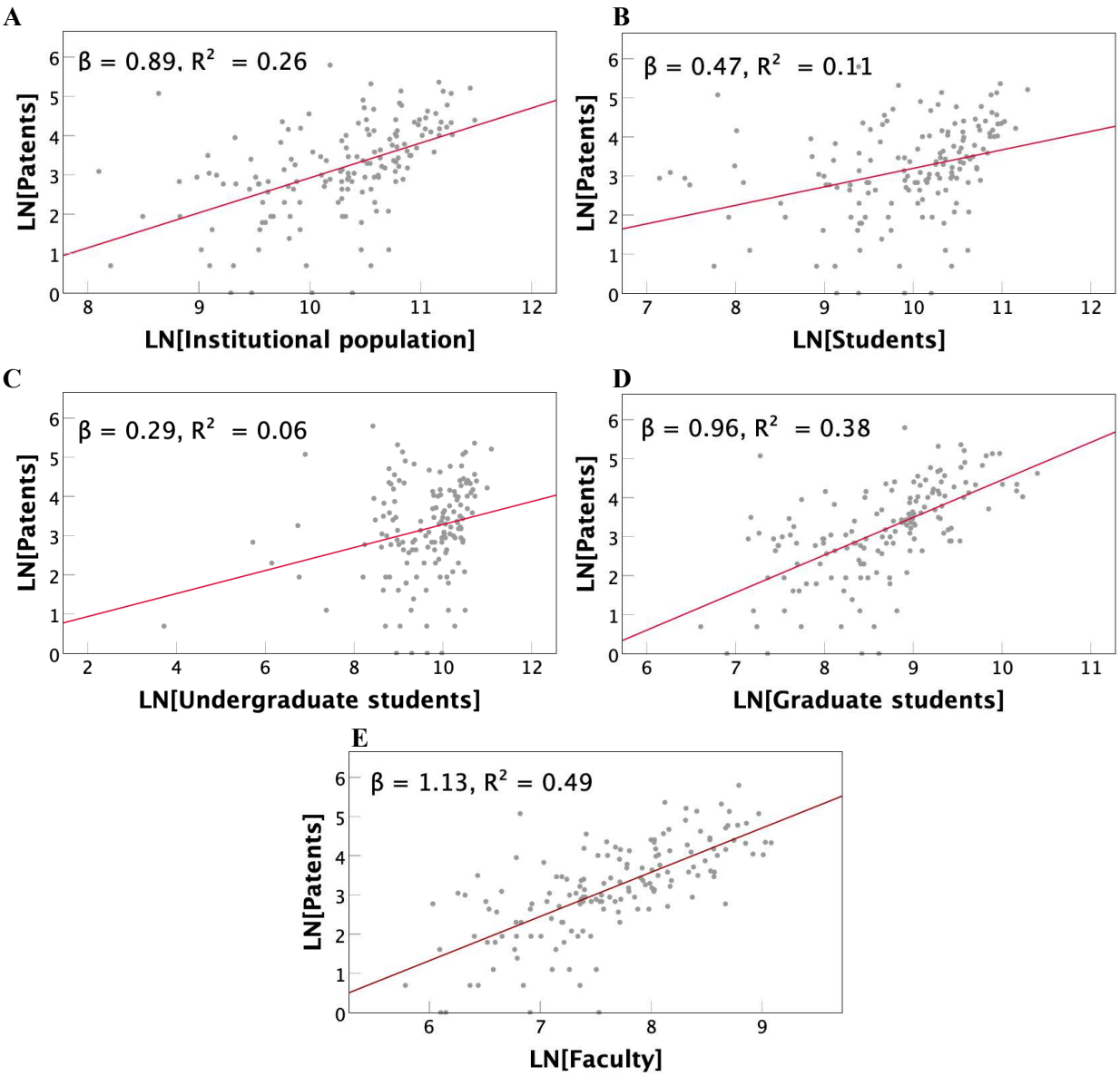


Fig. 1 Log–log scaling relationships between patent production and five candidate measures of institutional size. All variables were transformed using ln(x + 1).

The undergraduate decoupling

As described above, undergraduate enrollment exhibited almost no relationship with patent production, suggesting that undergraduates are largely decoupled from measurable university innovation outputs. Superficially, one might imagine that universities are even better at leveraging their total populations with regard to innovation than are cities. Indeed, university budgets often assume such a coupling when student funds are used to help support research. Student funds are used in this way either to 1) train students in doing research (in which case student mentoring should be apprised) or 2) student ideas contribute part of the innovation environment. The latter does not appear to be the case, at least not for the research-intensive universities considered here. It is possible that the story is different at smaller universities, such as liberal arts colleges, where student research represents a much larger part of the

whole, but is beyond the scope of the present study. Graduate students, by contrast, are embedded in the research enterprise in ways that undergraduates typically are not, as the stronger scaling relationship indicates.

Viewed through the framework of Bettencourt et al. (2007b), faculty may represent the closest analogue within universities to the inventor populations driving urban innovation. Bettencourt and colleagues argued that the superlinear scaling of patents in cities emerged from the increasing agglomeration of inventors and the opportunities for interaction among them. Consistent with this interpretation, faculty exhibited the strongest scaling relationship with patent production among the population-based measures considered here. Whether a measure restricted to faculty whose appointments include research responsibilities would exhibit even stronger scaling remains an important question for future research.

Universities within cities

Even if universities do not show the superlinear scaling rules observed among cities, they might be influenced by the scaling rules of the cities in which they exist. We therefore asked whether universities benefit from the same urban context that appears to enhance innovation in cities themselves. It is often noted that the entrepreneurial ecosystem of a university is significant to its success at technology transfer (Good et al., 2019). This is a frequent claim with regard to both Stanford and MIT, for example (Fishman et al., 2014; Etzkowitz, 2022). We found no relationship between city size and the number of patents at university: $\beta = 0.16$, $R^2 = 0.04$. This finding suggests that the size of a university's surrounding metropolitan area, by itself, contributes little to differences in patent output. It does not necessarily mean that local innovation ecosystems are irrelevant, but rather that the relevant features of those ecosystems may be qualitative rather than demographic.

Population or economic resources?

Lobo et al. (2013) asked whether innovation in cities is better explained by population or by economic activity, comparing scaling relationships between population and GDP with patent output. GDP exhibited a sublinear scaling exponent of $\beta = 0.77$ ($R^2 = 0.39$), substantially weaker than the relationship for population of $\beta = 1.39$ ($R^2 = 0.72$). We ask a related question in the university context, but the appropriate economic analogue differs. Whereas GDP reflects the entirety of a city's economic activity, R&D expenditures represent resources specifically devoted to research and innovation. Consequently, R&D expenditures should be expected to capture university innovation capacity more directly than GDP captures urban innovation capacity.

Consistent with this expectation, R&D expenditures were the strongest predictor of patent number ($\beta = 0.75$, $R^2 = 0.60$). The similarity between the R&D scaling exponent observed here and the GDP exponent reported by Lobo et al. (2013) is noteworthy, but the substantially higher explanatory power of R&D is perhaps unsurprising given that it measures investment devoted directly to research. Rather than demonstrating that financial resources generally outperform population measures, this comparison highlights that the most informative measure of "economic size" depends on the system under study. Table 3 places the present findings alongside the corresponding scaling relationships reported by Bettencourt et al. (2007a) and Lobo et al. (2013), allowing direct comparison between urban and university scaling.

Table 3 Comparison of scaling relationships for population and economic measures

	β	R^2 Adj	Observations
Population			
City population – Bettencourt et al. (2007)	1.27	0.72	331 U.S. cities
City population – Lobo et al. (2013)	1.39	0.72	366 international cities
Metropolitan population (present study)	0.16	0.04	153 U.S. universities
Institutional population (present study)	0.89	0.26	153 U.S. universities
Economic resources			
GDP – Lobo et al. (2013)	0.77	0.39	366 U.S. cities
R&D expenditures (present study)	0.75	0.60	158 U.S. universities

Beyond size: Organizational predictors of patent production

Not all research capacity is equal

The preceding analyses suggested that institutional population alone does not explain differences in patent production. We therefore turned to a natural subsequent inquiry: what characteristics of universities might influence how effectively research activity translates into patenting? We begin by considering two common organizational features of research universities: the presence of dedicated medical schools and engineering schools. Institutions with medical schools consistently report substantially higher R&D expenditures year after year, largely because of National Institutes of Health (NIH) funding, which disproportionately goes to academic medical centers and itself represents the largest individual source of federal research investment in U.S. higher education (NCSES, 2026).[3] By contrast, engineering schools may maintain an advantage in patenting less through overall funding than through the applied and commercialization-oriented nature of engineering research.

These trends are evident in our data, as well. Institutions with a medical school produced significantly more patents on average than those without (M = 50.61 vs. 32.99; t = 2.32, p = 0.022, d = 0.37), and also reported substantively higher R&D expenditures (M = US$1.02B vs. US$504M; t = 2.60, p = 0.010, d = 0.41). Institutions with a dedicated engineering school produced significantly more patents that those without (M = 47.76 vs. 17.38; t = 5.56, p < 0.001, d = 0.65), but did not differ significantly from those without in R&D expenditures (M = US$602M vs. US$453M; t = 1.43, p = 0.158).

[3] The US Department of Health and Human Services (HHS), which includes NIH, contributed 55% of all fiscal year (FY) 2024 federal R&D funds. Of these funds, HHS contributed US$30.9 billion to life science R&D including biomedical science. By comparison, a total of $US12.2 billion was awarded to engineering R&D across all federal granting agencies. Furthermore, the top 30 institutions in R&D expenditures accounted for 42% of all R&D spent on R&D in higher ed; 28 of those 30 institutions had medical schools (NCSES, 2026). The US Government has been the largest source of academic R&D funding since 1953; therefore, federal appropriations and funding decisions are able to drive expenditures in academic fields.

Table 4 Patent Output and R&D Expenditures by Institutional Characteristics

	Medical School		Engineering School	
	Yes (n = 87)	No (n = 76)	Yes (n = 125)	No (n = 32)
Patents Issued				
Mean	50.61	32.99	47.76	17.38
SD	42.54	52.83	51.82	16.35
R&D Expenditures (in thousands of USD)				
Mean	1,015,557	503,930	601,755	453,341
SD	1,296,923	1,194,805	610,345	498,143

Note: Group differences in patents issued were statistically significant for both medical school presence (t = 2.32, p = 0.022) and engineering school presence (t = 5.56, p < 0.001). Group differences in R&D expenditures were significant for medical school presence (t = 2.60, p = 0.010) but not engineering school presence (t = 1.43, p = 0.158).

Table 5 Medical and engineering school indicators as predictors of patent output, before and after controlling for R&D expenditures

	Medical school		Engineering school	
	Model 1 (alone)	Model 2 (+R&D)	Model 1 (alone)	Model 2 (+R&D)
Indicator	β = 0.309***	β = -0.041	β = 0.285***	β = 0.184***
R&D exp.	–	β = 0.805***	–	β = 0.801***
Adjusted R^2	0.090	0.616	0.075	0.709

*** $p < 0.001$

Medical schools, engineering schools, and patenting rates

The descriptive comparisons above raise the question of whether these advantages are simply consequences of research spending differences, or if they reflect something intrinsic to the respective organizational structures. To further examine the relationship between medical school presence and patent output, we estimated two simple regression models predicting log-transformed patent output from medical school status (Table 5). Medical school status alone was a statistically significant predictor (β = 0.309, p < 0.001) and explained about 9% of the variance. When R&D expenditures were added alongside medical school status, medical school was no longer statistically significant (β = -0.041, p = 0.462) while R&D expenditures became the strongest predictor (β = 0.805, p < 0.001). Adjusted R^2 increased from 0.090 to 0.616. In short, medical schools increase patent numbers but do so in such a way that is primarily explained by additional research dollars.

We then estimated the same pair of models using engineering school presence rather than medical school presence.[4] Engineering school status alone significantly predicted log patent output ($\beta = 0.285$, $p < 0.001$), explaining about 8% of variance, similar to the medical school result. Unlike medical school status, however, engineering school presence remained statistically significant after R&D expenditures were added to the model ($\beta = 0.184$, $p < 0.001$), alongside the substantially larger association with R&D expenditures ($\beta = .801$, $p < .001$). Adjusted R^2 rose from 0.075 to 0.709. Institutions with engineering schools therefore produced more patents than institutions with comparable R&D expenditures but without engineering schools.

Taken together, these results suggest that medical schools and engineering schools are associated with patent production through different mechanisms. The medical school advantage can be explained through greater research funding, whereas engineering school presence predicts additional patent output beyond what research spending would suggest.

Why might engineering schools confer a patent advantage independent of research dollars? One possibility is alignment. Engineering research is often directed toward the development of devices or technologies with direct commercial applications. Biomedical research, however, often involves longer pathways between research and commercialization, pathways that require extensive validation, regulation, and development from outside organizations before commercialization even becomes feasible. Consequently, engineering programs may generate more patentable outputs per research dollar. Alternatively, institutions with dedicated engineering schools may have developed stronger collaboration with industry and internal structures to support commercialization (Wu et al., 2015; Tang et al., 2026). Distinguishing among these explanations will require further analyses beyond the scope of this study.

Independent institutional predictors of patent output

The preceding analyses considered individual institutional characteristics separately. We next examined which characteristics remained independently associated with patent output when all candidate predictors were considered simultaneously. To do so, we estimated two stepwise multiple regression models using log-transformed patent counts as the outcome variable.

Both models included the same candidate predictors, all log-transformed except for binary indicators: R&D expenditures, graduate enrollment, faculty, and binary indicators for engineering and medical school presence. Model B additionally included log-transformed TTO staff as a possible predictor, but because TTO staffing data were missing for a substantial number of institutions, Model B was estimated on a reduced sample ($n = 112$) compared to Model A ($n = 151$). We present both models because Model A maximizes sample size, whereas Model B evaluates whether TTO staffing explains additional variance in patent output.

In both models, the stepwise procedure entered three predictors and excluded the rest. R&D expenditures entered first in both cases and alone explained the majority of variance in log patents: 67.9% in Model A ($\beta = 0.824$, $p < 0.001$) and 70.6% in Model B ($\beta = 0.840$, $p < 0.001$). This finding reinforces the earlier analyses showing that research investment is the strongest predictor of patent production across universities.

Engineering school presence entered second in both models, adding roughly 3% of explained variance in each case (Model A: $\beta = 0.184$, $p < 0.001$; Model B: $\beta = 0.163$, $p = 0.001$). This is notable because institutions with and without engineering schools do not differ significantly in R&D expenditures, indicating that the engineering school effect is not simply a proxy for greater research expenditures.

The third variable to enter differed between models. In Model A, graduate enrollment contributed an additional 1% of explained variance ($\beta = 0.132$, $p = 0.021$). In Model B, TTO staff contributed 1.9% (β

[4] This is a noteworthy test because, unlike medical school status, the presence of a dedicated engineering school is not tracked in any public database. Ours is likely the first such indicator constructed at this scale, gathered via institutional website review.

= 0.259, p = 0.005). Although graduate enrollment and TTO staffing capture different institutional characteristics, both point to dimensions of research capacity beyond research expenditures alone. Graduate enrollment reflects research personnel, whereas TTO staffing represents commercialization capacity. The retained power of TTO staffing suggests that patent output is influenced by institutional infrastructure focused on commercialization outcomes.[5]

Medical school presence and faculty size did not enter either model. Although institutions with medical schools produce more patents on average, this apparent advantage disappears after accounting for research expenditures, reinforcing the earlier finding that the medical school effect is largely explained by greater research investment. By contrast, engineering school presence remained an independent predictor throughout the analyses, suggesting that organizational or disciplinary characteristics associated with engineering schools contribute to patent production beyond differences in research spending alone.

Despite relying on only three predictors, the final models explained approximately 72–75% of the variance in log-transformed patent output (adjusted R^2 = 0.717 and 0.745, respectively).

Table 6 Stepwise regression model results

	Model A (n=151)		**Model B (n=112)**	
	β	p	β	p
R&D expenditures	0.824	<.001	0.84	<.001
Engineering school	0.184	<.001	0.163	0.001
Graduate enrollment	0.132	0.021	–	–
TTO staff	–	–	0.259	0.005
Medical school	–	–	–	–
Faculty	–	–	–	–
Adj R^2	0.717		0.745	

Institutional inertia

In considering cities, Geoffrey West noted their inertia, writing, “Roughly speaking, all cities rise and fall together, or to put it bluntly: if a city was doing well in 1960 it’s likely to be doing well now, and if it was crappy then, it’s likely to be crappy still” (West, 2017, ch. 8). We find a similar pattern with universities. R&D expenditures across U.S. institutions reporting to HERD were remarkably stable over the three decades from 1994 to 2024, with cross-decade correlations ranging from 0.942 to 0.978 (p < 0.001). Institutional R&D expenditures in 1994 explained nearly 90% of the variation in expenditures three decades later. Leadership changes, strategic plans, and spending plans notwithstanding, the hierarchy of research investment has proven remarkably stable. When writing about the similar phenomenon in cities, West notes, mayors of (successful) cities “who take credit and boast that their policies have led to economic success as evidenced by their city’s being near the top of the per capita GDP rankings are therefore giving a misleading impression” (West, 2017, ch. 8). Likewise, university

[5] Chapple et al. (2005) found that differences in TTO resources were associated with overall technology transfer performance in U.K. universities. However, they also found decreasing returns to scale within those TTOs, suggesting more staffing did not lead to greater efficiency.

administrators deserve neither full credit nor full blame for success or failure in changing an institution's status quo.

Patent output exhibited slightly more variation through time than R&D expenditures (though the variation is nonetheless modest).[6] Cross-decade correlations in patent counts ranged from 0.773 to 0.916 ($p < 0.001$), indicating that the institutions producing the most patents in the early 1990s were largely still the most productive, relatively, three decades later. Over that same period, however, mean output grew substantially (from roughly 12-14 per institution in the early 1990s to more than 50 per institution around 2019-2021) but this growth was not evenly distributed. Standard deviations almost tripled over the period, indicating that the gap between high- and low-patenting institutions widened considerably. This pattern is consistent with the Matthew effect (Merton, 1968): institutions that began with advantages in research capacity and commercialization tended to accumulate still greater advantages over time. Universities, at least with respect to patent production, do not appear to compete on an even playing field; rather, longstanding institutional advantages have proven remarkably persistent. As with cities, universities appear to possess considerable institutional inertia. Success, once established, is remarkably durable.

Table 7 Stability of institutional R&D expenditures across three decades, 1994-2024

	1994	1999	2004	2009	2014	2019	2024
1994	–						
1999	0.988	–					
2004	0.977	0.989	–				
2009	0.972	0.982	0.992	–			
2014	0.965	0.969	0.978	0.987	–		
2019	0.949	0.956	0.968	0.975	0.986	–	
2024	.942	.948	.961	.970	.978	.992	–

Note. All correlations significant at p < 0.01. Sample size ranges from 605 to 890, depending on reporting year.

Table 8 Stability of patent output, 1994-2024

	1994	2004	2014	2024
1994	–			
2004	0.888	–		
2014	0.904	0.921	–	
2024	0.788	0.814	0.891	–

Note. All correlations significant at p < 0.01. Yearly samples are comprised of 85-106 U.S. universities responding to AUTM LAS.

[6] Variability in patent or other commercialization counts across years partly reflects limitations of the AUTM LAS data. As a voluntary survey, the LAS is subject to inconsistent institutional participation and variable reporting quality, limiting confidence in any individual data point. However, the longitudinal patterns described here are unlikely to be simply artifacts of reporting inconsistency alone, and we consider them broadly reliable for interpreting trends over time.

Conclusions and Implications

This study represents the first broad application of urban scaling theory to university patent production. Although universities resemble cities in many respects, they do not exhibit the superlinear patent scaling characteristic of urban innovation. Instead, patent production is more closely associated with research resources and organizational characteristics than with institutional population itself.

One interpretation is that cities derive their innovative advantage from interactions among large numbers of heterogeneous individuals, whereas universities are famously siloed organizations with comparatively fixed structures, budgets, and missions. Population growth alone may therefore produce fewer new opportunities for interaction than it does in cities. Distinguishing between interaction-driven and organization-driven innovation is a worthwhile direction for future research in this area.

If research investment is the dominant predictor of patent production, and if institutional rankings remain remarkably stable through time, then meaningful changes in university innovation will likely require meaningful changes in patterns of research investment.

As noted above, federal funding decisions can impact R&D spending patterns. Federal granting patterns have remained consistent with university R&D spending patterns. From FY 2014 to FY 2023, only 15 universities appeared in the annual lists of the top 10 recipients of U.S. federal science and engineering funding (NCSES, 2026), and Johns Hopkins University was the top recipient each year. Applicants' previous success (Qui, 2023) and research topic (Hoppe et al., 2019) also impact probability of funding success. Recent shifts in U.S. research priorities, however, represent the type of external shock that could alter long-standing trajectories. The landscape of US federal R&D funding is currently changing (Exec. Order No. 14332, 2025), with redirections of priority funding areas (Exec. Order No. 14409, 2026; White House, 2025) and universities (Garisto, 2026). Major shifts could impact the relative rankings of university R&D expenditures, and therefore the relative rankings of patent outputs. Additional sources, such as industry and non-governmental organizations, could provide additional university R&D funding to support innovation and patenting. State and local governments could also provide R&D funding through appropriations, as has been proposed in California (CA Science and Health Research Bond Act, 2026), or tax incentives. Whether changes in federal, state, industry, or philanthropic investment substantially reshape university innovation remains an important question for future research.

This study has several limitations. Patent counts represent only one form of innovation and likely favor engineering and biomedical fields over other forms of scholarly impact. Our analyses were also limited by the availability and completeness of existing datasets, particularly AUTM LAS reporting and its included TTO staffing data. Finally, because the analyses are based on a modest sample of research-active U.S. universities, confidence intervals around several scaling exponents remain relatively wide. Future work using larger or international samples, improved technology transfer data, and broader measures of innovation will allow more precise estimation of university scaling relationships.

Scaling theory has proven useful for understanding organisms, cities, and now universities. Yet universities appear to occupy an intermediate position between cities and firms: they are sufficiently complex to support innovation but sufficiently organized that growth alone does not generate increasing returns. Understanding why universities occupy this intermediate position may improve not only our understanding of university innovation, but of how complex organizations more generally transform knowledge into societal benefit. More broadly, these findings suggest that applying scaling theory to organizations may be most informative not when organizations conform to urban scaling laws, but when deviations from those laws reveal the organizational processes that shape innovation.

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