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Higher Education Quality, Income and Innovation: Cross-Country Evidence

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Abstract

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Keywords

education quality, human capital, economic development, innovation, college education, university rankings

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Higher Education Quality, Income, and Innovation: Cross-Country Evidence

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I. Introduction

Research has increasingly focused on cross-country differences in educational quality and their impacts at both individual and societal levels. These studies indicate, beyond the quantity of education—measured by enrollment rates or years of schooling—the quality, reflected in actual learning outcomes and acquired skills, is critical for economic development (Lee and Barro 2001; Hanushek and Woessmann, 2008; Angrist et al., 2021; Lee and Lee, 2024).

Scholars have been emphasizing the importance of educational quality across all levels, from primary schools to universities, in realizing full economic returns to education. Evidence indicates that schooling without effective learning yields limited individual benefits, while a growing body of literature shows that educational quality accounts for a substantial share of cross-country differences in national income (see Section II for a detailed review).

Although the recent development discourse has shifted toward learning outcomes and the accumulation of national knowledge capital, several questions remain unresolved. How should higher education quality be measured across countries and to what extent does it influence long-run economic development and innovation?

This study addresses these questions by constructing a new cross-country measure of higher education quality and analyzing its impact on national economic outcomes. The study draws on data compiled by Martellini et al. (2024), which document the wage outcomes of college graduates employed overseas. The study shows that these earnings are systematically linked to observable institutional characteristics—specifically faculty-to-student ratios and Times Higher Education (THE) global rankings. Using US data, it validates that global rankings are strongly correlated with key quality dimensions, including research output, teaching environment, internationalization, enrollment size, and student selectivity.

Building on this relationship, a country-level index of college education quality is constructed by aggregating institutional characteristics weighted by their estimated contributions to graduates' earnings. As discussed in Section II (literature review), consistent and scalable indicators of tertiary education quality spanning a broad range of countries remain scarce. To the best of our t knowledge, this is the first study to integrate institution-level indicators with international graduate outcomes to generate a consistent and comparable measure of tertiary education quality across 98 countries.

The study examines whether variations in this index help explain cross-country differences in income levels and technological innovation. To address potential endogeneity, it employs an instrumental variable (IV) strategy based on geographic distance to the world's top 20 universities. This approach captures a country's exposure to global academic hubs and generates plausible exogenous variation in education quality. The study demonstrates that the instrument is strong (first-stage F-statistic > 10) and argues that its exclusion restriction is reasonable, as proximity to top-ranked universities influences development outcomes, primarily through educational spillovers.

The results indicate that the quality of college education has a large, positive, and statistically significant effect on gross domestic product (GDP) per worker, resident patenting activity, and research and development (R&D) expenditure. While previous studies have explored educational quality and its implications at both micro and macro levels, limited research has focused on measuring the quality of college education at the national level and linking it to economic and technological outcomes. This study addresses this gap and contributes to the literature on economic development, education economics, and technological innovation.

The remainder of the study is organized as follows. Section II reviews the literature on measuring educational quality, particularly at the tertiary level, and its economic effects. Section III describes the construction of the higher education quality index. Section IV presents cross-country regression results of the impact of the quality of college education on economic development and technological innovation. The conclusions are presented in Section V.

II. Literature Review

Educational quality plays a critical role in shaping long-term economic development by influencing human capital formation. It broadly refers to the extent to which the education system imparts knowledge, skills, and competencies that are relevant, durable, and conducive to personal and national development. Unlike educational attainment—which is relatively easy to quantify—educational quality is multidimensional and therefore less directly observable. Consequently, researchers and international organizations have relied on both direct assessments and proxy indicators for evaluation.

At the primary and secondary levels, the most direct measures of educational quality are standardized assessments such as the Programme for International Student Assessment (PISA), Trends in International Mathematics and Science Study (TIMSS), and Progress in International Reading Literacy Study (PIRLS). These tests provide widely used benchmarks for cross-country comparisons, revealing substantial variations in cognitive skills. A large body of evidence shows that such variation is a strong predictor of long-term economic development (Hanushek and Kimko, 2000; Hanushek and Woessmann, 2008; Kaarsen, 2014; Angrist et al., 2021; Lee and Lee, 2024).

Beyond test scores, educational quality is often inferred from input indicators such as per-pupil spending, class size, student–teacher ratios, teacher qualifications, and instructional time. While these inputs do not always directly translate into learning gains, extremely low input levels are consistently associated with poor learning outcomes, especially in low-income countries (OECD, 2022).

Although the quality of primary and secondary education has been extensively examined, measuring the quality of tertiary education across countries remains significantly more challenging and underexplored. Colleges and universities differ widely in their mission, disciplinary focus, research intensity, and student population. Despite this heterogeneity, various approaches have emerged to assess the quality of tertiary education using both input and outcome metrics.

A commonly used—albeit contested—proxy is international university rankings, such as those published by Quacquarelli Symonds (QS), Times Higher Education (THE), Center for World University Rankings (CWUR), and Academic Ranking of World Universities (ARWU). These rankings aggregate metrics such as faculty research output, academic credentials, citation counts, and institutional reputation. However, they often prioritize research performance over teaching quality and may conflate institutional prestige with actual educational effectiveness (OECD, 2013; Ge et al., 2022). Scholars have cautioned against interpreting these rankings as direct indicators of undergraduate instructional quality, due to the lack of learning-focused metrics.

Accordingly, efforts have been made to assess student learning in higher education directly. The pilot study of the Organisation for Economic Co-operation and Development's (OECD) Assessment of Higher Education Learning Outcomes demonstrated the feasibility of evaluating graduate students' cognitive skills across countries (OECD, 2013). Related initiatives—such as the Collegiate Learning Assessment Plus (CLA+)—evaluate critical reasoning and communication in six OECD countries (OECD, 2021).

Complementing these efforts is the Programme for the International Assessment of Adult Competencies, also developed by the OECD, which evaluates the literacy and numeracy skills of adults aged 16–65 across 39 countries. The data reveal significant cross-country disparities in the skill level of adults with a college education. For example, 54% of young university graduates in Finland scored at the highest literacy level, compared to only 2.5% in Turkey (OECD, 2016). Loyalka et al. (2021) further highlighted differences in the critical thinking and academic skills of Science, Technology, Engineering, and Mathematics undergraduates in China, India, Russia, and the US using standardized assessments.

An increasingly prominent approach to evaluating tertiary education quality involves analyzing labor market outcomes. Administrative data on graduate earnings and employment, disaggregated by institution and field of study, allow estimation of institutional value-added. In the UK, earnings differentials across universities persist, even after accounting for student background (Walker and Zhu, 2018). In the US, studies using the College Scorecard reveal considerable heterogeneity in returns to college, even after adjusting for selection effects (Black and Smith, 2006; Mountjoy and Hickman, 2021).

Martellini et al. (2024) developed a measure of college education quality based on the average earnings of internationally mobile college graduates. By controlling for host country labor market conditions, the study isolates the effects of institutional quality across 2,800 institutions in 48 countries. This approach provides a valuable framework for comparing college education quality internationally, helping address a critical data gap.

A substantial body of research links educational quality with economic outcomes. At the individual level, higher cognitive skills—particularly at the primary and secondary levels—are associated with higher earnings even after controlling for years of schooling (Mulligan, 1999; Bratsberg and Terrell, 2002; Hendricks, 2002). Among immigrants, the quality of education in the country of origin predicts earnings in host labor markets (Hanushek and Woessmann, 2012; Schoellman, 2012; Li and Sweetman, 2014; Lee and Lee, 2024).

At the macro level, educational quality accounts for a substantial proportion of cross-country variation in productivity and per capita income. Studies such as those by Caselli (2005), Schoellman (2012), Kaarsen (2014), Hendricks and Schoellman (2018), Angrist et al. (2021), and Lee and Lee (2024) demonstrate the positive contribution of educational quality to national economic performance.

A growing body of research has also shown that the quality of tertiary institutions significantly influences labor market outcomes within individual countries. Graduates from more selective or prestigious universities tend to earn higher wages, have greater employment prospects, and are more likely to pursue postgraduate education (Dale and Krueger, 2002; Hartog et al., 2010; MacLeod et al., 2017; Sekhri, 2020; Schwerter, 2020; Ge et al., 2022). However, disentangling causal effects is challenging due to student sorting. Dale and Krueger

(2014) determine that much of the observed earnings advantage among elite college graduates disappears after accounting for students' abilities and college admission choices. Mountjoy and Hickman (2021) show that institutional value-added accounts only for a small portion of the observed variation in student earnings, as most outcome disparities reflect factors beyond college choice within students' admissible sets. Nonetheless, high-quality colleges provide significant benefits for specific groups, particularly women, low-income students, and underrepresented minorities (Chetty et al., 2017; Ge et al., 2022).

Several studies have directly linked university activities to regional economic outcomes. Aghion et al. (2009) find that exogenous increases in investment in four-year colleges, instrumented by political factors, promoted state-level growth and patenting in the US. Hausman (2022) shows that innovative output from universities positively influences long-run employment and wages in surrounding counties, particularly in sectors associated with the university's research strength, with the effect diminishing with distance.

However, at the global level, consistent and scalable indicators of tertiary education quality are lacking and evidence of its macroeconomic effects remains limited. Valero and Van Reenen (2019) show that regions with more universities experience faster long-term growth; however, their analysis focuses on quantity rather than quality. Martellini et al. (2024) demonstrate the positive relationship between the average quality of the top 5% of colleges in the CWUR global rankings and GDP per worker across countries. However, their study is limited to countries with data on internationally-mobile graduates and does not address potential endogeneity.

In summary, while the literature provides robust and consistent evidence that educational quality—particularly at the tertiary level—has significant micro and macroeconomic effects, major challenges remain. These include the development of cross-country indicators encompassing a wide range of countries, identification of causal effects, and a deeper understanding of the mechanisms linking education quality to development and innovation.

III. Constructing a Measure of Higher Education Quality

A. Data on college graduates' average earnings, faculty–student ratio, and international ranking

The study examines the relationship between the earnings of internationally-employed college graduates and college-level indicators such as faculty-to-student ratios and international rankings using institution-level data compiled across countries.

The earnings data for these graduates is sourced from Martellini et al. (2024), who construct a measure of "college graduate quality" based on the (logarithm of) average earnings of college graduates—adjusted to reflect what graduates would earn in a common labor market—for approximately 2,800 universities across 48 countries from 2006 to 2022. Their primary data source is Glassdoor, which provides earnings and education information for both migrants and non-migrants across numerous colleges and countries, enabling international comparisons of graduate quality.

Direct comparisons of average earnings across countries can be misleading, as earnings reflect not only individual human capital but also country-specific factors, such as overall productivity, capital intensity, and labor market characteristics for skilled labor. Martellini et al. (2024) employ a two-step estimation procedure to isolate the contribution of colleges to graduate earnings. First, they use data from individuals reporting earnings in multiple countries. By analyzing earnings changes when individuals move between countries, they estimate country-specific skill prices. This step also accounts for complexities, such as imperfect skill portability and self-selection.

Next, individual workers' reported earnings are adjusted by subtracting the estimated skill price of the country of their employment, effectively normalizing earnings to a common labor market standard. These adjusted earnings are then regressed on college fixed effects. The estimated fixed effect for each college represents its "college graduate quality"—i.e., the average, market-adjusted earnings of its graduates.

This study link the average earnings of college graduates—net of country effects—to two major college-level quality indicators to construct a higher education quality index across a broad set of countries. The first indicator captures the number of faculty per student at each tertiary education institution, based on the full-time equivalent (FTE) count of academic staff and FTE student enrollment across all years and programs. The data are primarily based on average figures from THE World University Rankings dataset for 2010–2022 (Times Higher Education, 2024). For US institutions not covered by THE, data from the Institute of Education Sciences were used. For universities in other countries not included in the THE dataset, information was sourced from their respective ministries of education, ranking agencies, statistical agencies, and self-reported figures from the universities.

International university rankings serve as a second indicator of college quality. University rankings significantly influence perceptions of institutional quality and academic reputation worldwide. Among the four major ranking systems—THE, CWUR, ARWU, and QS—the study uses THE World University Rankings, covering all listed universities from 2010 to 2022.[1] THE began publishing joint rankings with QS from 2004 to 2009 and independent rankings in 2010. The methodology incorporates a broad set of indicators, including research quality and impact, teaching environment, international outlook (e.g., proportions of international students and faculty), and industry income and innovation.

THE rankings are suitable for evaluating research-intensive institutions by combining subjective reputation surveys with objective metrics. Although this comprehensive approach captures a broad spectrum of institutional activities, its emphasis on global reputation tends to favor historically prestigious universities and may disadvantage lesser-known institutions. In the 2022 THE rankings, the top 20 include 12 universities from the US (average rank 8.7), 4 from the UK (average rank 9), 2 from China (16), and 1 each from Switzerland (15) and Canada (18). Appendix Table B.1 presents the rankings of the top 50 universities in 2022 and, for comparison, in 2010.

B. Effect of college quality indicators on average earnings of graduates

Using the newly-constructed global database on college-level education quality, the authors assess how quality indicators influence the average earnings of college-educated workers across countries.

A Mincer-type wage regression was estimated using college-level data as follows:

$$W_i^j = \alpha + \beta * \log(\text{Faculty} - \text{Student ratio})_i^j + \sum_{k=1}^{4} \lambda_k * \text{Ranking}_{i\in k}^j + \eta^j + \varepsilon_i^j \quad (1)$$

where W_i^j is the logarithm of average earnings of graduates from the tertiary institution *i* in country *j*. The faculty–student ratio measures the number of faculty per 100 students at college *i*. $\text{Ranking}_{i\in k}^j$ is a dummy variable equal to 1 if institution *i* belongs to tier *k*, based on its average THE World University Ranking from 2010 to 2022.

The institutions are grouped into five tiers based on their average THE rankings from 2011 to 2018: Group 1 (ranks 1–20), Group 2 (21–50), Group 3 (51–100), Group 4 (101–200),

[1] Online Appendix A compares the methodologies of four global university rankings and presents the top 50 universities in 2022 across the four rankings.

and Group 5 (ranks below 200 or unranked). Group 5 serves as the reference category. Country-fixed effects η^j are included to control for country-specific factors, and ε_i^j is the error term.

In this specification, coefficient β captures the effect of the faculty–student ratio on average graduate earnings, conditional on ranking group. Each λ_k measures the additional return associated with attending a college in ranking tier *k*, relative to unranked institutions (i.e., those outside the global top 200).

Estimating Equation (1) poses several empirical challenges, particularly, the risk of omitted variable bias. Factors influencing both graduates' earnings and college quality—such as country-level shocks, students' abilities, and socioeconomic backgrounds—are unobserved. Since the quality indicators do not exploit exogenous variation, the analysis does not produce fully causal estimates. However, the inclusion of country-fixed effects helps mitigate bias at the national level. Moreover, the use of institution-level quality measures for individual graduates reduces endogeneity concerns.

Table 1 presents the regression results for Equation (1). Column (1) includes only the faculty–student ratio. The estimated coefficient is 0.115, which is statistically significant. Column (2) includes only four global university ranking group variables. All are statistically significant with coefficients of 0.411, 0.224, 0.180, and 0.137, indicating stronger effects at higher rankings.

[Please insert Table 1 around here]

Column (3) includes both faculty–student ratio and ranking group indicators. The estimated coefficients are slightly smaller: 0.103 for the faculty–student ratio and 0.360, 0.205, 0.172, and 0.130 for Groups 1–4, respectively. For example, a one-log-unit increase in the faculty–student ratio (with a standard deviation (SD) of 0.44) is associated with a 0.103-point increase in average log earnings (with an SD of 0.72). Similarly, attending a tier 1-ranked college is associated with a 0.360-point increase in average log earnings.

C. Construction of cross-country higher education quality

A country-level higher education quality index is constructed using the estimated coefficients from Column (3) of Table 1. Since the coefficient of the faculty–student ratio (β) and ranking group indicators (λ_k) represent the marginal contributions of these quality dimensions to graduates' earnings, they can be combined with institutional characteristics to create a composite quality score for each college.

To aggregate these scores at the country level, each institution's composite quality score is weighted by its share of national university enrollment, yielding the average quality index for each country's higher education system.

Assuming that the estimated coefficients apply to all institutions, including those without graduate earnings data, a country-level index is generated reflecting overall higher education quality.

The index of higher education quality for country j, denoted as h_q^j, is defined as

$$h_q^j = \exp[\beta * log(\overline{Faculty - student\ ratio}^j) + \sum_{k=1}^{5} \lambda_k * (share\ of\ students\ in\ Ranking_{i\in k}^j)] \quad (2)$$

This exponential form is consistent with the log specification in Equation (1). $\lambda_k = 0$ for the group $k = 0$. Since the index is constructed at the country level, the log of national average number of faculty per 100 students from the UNESCO database for 2010–2022 is used to supplement missing observations with THE data.[2]

The higher education quality index from 2011–2022 is calculated for 98 countries. Appendix Table B.2 presents the index values, along with each country's share of university enrollments in the top 20, 50, 100, and 200-ranked institutions and faculty–student ratios (averaged from 2011–18), which are used in the regressions in the next section.

D. Determinants of global university rankings

As illustrated in Section 3.C, the regressions indicate that a college's THE global ranking is strongly associated with its graduates' average earnings. Accordingly, the rankings are used as input to construct a broad measure of higher education quality at the country level.

The study also examines the extent to which global university rankings are associated with observable institutional characteristics using data on ranking scores and institutional features of US universities ranked by THE in 2023. Accordingly, 2,345 universities were evaluated, of which 177 were from the US. Among these, 12 were ranked 1–20, 11 in the 21–

[2] To ensure consistency between the two data sources, the log of the country-level average faculty–student ratio reported by UNESCO (2025) is regressed on the log of the national average faculty–student ratio derived from THE data, using a common sample of 43 countries over the 2010–2022 period. The estimated relationship is:

$\log(\text{UNESCO}) = 1.031\ (0.041) \times \log(\text{THE}),\ R^2 = 0.937,$

where standard errors are reported in parentheses. This estimated relationship is used to impute missing values for five countries—Australia, Chile, Hong Kong (China), Israel, and South Africa—in the UNESCO database.

50, another 11 in the 51–100 range, 24 in the 101–200 range, and 119 were ranked outside the top 200.

The study focuses on institutional variables that capture the key dimensions of quality, including research performance, teaching environment, institutional size, international outlook, and student selectivity (Marconi et al., 2015; Robinson-Garcia et al., 2019; THE, 2024). Data on institutional characteristics are obtained from the Integrated Postsecondary Education Data System (National Center for Education Statistics, 2022). After including these institutional variables, the sample size decreased to 168.

Using college-level data from US universities, the effects of institutional characteristics on THE rankings are estimated. US universities included in the 2023 THE ranking are categorized into five groups: ranks 1–20, 21–50, 51–100, and 101–200, and those ranked outside the top 200. A multinomial logistic (MNL) model is estimated where each university *i* belongs to one of the ranking groups *k*.

$$y_i = \begin{cases} 1: Ranking: 1-20 \\ 2: Ranking: 21-50 \\ 3: Ranking: 51-100 \\ 4: Ranking: 101-200 \\ 5: Ranking: 200+ \end{cases} . \quad (3)$$

This specification enables a more straightforward interpretation of the estimated coefficients measuring covariate effects on ranking group membership. Ranking group 5 (institutions ranked 200 and above) serves as the baseline category in the analysis, and the probability of university *i* being in ranking group *j* is given by

$$P(y_i = j|X_i) = \exp\left(\beta_0 + X_i\beta_j\right) / [1 + \textstyle\sum_{k=1}^{4} \exp(\beta_0 + X_i\beta_k)], \quad (4)$$

where X_i denotes the set of covariates. To mitigate endogeneity concerns, these variables are lagged by one year. The covariates include:

(i) Research expenses per 12-month FTE enrollment and (ii) instruction expenses per FTE enrollment, both expressed in thousands of dollars;

(iii) The log of the number of doctoral degrees (awarded in one year);

(iv) The faculty-to-student ratio, defined as the number of FTE students per 100 FTE instructional staff, excluding graduate and professional programs;

(v) The log of total enrollment

(vi) The ratio of international students to total students

(vii) The ratio of international faculty to full-time instructional staff

(viii) The admission rate (percentage of total enrolled students relative to total applicants).

Table 2 summarizes the results of the MNL model. The pseudo R^2 is 0.730, indicating a good overall model fit. Research expenditure per FTE emerges as an important factor across all ranking tiers, suggesting that research intensity is fundamental to achieving higher-ranking positions, with the strongest effects observed in the top two tiers (1–21 and 21–50).

[Please insert Table 2 around here]

University scale, measured by the log of total enrollment, exhibits strongly positive effects that increase across ranking tiers—from 8.36 for ranks 101–200 to 18.62 for ranks 1–21—suggesting significant economies of scale in achieving top-tier rankings and reflecting the resource advantages of larger institutions.

Faculty-to-student ratio exhibits predominantly positive effects across ranking groups, with significant coefficients in three of four categories. However, the number of doctoral degree recipients is not a significant factor across any group.

Instructional expenditure per FTE positively influenced the top three ranking categories, but not ranks 101–200, suggesting that educational investment is particularly crucial for achieving and maintaining elite status.

International student ratio demonstrates consistent positive effects across all ranking groups, underscoring the importance of student internationalization in university ranking performance. Conversely, international faculty ratio has no significant effect.

Admission rate consistently exhibits negative effects across groups, particularly the top tier, reinforcing the importance of selectivity in global university rankings. This also suggests that rankings may partly reflect the quality of incoming students rather than institutional quality, as higher-ranked universities tend to attract more capable students.

IV. Effects of Higher Educational Quality on Economic Development and Technology Innovation across Countries

The newly constructed database is used to examine how higher education quality helps explain cross-country disparities in economic development and technological innovation. Although the analysis relies on a simple regression framework, identifying precise causal effects remains challenging. Accordingly, an IV approach is employed to estimate the causal impact of higher education quality on economic and technological outcomes.

A. Cross-country indicators and bivariate patterns

The study considers several key indicators of economic development and innovation:

(i) GDP per worker: This is the primary measure of economic development, representing national output per worker or aggregate labor productivity. It is constructed by combining real GDP per capita (in constant 2017 international prices) from the Penn World Table 10.1 (Feenstra et al., 2015) with working-age population data from the United Nations (2024). Alternatively, per capita GDP (in current international dollars) from the World Bank (2025) is used.

(ii) Resident patent applications per million population: This indicator measures the number of patent applications filed by resident applicants, scaled per million inhabitants. It is sourced from the World Intellectual Property Organization (2025).

(iii) Research and development (R&D) expenditure (% of GDP): This reflects the share of a country's GDP allocated to R&D activities, based on data from World Bank (2025).

To ensure consistency in timing and data availability, the study uses the average value of the higher education quality index from 2011 to 2018 and matches it with economic and technological indicators from 2019. The sample includes only countries with available data on GDP per capita (from the Penn World Table and World Bank) and other relevant indicators.

Figures 1–3 plot the higher education quality index against each of the three key indicators of economic development and technological innovation. The horizontal axis in each plot exhibits substantial cross-country variation in the quality of higher education. Figure 1 demonstrates a clear positive bivariate relationship between higher educational quality and GDP per worker. Countries such as Luxembourg, Switzerland, Canada, Germany, and Singapore tend to exhibit both high educational quality and high per-worker output. Conversely, countries such as Nepal, Sudan, Pakistan, and Ethiopia rank low on both metrics.

[Please insert Figure 1 around here]

Figures 2 and 3 also reveal strong positive bivariate relationships between higher educational quality and both technological innovation indicators. In addition to the countries mentioned above, Austria, Japan, Sweden and the US also perform strongly in both higher education quality and technological innovation.

[Please insert Figure 2 around here]

[Please insert Figure 3 around here]

B. Regression specification and IV approach

A simple cross-country regression model is established to examine the relationship between college education quality and an economic or technological indicator in year t (i.e., 2019), Y_t^j, as follows:

$$Y_t^j = \gamma_0 + \gamma_1 h_q^j + \gamma_2 ln\left(GDPpw_{t_0}^j\right) + \gamma_3 X^j + e^j. \quad (5)$$

where h_q^j is the higher education quality index for country *j*, averaged over 2011–2018; $ln\left(GDPpw_{t_0}^j\right)$ denotes the initial GDP per worker in 2011; and X^j represents other control variables. These include tertiary enrollment (relative to working-age population) as a measure of higher education quantity and population growth rate, which may influence both education systems and broader national outcomes.

In this specification, coefficient γ_1 captures the association between higher education quality and outcome variable, controlling for initial income levels and other relevant country-specific factors.

In estimating Equation (5), identifying the causal impact of higher education quality on economic or technological outcomes poses empirical challenges. Ordinary least squares (OLS) estimators face unresolved identification issues due to the potential for omitted variable bias and reverse causality. For example, wealthier countries may simultaneously benefit from higher per capita GDP, more advanced technology, and better universities, making it challenging to isolate the causal effect of education quality.

To address endogeneity issues, an IV strategy is employed to generate exogenous variation in higher education quality. This approach leverages a country's proximity to global academic hubs as a plausible exogenous determinant of domestic higher education quality. The primary instrument is the geographic distance to the world's top 20 universities. The rationale is that countries farther from these top global universities may have fewer opportunities to absorb best practices in research, governance, and curricula, as well as to reduces access to international collaboration, student exchange, and reputational spillovers.[3]

Appendix Table B.1 lists the top 20 universities based on the 2010 THE rankings. For

[3] The authors also tested an alternative IV based on distance to the top 50 universities, and the main results remain robust. In addition, the founding year of the oldest continuously operating university in each country is used as an alternative instrument for higher education quality, as it may capture the historical legacy and path dependence of higher education development. However, this instrument turned out to be weak and was not used in the final analysis.

each country, geodesic distances are calculated from the capital city to the cities hosting these institutions. The minimum distance—i.e., the distance to the nearest top 20 global university—is used as the instrument.

Geographic coordinates for each country's capital city are obtained from the World Bank API, while university locations are sourced using the Google Geocoding API. Distances are computed using the geodesic method, which accounts for the Earth's curvature. For countries that host one of the top 20 universities, the distance is coded as zero.

Alternatively, the authors construct the Diffusion Distance Index (DDI) that quantifies a country's exposure to knowledge diffusion from the top 20 global universities. Inspired by the gravity model, DDI incorporates both geographic distance and influence (or weight) of each university. Weight w_i is defined as the reciprocal of university i's rank ($w_i = 1/Rank_i$), and is normalized across all institutions. The DDI for Country C is calculated as:

$$\mathrm{DDI_C} = \sum_i \frac{w_i}{1+d_{ci}} \tag{6}$$

where d_{ci} represents the geographical distance between country C and the university i.

DDI captures the notion that proximity to highly ranked institutions enhances potential exposure to educational spillovers, with a university's influence declining in proportion to both its distance and rank. As a theoretically grounded and continuous measure, DDI is well-suited for analyzing cross-country differences in higher education quality.

Empirical evidence supports the premise that geographical distance limits the diffusion of knowledge. Belenzon and Schankerman (2013) show that patent citations decline sharply with distance, particularly within 150 miles (approximately 240 km). Similarly, von Graevenitz et al. (2022) find that geographic distance negatively affects innovation diffusion, as measured by the dissemination of new terms in US trademark data. For geographic distance to serve as a valid IV, it must also be uncorrelated with unobserved determinants of economic or technological outcomes, a plausible assumption given the exogenous nature of physical distance.

The identification strategy relies on the exogenous variation generated by geographic distance to world-leading universities. For the IV approach to be valid, the instrument must be strongly correlated with the endogenous regressor—namely, the higher education quality index—while remaining exogenous to unobserved determinants of economic outcomes.

To assess instrument relevance, Table 2 presents the first-stage regression results across alternative specifications with varying sets of control variables. Both the minimum distance measure and DDI are significantly associated with a higher education quality index, confirming their predictive power.

[Please insert Table 2 around here]

The strength of the instruments is further evaluated using Stock and Yogo's (2005) weak instrument tests. The results indicate that the first-stage F-statistics exceed the conventional threshold of 10, suggesting that weak instrument bias is unlikely to be a concern.

C. Regression results for GDP per worker

Equation (3) is estimated using both OLS and two-stage least squares (2SLS) methods. Table 3 presents the estimation results. Column (1) reports the OLS estimates using only higher education quality index and initial GDP per worker as explanatory variables. The estimated coefficient for higher education quality is 0.978 and is statistically significant, indicating that a one-SD increase in higher education quality (0.07) is associated with a 0.07-point increase in the log of GDP per worker (with SD of 0.91).

[Please insert Table 3 around here]

Column (2) presents the 2SLS estimtes, using the log of the distance to the nearest top 20 global university as the instrumental variable.[4] The coefficient for higher education quality increases to 2.584 and remains statistically significant, representing a more than 2.6-fold increase compared to the OLS estimate.

Column (3) reports the 2SLS results using DDI as an alternative instrument. The estimated coefficient remains statistically significant and increases to 4.061.

Overall, the 2SLS results suggest a strong causal relationship between higher educational quality and economic performance. Specifically, a one-SD increase in higher education quality is associated with a 0.18 to 0.28-point increase in log GDP per worker (with an SD of 0.91), highlighting the potentially large economic returns of improving higher education systems.

Table 4 presents results based on the baseline 2SLS regression specification from Table 3, augmented with additional control variables. Columns (1)–(3) use the log of the distance to

[4] Since the minimum distance is 0 for some observations, 1 kilometer is added before considering the log to prevent undefined values.

the nearest top 20 global university as the IV, while Columns (4)–(6) employ the DDI as the IV.

[Please insert Table 4 around here]

In Column (1), controlling for the tertiary enrollment ratio in 2011–2018, the coefficient for higher education quality (2.685) is similar to that of the baseline OLS results in Table 3. The coefficient for tertiary enrollment ratio is positive and statistically significant. In Column (2), when controlling for the population growth rate in 2011–2018, the coefficient for higher education quality decreases to 1.702, while that of population growth remains negative and statistically significant. In Column (3), which includes both tertiary enrollment ratio and population growth rate as controls, the coefficient of higher education quality reached 1.780, which is statistically significant.

The 2SLS estimates in Columns (4)–(6), using the DDI as the instrument, exhibit similar patterns: the coefficient for higher education quality remains positive and statistically significant across all specifications. In Column (6), which includes both control variables, the coefficient of higher education quality is 3.862.

Appendix Table C assesses the robustness of the main findings by re-estimating the specifications from Table 3 using per capita GDP (current international $) from the World Bank's WDI database. The results remain robust even when using per capita GDP from the WDI database.

D. Regression results for technological innovation

Tables 5 and 6 presents estimation results for two technological-innovation indicators, showing both OLS and 2SLS estimates. In the 2SLS specifications, DDI is used as an instrument.[5] In every estimation, the coefficient on higher-education quality is positive and statistically significant.

Table 5 presents the estimation results for the log of resident patent applications per million population in 2019. Column (1) reports OLS results, controlling only for initial GDP per worker. The coefficient of higher education quality is 7.809, which is statistically significant. This implies that a one-SD increase in higher education quality is associated with a 0.55 log-point rise in patenting activity, equivalent to approximately 25% of the outcome's

[5] The main results remain robust when using the log of the distance to the nearest top-20 global university as an instrument. Results are available from the authors upon request.

own SD (2.21).

[Please insert Table 5 around here]
[Please insert Table 6 around here]

Instrumentation with DDI in Column (2) exhibits the strength of the first stage (F >35). The coefficient of higher education quality increases to 44.87. This 2SLS estimate suggests that a one-SD increase in higher education quality leads to a 3.14 log-point gain in patenting (about 142% of SD), more than five times the OLS effect, highlighting a substantially stronger causal link between university quality and innovation activity.

Column (4) presents the estimation results with additional control variables. When controlling for both tertiary enrollment and population growth, the coefficient of higher education quality remains high at 44.54 and statistically significant.

Table 7 presents the estimation results for R&D expenditure as a percentage of GDP in 2019. In Column (1), the OLS estimate indicates that a one-unit increase in higher education quality raises national R&D intensity by 3.28 percentage points of GDP. A 0.07-SD improvement in educational quality corresponds to a 0.23 log-point increase, representing approximately 21% of the outcome's SD (SD = 1.117).

[Please insert Table 7 around here]

In Column (2), the IV coefficient using DDI as the instrument yields 47.99, corresponding to a 3.35 log-point gain, approximately 150% of one SD of the outcome variable. The instrument remains robust, with an F-statistic of 35. In Column (3), which includes both the tertiary enrollment ratio and population growth rate as additional controls, the coefficient of higher education quality remains similar in magnitude and statistical significance.

Overall, the 2SLS estimates are substantially larger than the corresponding OLS estimates, reflecting a downward bias in OLS estimates, possibly attributable to omitted variables or measurement errors in educational quality. Alternatively, the larger 2SLS estimates may reflect a local average treatment effect, capturing the causal impact for countries where innovation is particularly responsive to improvements in higher education quality. Additionally, the results could indicate that the instrument (DDI) exerts a direct effect on patenting activity beyond its indirect influence through the education system.

V. Conclusion

This study constructed a new cross-country database of higher education quality based on the relationship between institution-level characteristics—such as faculty-to-student ratios and global university rankings—and the earnings of internationally-employed college graduates. It shows that average graduate earnings are strongly linked to observable indicators of institutional quality. Building on this relationship, a country-level indicator of higher education quality was constructed, capturing cross-country variations in institutional characteristics weighted by their estimated effects on graduate earnings from 2011–2022. The resulting measure reveals substantial variations in higher education quality across countries.

Using this new measure, the study evaluates the role of tertiary education quality to explain cross-country differences in GDP per worker and technological innovation. The IV estimates show that higher education quality has a large and statistically significant effect on both economic output and innovation capacity.

The findings underscore the importance of not only expanding access to tertiary education, but also enhancing its quality as a driver of long-term development. While policy debates often focus on enrollment and attainment, this study suggests that strengthening faculty resources and improving international institutional standing can provide meaningful economic benefits. Educational policy reforms should emphasize investments in faculty development, research capacity, and global engagement.

This study has several limitations. First, graduate earnings regressions are based on average earnings by college rather than institution-level value-added estimates, making it challenging to disentangle the effects of institutional quality from student selectivity. The supplementary US data analysis shows that global rankings correlate not only with research and teaching quality, but also with student ability, thereby complicating causal interpretation. Second, the aggregation of institution-level effects to the country level assumes that returns to college quality indicators are consistent across countries. However, in practice, differences in labor markets, industrial structures, and institutional environments may shape how educational quality translates into graduate outcomes. Finally, while the index captures several key dimensions of institutional quality, it may overlook certain aspects of tertiary education such as curriculum design, teaching practices, and student support services.

Future research should explore the causal pathways linking higher education quality to national economic outcomes using richer micro-level data and stronger identification strategies. In particular, assessing the relative contributions of specific quality dimensions, such as research impact, learning environment, internationalization, and industry collaboration, would provide more targeted policy insights. Developing value-added measures that isolate institutional effects from student selection by linking administrative or survey-based graduate earnings data with detailed pre-enrolment characteristics could further strengthen causal inference. In addition, new international assessments of higher education that encompasses a broader range of countries would facilitate more robust global comparisons of educational outcomes.

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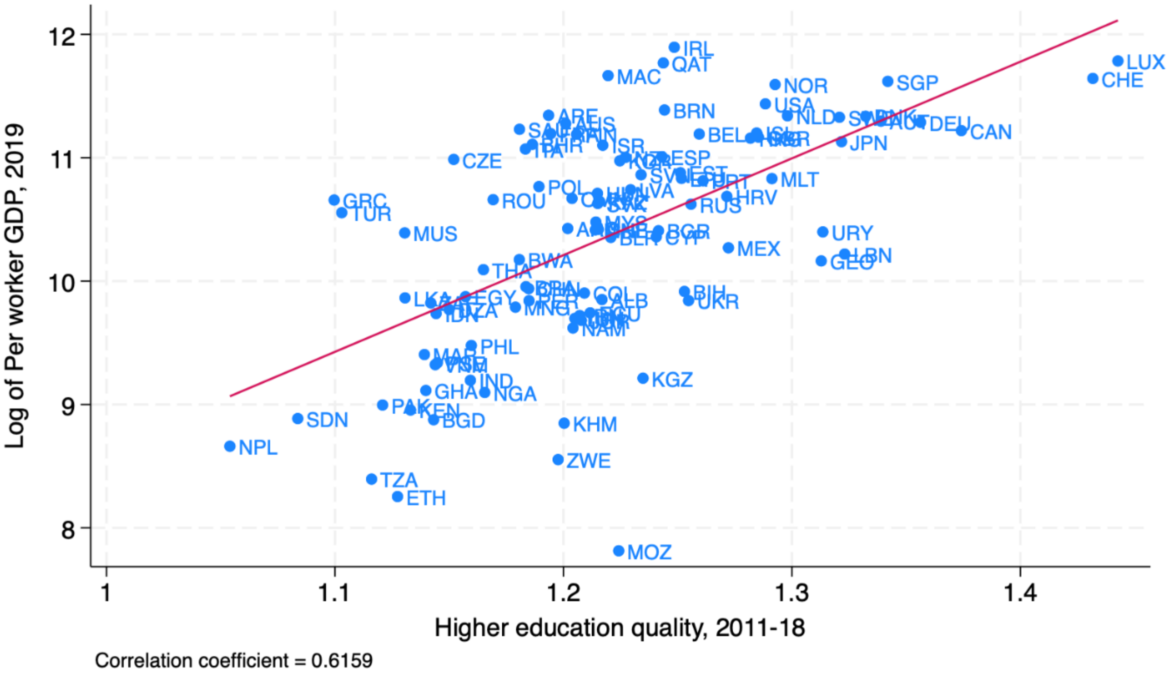

Figure 1. Relationship between higher education quality and log of GDP per worker

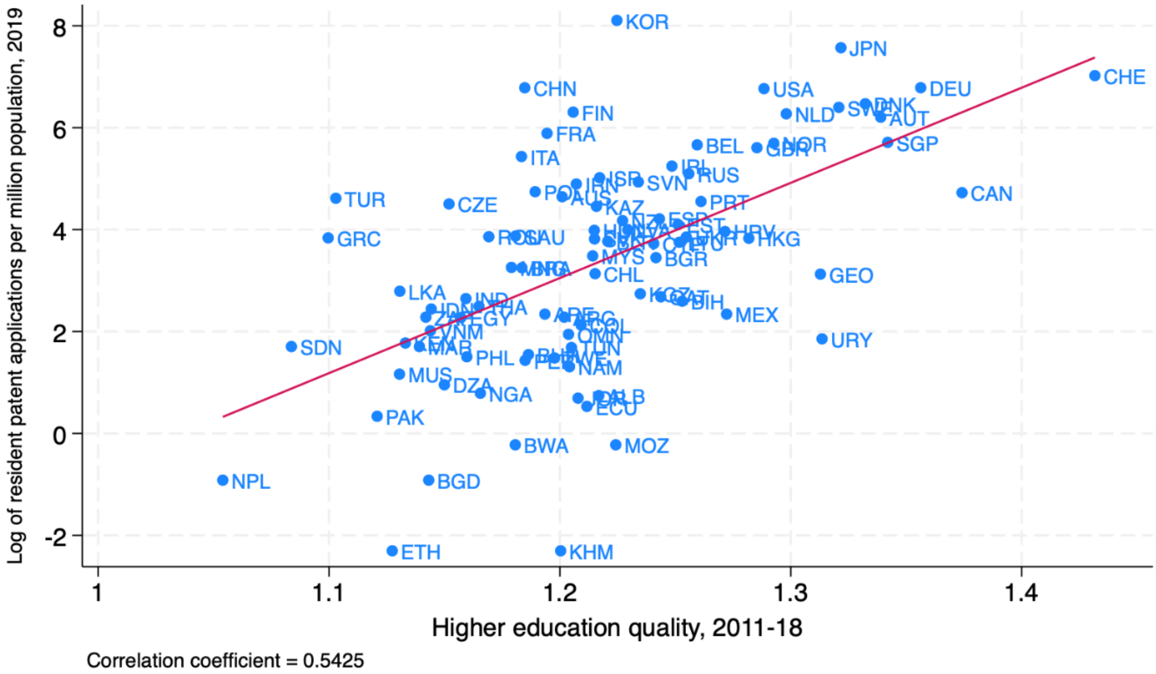

Figure 2. Relationship between higher education quality and log of resident applications per million population

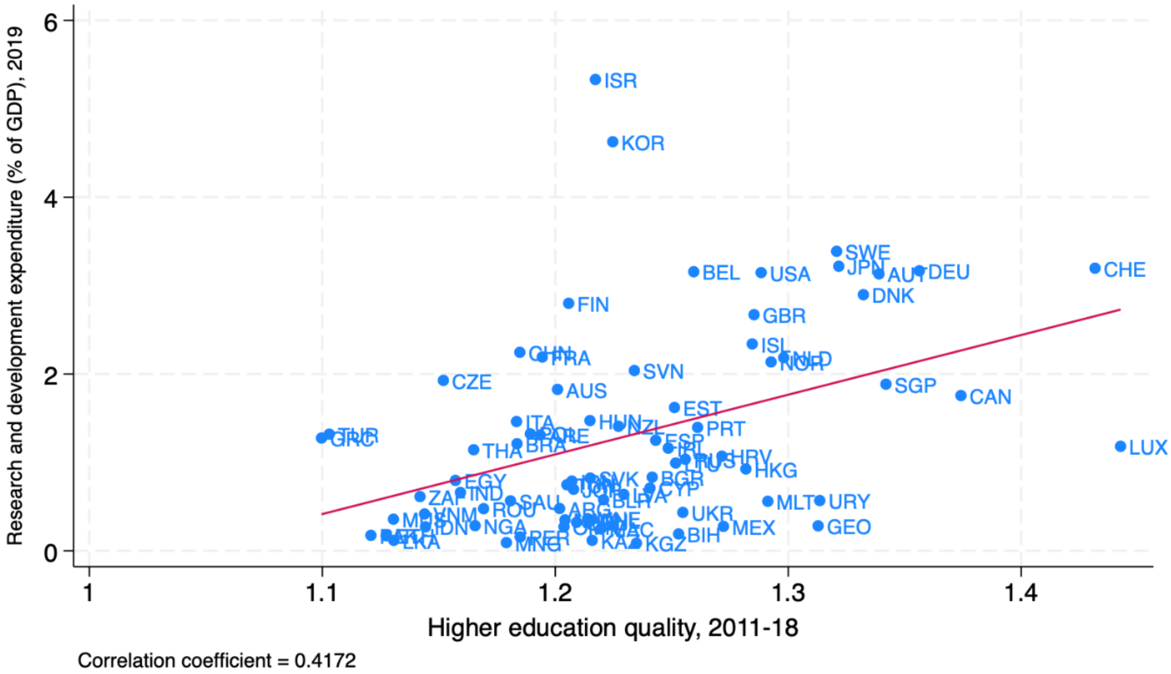

Figure 3. Relationship between higher education quality and research and development expenditure (% of GDP)

Table 1. Effects of college quality indicators on average earnings of college graduates

	(1)	(2)	(3)
Log of staff-students	0.115***		0.104***
	(0.008)		(0.008)
Ranking 1–20		0.411***	0.360***
		(0.042)	(0.039)
Ranking 21–50		0.224***	0.205***
		(0.035)	(0.034)
Ranking 51–100		0.180***	0.172***
		(0.029)	(0.028)
Ranking 101–200		0.137***	0.130***
		(0.020)	(0.019)
Constant	-0.364***	-0.186***	-0.352***
	(0.015)	(0.003)	(0.015)
Observations	2,550	2,871	2,550
R-squared	0.438	0.527	0.476
Country fixed effects	Yes	Yes	Yes

Notes: The outcome variable is the average earnings of college graduates from each institution, sourced from Martellini et al. (2024). The specification includes four dummy variables corresponding to each tier of THE World University Rankings: Tier 1 (ranks 1–20), Tier 2 (ranks 21–50), Tier 3 (ranks 51–100), and Tier 4 (ranks 101–200). Universities ranked beyond 200 serve as the omitted baseline category. Robust standard errors are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2. Effects of quality indicators on global rankings of US colleges

	(1) 1-21	(2) 21-50	(3) 51-100	(4) 101-200
Research expenses per FTE enrollment	0.531***	0.534***	0.312**	0.323***
	(0.142)	(0.141)	(0.135)	(0.103)
Log of number of students receiving a doctor's degree	0.582	-0.0813	-0.451	-0.226
	(1.836)	(1.840)	(1.513)	(1.245)
Faculty-to-student ratio	0.918**	0.769*	0.551	0.538*
	(0.370)	(0.438)	(0.355)	(0.277)
Instruction expenses per FTE enrollment	0.356***	0.353***	0.391***	0.129
	(0.129)	(0.131)	(0.134)	(0.108)
Log of total enrollment	18.62***	18.31***	13.67***	8.364***
	(4.624)	(4.817)	(3.749)	(2.751)
International student ratio (%)	0.475***	0.541***	0.253*	0.251***
	(0.175)	(0.175)	(0.142)	(0.0911)
International faculty ratio (%)	0.219	0.188	0.0613	0.151
	(0.263)	(0.275)	(0.226)	(0.181)
Admission rate (%)	-1.810***	-0.957***	-1.096***	-0.437***
	(0.413)	(0.371)	(0.271)	(0.117)
Constant	-178.8***	-175.2***	-121.4***	-77.52***
	(36.49)	(37.93)	(29.93)	(21.74)
Pseudo R-squared		0.730		
Observations	168	168	168	168

Notes: The outcome variable is a categorical variable consisting of five ranking groups. US universities included in the 2023 THE rankings are categorized into five groups: ranks 1–20, 21–50, 51–100, 101–200, and those ranked outside the top 200. Robust standard errors are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3. Impact of distance measure on higher education quality (1st-stage of 2SLS)

	(1)	(2)	(3)	(4)
Log of distance to nearest top 20 global university	-0.013***	-0.012***		
	(0.003)	(0.003)		
Diffusion distance index top 20 global university			0.044**	0.042**
			(0.018)	(0.018)
Initial log of per-worker GDP, 2011	0.033***	0.035***	0.041***	0.042***
	(0.006)	(0.007)	(0.007)	(0.008)
Tertiary enrollment rate, 2011–18		-0.348		-0.470
		(0.416)		(0.429)
Population growth rate, 2011–2018		-0.453		-0.852
		(0.515)		(0.516)
Constant	0.801***	0.808***	0.793***	0.812***
	(0.062)	(0.065)	(0.070)	(0.074)
Observations	98	98	98	98
R-squared	0.426	0.435	0.334	0.358
F-statistics	28.99	14.68	39.97	21.31

Notes: This table presents first-stage regression results. The dependent variable is "Higher education quality, 2011–18." Columns (1) and (2) use the "log of distance to the nearest top 20 global university" as the instrumental variable, while Columns (3) and (4) use the "diffusion distance index top 20 global university." Robust standard errors are reported in parentheses. F-statistics are also reported. The significance levels are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Cross-sectional regression for log of per-worker GDP in 2019 (OLS and IV estimates)

	(1) OLS	(3) 2SLS	(5) 2SLS
Higher education quality, 2011–18	0.978***	2.584***	4.061***
	(0.327)	(0.904)	(1.367)
Initial log of per-worker GDP, 2011	0.866***	0.798***	0.737***
	(0.033)	(0.045)	(0.082)
Constant	0.296	-0.970	-2.136**
	(0.289)	(0.778)	(0.922)
IV		Log of distance to nearest top 20 global university	Diffusion distance index
First-stage F-statistics		28.99	39.97
Observations	98	98	98

Notes: This table presents cross-sectional regression results for the log of per-worker GDP in 2019. Robust standard errors are reported in parentheses. Significance levels are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5. Cross-sectional regression for log of per-worker GDP in 2019 with additional controls (IV estimates)

	(1)	(2)	(3)	(4)	(5)	(6)
Higher education quality, 2011–2018	2.685***	1.702***	1.780***	4.189***	3.747***	3.862***
	(0.894)	(0.634)	(0.662)	(1.323)	(1.310)	(1.321)
Initial log of per-worker GDP, 2011	0.781***	0.818***	0.810***	0.715***	0.735***	0.721***
	(0.043)	(0.036)	(0.037)	(0.080)	(0.074)	(0.077)
Tertiary enrollment rate, 2011–2018	2.454**		0.967	2.978*		1.951
	(1.180)		(1.055)	(1.587)		(1.565)
Population growth rate, 2011–2018		-8.462***	-8.101***		-7.014***	-6.316**
		(1.439)	(1.552)		(2.266)	(2.482)
Constant	-1.006	-0.006	-0.062	-2.183**	-1.665*	-1.743*
	(0.780)	(0.532)	(0.562)	(0.892)	(0.927)	(0.934)
IV	Log of distance to nearest top 20 global university			Diffusion distance index		
First-stage F statistics	19.70	19.42	14.68	27.31	27.26	21.31
Observations	98	98	98	98	98	98

Notes: This table presents cross-sectional regression results for the log of per-worker GDP in 2019. Robust standard errors are reported in parentheses. Significance levels are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

Table 6. Cross-sectional regression for log of resident patent applications per million population in 2019 (OLS and IV estimates)

	(1)	(2)	(3)
	OLS	2SLS	2SLS
Higher education quality, 2011–2018	7.809***	44.871***	44.540***
	(2.650)	(12.562)	(13.043)
Initial log of per-worker GDP, 2011	1.401***	-0.247	-0.245
	(0.256)	(0.734)	(0.727)
Tertiary enrollment rate, 2011–2018			14.958
			(20.841)
Population growth rate, 2011–2018			-10.600
			(26.743)
Constant	-20.506***	-48.784***	-48.758***
	(2.190)	(9.080)	(9.776)
IV		Diffusion distance index	
First-stage F-statistics		35.34	19.42
Observations	88	88	88

Notes: This table presents cross-sectional regression results for the log of resident applications per million population in 2019. Robust standard errors are reported in parentheses. Significance levels are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7. Cross-sectional regression for research and development expenditure (% of GDP) in 2019 (OLS and IV estimates)

	(1) OLS	(2) 2SLS	(3) 2SLS
Higher education quality, 2011–2018	3.281*	47.648***	49.187***
	(1.812)	(17.684)	(18.703)
Initial log of per-worker GDP, 2011	0.519***	-1.615	-1.703
	(0.173)	(1.101)	(1.156)
Tertiary enrollment rate, 2011–2018		-41.359***	32.321
		(12.240)	(27.987)
Population growth rate, 2011–2018			41.479
			(30.823)
Constant	-8.198***	-48.784***	-42.969***
	(1.621)	(9.080)	(12.656)
IV		Diffusion distance index	
First-stage F-statistics		35	22.10
Observations	79	79	79

Notes: This table presents cross-sectional regression results for R&D expenditures (% of GDP) in 2019. Robust standard errors are reported in parentheses. Significance levels are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Online Appendix

Appendix A. Global University Rankings

This appendix reviews the methodologies of four influential global university rankings—Times Higher Education (THE), Center for World University Rankings (CWUR), Academic Ranking of World Universities (ARWU), and Quacquarelli Symonds (QS)—highlighting how their distinct criteria shape national and institutional representations.

THE began publishing global university rankings in 2010 in collaboration with Thomson Reuters, later partnering with Elsevier. It assesses research-intensive universities across five domains–teaching, research environment, research quality, international outlook, and industry collaboration–including income and patent activity. THE integrates extensive reputational surveys with bibliometric and institutional data. While this multidimensional approach captures various institutional strengths, its reliance on subjective perceptions tends to benefit long-established, globally recognized universities (Hazelkorn, 2015).

UAE-based CWUR, launched in 2012, relies exclusively on measurable outcomes. It ranks universities based on alumni success, faculty honors, research productivity, and impact without using surveys or data submitted by institutions. Metrics are size-adjusted to account for differences in institutional scale, benefiting smaller universities. However, CWUR's exclusion of teaching quality and student experience metrics limits its comprehensiveness (Shin and Toutkoushian, 2011).

ARWU, introduced in 2003 by Shanghai Jiao Tong University, initially assessed the global standing of Chinese universities, with emphasis on research excellenceusing indicators such as Nobel and Fields Medal winners, highly cited researchers, and publications in Nature and Science. This strong focus on elite scientific output favors large research universities in the US and UK (Liu and Cheng, 2005).

QS, which began publishing its independent rankings in 2010 after parting from THE, is managed by the British firm Quacquarelli Symonds. It combines survey-based indicators (academic and employer reputation) with objective measures, including faculty citations, student–faculty ratios, and international student and faculty compositions. Sustainability and employability outcomes were recently incorporated. Although QS highlights universities with strong global engagement, its significant use of reputation surveys may introduce a bias toward more visible and well-known institutions (Shin and Toutkoushian, 2011).

This methodological diversity led to varied patterns of national representation. US universities consistently lead in ARWU and CWUR rankings because of their prominence in high-impact research and employment outcomes. Conversely, QS and THE exhibit broader geographic diversity, frequently highlighting institutions from countries such as China, Singapore, Switzerland, and Australia, reflecting QS's emphasis on internationalization and THE's broader performance framework.

At the institutional level, research-intensive universities excel in ARWU, whereas those with a strong reputation, graduate employability, or international reach perform better in QS and THE. CWUR provides more visibility to universities with distinguished faculty or successful alumni, particularly in high-income economies with strong innovation ecosystems.

Table A.1 presents the top 50 institutions across these four rankings in 2022, illustrating both consistent dominance by US universities and variation based on each ranking's underlying criteria.

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Table A.1. Top 50 universities from THE, CWUE, ARWU, and QS rankings in 2022

Ranking	THE		CWUR		ARWU		QS	
1	Caltech	USA	Harvard University	USA	Harvard University	USA	MIT	USA
2	Carnegie Mellon University	USA	MIT	USA	Stanford University	USA	University of Oxford	GBR
3	Columbia University	USA	Stanford University	USA	MIT	USA	Stanford University	USA
4	Cornell University	USA	University of Cambridge	GBR	University of Cambridge	GBR	University of Cambridge	GBR
5	Duke University	USA	University of Oxford	GBR	University of California, Berkeley	USA	Harvard University	USA
6	École Polytechnique Fédérale de Lausanne	CHE	Princeton University	USA	Princeton University	USA	Caltech	USA
7	ETH Zurich	CHE	University of Chicago	USA	University of Oxford	GBR	Imperial College London	GBR
8	Georgia Institute of Technology	USA	Columbia University	USA	Columbia University	USA	ETH Zurich	CHE
9	Harvard University	USA	University of Pennsylvania	USA	California Institute of Technology	USA	UCL	GBR
10	Imperial College London	GBR	California Institute of Technology	USA	University of Chicago	USA	University of Chicago	USA
11	Johns Hopkins University	USA	Yale University	USA	Yale University	USA	National University of Singapore	SGP
12	Karolinska Institute	SWE	University of California, Berkeley	USA	Cornell University	USA	Nanyang Technological University	SGP
13	King’s College London	GBR	The University of Tokyo	JPN	University of California, Los Angeles	USA	University of Pennsylvania	USA
14	KU Leuven	BEL	Cornell University	USA	Johns Hopkins University	USA	École polytechnique fédérale de Lausanne	CHE
15	LMU Munich	DEU	University of Michigan, Ann Arbor	USA	University of Pennsylvania	USA	Yale University	USA
16	LSE	GBR	Johns Hopkins University	USA	Paris-Saclay University	FRA	The University of Edinburgh	GBR
17	MIT	USA	Northwestern University	USA	University of Washington	USA	Tsinghua University	CHN
18	McGill University	CAN	University of California, Los Angeles	USA	University College London	GBR	Peking University	CHN
19	Nanyang Technological University	SGP	PSL University	FRA	University of California, San Francisco	USA	Columbia University	USA

20	National University of Singapore	SGP	Duke University	USA	ETH Zurich	CHE	Princeton University	USA
21	New York University	USA	University College London	GBR	University of California, San Diego	USA	Cornell University	USA
22	Northwestern University	USA	University of Illinois at Urbana–Champaign	USA	University of Toronto	CAN	University of Hong Kong	HKG
23	Paris Sciences et Lettres	FRA	New York University	USA	Imperial College London	UK GBR	The University of Tokyo	JPN
24	Peking University	CHN	University of Toronto	CAN	The University of Tokyo	JPN	University of Michigan-Ann Arbor	USA
25	Princeton University	USA	University of Washington	USA	New York University	USA	Johns Hopkins University	USA
26	Stanford University	USA	Kyoto University	JPN	Tsinghua University	CHN	University of Toronto	CAN
27	Technical University of Munich	DEU	University of Wisconsin–Madison	USA	Washington University in St. Louis	USA	McGill University	CAN
28	The Chinese University of Hong Kong	HKG	McGill University	CAN	University of Michigan-Ann Arbor	USA	Australian National University	USA
29	The University of Chicago	USA	ETH Zurich	CHE	University of North Carolina at Chapel Hill	USA	The University of Manchester	GBR
30	The University of Tokyo	JPN	Imperial College London	GBR	Northwestern University	USA	Northwestern University	USA
31	Tsinghua University	CHN	Seoul National University	KOR	Duke University	USA	Fudan University	CHN
32	UCL	GBR	Paris-Saclay University	FRA	University of Melbourne	AUS	University of California, Berkeley	USA
33	Universität Heidelberg	DEU	University of Texas at Austin	USA	University of Wisconsin - Madison	USA	Kyoto University	JPN
34	University of British Columbia	CAN	University of California, San Diego	USA	Peking University	CHN	HKUST	HKG
35	University of California, Berkeley	USA	University of California, San Francisco	USA	The University of Edinburgh	GBR	King's College London	GBR
36	University of California, Los Angeles	USA	University of Copenhagen	DNK	Zhejiang University	CHN	Seoul National University	KOR
37	University of California, San Diego	USA	Karolinska Institute	SWE	The University of Texas at Austin	USA	University of Melbourne	AUS
38	University of Cambridge	GBR	Sorbonne University	FRA	The University of Manchester	GBR	The University of Sydney	AUS
39	University of Edinburgh	GBR	University of North Carolina at Chapel Hill	USA	University of Copenhagen	DNK	The Chinese University of Hong Kong	HKG

40	University of Hong Kong	HKG	King's College London	GBR	PSL University	FRA	University of California, Los Angeles	USA
41	University of Illinois at Urbana-Champaign	USA	Dartmouth College	USA	Karolinska Institute	SWE	KAIST	KOR
41	University of Manchester	GBR	Paris City University	FRA	Kyoto University	JPN	New York University	USA
43	University of Melbourne	AUS	Institut Polytechnique de Paris	FRA	Sorbonne University	FRA	The University of New South Wales	AUS
44	University of Michigan-Ann Arbor	USA	Ludwig Maximilian University of Munich	DEU	Rockefeller University	USA	Université PSL	FRA
44	University of Oxford	GBR	University of Edinburgh	GBR	University of British Columbia	CAN	Zhejiang University	CHN
44	University of Pennsylvania	USA	Washington University in St. Louis	USA	University of Minnesota, Twin Cities	USA	University of British Columbia	CAN
47	University of Texas at Austin	USA	Tsinghua University	CHN	The University of Queensland	AUS	The University of Queensland	AUS
48	University of Toronto	CAN	University of Minnesota - Twin Cities	USA	King's College London	GBR	University of California, San Diego	USA
49	University of Washington	USA	University of British Columbia	CAN	University of Illinois at Urbana-Champaign	USA	Institut Polytechnique de Paris	FRA
50	Yale University	USA	University of Southern California	USA	University of Maryland, College Park	USA	LSE	GBR

Source: THE (2021), CWUR (2022), Shanghai Ranking Consultancy (2022), QS (2021).

Appendix B

Table B.1. Top 20 and 50 universities in the Times Higher Education (THE) World University Rankings, 2010 and 2022

University	Country	Ranking, 2022	Ranking, 2010
University of Oxford	United Kingdom	1	6
California Institute of Technology	United States	2	2
Harvard University	United States	2	1
Stanford University	United States	4	4
Massachusetts Institute of Technology	United States	5	3
University of Cambridge	United Kingdom	5	6
Princeton University	United States	7	5
University of California, Berkeley	United States	8	8
Yale University	United States	9	10
The University of Chicago	United States	10	12
Columbia University	United States	11	18
Imperial College London	United Kingdom	12	9
Johns Hopkins University	United States	13	13
University of Pennsylvania	United States	13	19
ETH Zurich	Switzerland	15	15
Peking University	China	16	37
Tsinghua University	China	16	58
UCL	United Kingdom	18	N/A
University of Toronto	Canada	18	17
University of California, Los Angeles	United States	20	11
National University of Singapore	Singapore	21	34
Cornell University	United States	22	14
Duke University	United States	23	24
Northwestern University	United States	24	25
University of Michigan-Ann Arbor	United States	24	15
New York University	United States	26	60
London School of Economics and Political Science	United Kingdom	27	86
Carnegie Mellon University	United States	28	20
University of Washington	United States	29	23
University of Edinburgh	United Kingdom	30	40
University of Hong Kong	Hong Kong	30	21
LMU Munich	Germany	32	61

University of Melbourne	Australia	33	36
University of California, San Diego	United States	34	32
King's College London	United Kingdom	35	77
The University of Tokyo	Japan	35	26
University of British Columbia	Canada	37	30
Technical University of Munich	Germany	38	101
Karolinska Institute	Sweden	39	43
École Polytechnique Fédérale de Lausanne	Switzerland	40	48
Paris Sciences et Lettres – PSL Research University Paris	France	40	N/A
KU Leuven	Belgium	42	119
Universität Heidelberg	Germany	42	83
McGill University	Canada	44	35
Georgia Institute of Technology	United States	45	27
Nanyang Technological University, Singapore	Singapore	46	174
University of Texas at Austin	United States	47	N/A
University of Illinois at Urbana-Champaign	United States	48	33
The Chinese University of Hong Kong	Hong Kong	49	N/A
University of Manchester	United Kingdom	50	87

Source: THE (2011, 2021)

Table B.2. Enrollment share of universities ranked in the top 20, 50, 100, and 200, faculty-to-student ratios, and estimated higher education quality (averages over 2011-18)

Country	Enrollment share of universities ranked in				Faculty-to-student ratios (per 100 students)	Higher education quality
	Top 20	Top 50	Top 100	Top 200		
Luxembourg	0.000	0.000	0.000	1.628	16.2	1.443
Switzerland	0.094	0.094	0.188	0.502	13.5	1.432
Canada	0.151	0.151	0.181	0.297	12.5	1.374
Germany	0.030	0.030	0.112	0.254	13.2	1.356
Singapore	0.268	0.268	0.429	0.482	7.3	1.342
Austria	0.000	0.000	0.000	0.199	13.2	1.339
Denmark	0.000	0.000	0.033	0.327	10.6	1.332
Lebanon	0.000	0.000	0.000	0.000	15.2	1.323
Japan	0.010	0.010	0.018	0.030	14.3	1.322
Sweden	0.031	0.031	0.198	0.461	7.6	1.321
Uruguay	0.000	0.000	0.000	0.000	14.1	1.314
Georgia	0.000	0.000	0.000	0.000	14.0	1.313
Netherlands	0.002	0.002	0.193	0.336	7.6	1.298
Norway	0.000	0.000	0.000	0.130	10.3	1.293
Malta	0.000	0.000	0.000	0.000	12.0	1.291
United States	0.073	0.073	0.124	0.192	8.1	1.288
United Kingdom	0.089	0.089	0.157	0.367	6.1	1.285
Iceland	0.000	0.000	0.000	0.000	11.4	1.285
China, Hong Kong	0.156	0.156	0.232	0.408	5.8	1.282
Mexico	0.000	0.000	0.000	0.000	10.4	1.272
Croatia	0.000	0.000	0.000	0.000	10.3	1.272
Portugal	0.000	0.000	0.000	0.000	9.5	1.261
Belgium	0.044	0.044	0.136	0.306	6.0	1.259
Russian Federation	0.000	0.000	0.000	0.005	9.1	1.256
Ukraine	0.000	0.000	0.000	0.000	9.1	1.255
Bosnia and Herzegovina	0.000	0.000	0.000	0.000	8.9	1.253
Lithuania	0.000	0.000	0.000	0.000	8.8	1.252
Estonia	0.000	0.000	0.000	0.000	8.8	1.251
Ireland	0.000	0.000	0.039	0.212	6.5	1.249
Brunei Darussalam	0.000	0.000	0.000	0.000	8.3	1.244
Qatar	0.000	0.000	0.000	0.000	8.3	1.244
Spain	0.000	0.000	0.000	0.028	8.0	1.243
Bulgaria	0.000	0.000	0.000	0.000	8.2	1.242
Cyprus	0.000	0.000	0.000	0.000	8.1	1.241
Kyrgyzstan	0.000	0.000	0.000	0.000	7.8	1.235
Slovenia	0.000	0.000	0.000	0.000	7.7	1.234
Latvia	0.000	0.000	0.000	0.000	7.4	1.229
New Zealand	0.000	0.000	0.000	0.164	5.9	1.227
Republic of Korea	0.003	0.003	0.014	0.028	6.9	1.225
Mozambique	0.000	0.000	0.000	0.000	7.1	1.224
Belarus	0.000	0.000	0.000	0.000	6.9	1.221
China, Macao	0.000	0.000	0.000	0.000	6.9	1.220
Israel	0.000	0.000	0.000	0.117	5.9	1.217
Albania	0.000	0.000	0.000	0.000	6.7	1.217
Kazakhstan	0.000	0.000	0.000	0.000	6.7	1.216
Chile	0.000	0.000	0.000	0.000	6.6	1.215

Slovakia	0.000	0.000	0.000	0.000	6.6	1.215
Hungary	0.000	0.000	0.000	0.000	6.6	1.215
Malaysia	0.000	0.000	0.000	0.000	6.6	1.214
Montenegro	0.000	0.000	0.000	0.000	6.6	1.214
Ecuador	0.000	0.000	0.000	0.000	6.5	1.212
Colombia	0.000	0.000	0.000	0.000	6.3	1.209
Jordan	0.000	0.000	0.000	0.000	6.3	1.208
Iran	0.000	0.000	0.000	0.000	6.2	1.207
Finland	0.000	0.000	0.067	0.114	5.2	1.206
Tunisia	0.000	0.000	0.000	0.000	6.1	1.205
Namibia	0.000	0.000	0.000	0.000	6.1	1.204
Oman	0.000	0.000	0.000	0.000	6.1	1.204
Argentina	0.000	0.000	0.000	0.000	6.0	1.202
Australia	0.057	0.057	0.203	0.270	3.8	1.201
Cambodia	0.000	0.000	0.000	0.000	5.9	1.200
Zimbabwe	0.000	0.000	0.000	0.000	5.8	1.198
France	0.011	0.011	0.036	0.099	4.9	1.194
United Arab Emirates	0.000	0.000	0.000	0.000	5.6	1.193
Poland	0.000	0.000	0.000	0.000	5.4	1.189
Bahrain	0.000	0.000	0.000	0.000	5.3	1.186
Peru	0.000	0.000	0.000	0.000	5.2	1.185
China	0.003	0.003	0.004	0.006	5.1	1.185
Brazil	0.000	0.000	0.000	0.003	5.1	1.184
Italy	0.000	0.000	0.000	0.003	5.1	1.183
Saudi Arabia	0.000	0.000	0.000	0.000	5.0	1.181
Botswana	0.000	0.000	0.000	0.000	5.0	1.181
Mongolia	0.000	0.000	0.000	0.000	4.9	1.179
Romania	0.000	0.000	0.000	0.000	4.6	1.169
Nigeria	0.000	0.000	0.000	0.000	4.4	1.166
Thailand	0.000	0.000	0.000	0.000	4.4	1.165
Philippines	0.000	0.000	0.000	0.000	4.2	1.160
India	0.000	0.000	0.000	0.000	4.2	1.159
Egypt	0.000	0.000	0.000	0.011	4.1	1.157
Czechia	0.000	0.000	0.000	0.000	3.9	1.152
Algeria	0.000	0.000	0.000	0.000	3.9	1.150
Palestine	0.000	0.000	0.000	0.000	3.7	1.145
Indonesia	0.000	0.000	0.000	0.000	3.7	1.144
Viet Nam	0.000	0.000	0.000	0.000	3.7	1.144
Bangladesh	0.000	0.000	0.000	0.000	3.7	1.143
South Africa	0.000	0.000	0.000	0.036	3.5	1.142
Ghana	0.000	0.000	0.000	0.000	3.6	1.140
Morocco	0.000	0.000	0.000	0.000	3.5	1.139
Kenya	0.000	0.000	0.000	0.000	3.4	1.133
Sri Lanka	0.000	0.000	0.000	0.000	3.3	1.131
Mauritius	0.000	0.000	0.000	0.000	3.3	1.131
Ethiopia	0.000	0.000	0.000	0.000	3.2	1.127
Pakistan	0.000	0.000	0.000	0.000	3.0	1.121
United Republic of Tanzania	0.000	0.000	0.000	0.000	2.9	1.116
Turkey	0.000	0.000	0.001	0.005	2.6	1.103
Greece	0.000	0.000	0.000	0.000	2.5	1.100
Sudan	0.000	0.000	0.000	0.000	2.2	1.084
Nepal	0.000	0.000	0.000	0.000	1.7	1.054

Source: Authors' calculation from THE and UNESCO.

Table B.3. Descriptive statistics for variables in Table 1

Variable	Observation number	Mean	Std. dev.	Min	Max
Average earnings of college graduates (index)	2,871	-0.176	0.231	-1.115	0.819
Ranking 1-20	2,871	0.005	0.072	0	1
Ranking 21-50	2,871	0.008	0.087	0	1
Ranking 51-100	2,871	0.013	0.111	0	1
Ranking 101-200	2,871	0.026	0.158	0	1
Log of staffs per 100 students, 2010-22	2,550	1.866	0.441	-1.564	5.809

Table B.4. Descriptive statistics for variables in Tables 3−7

	Observation number	Mean	Std. dev.	Min	Max
Log of per-worker GDP, 2019	98	10.363	0.910	7.786	11.954
Log of resident patent applications per million population, 2019	88	3.338	2.206	-2.303	8.106
Research and development expenditure (% of GDP), 2019	79	1.276	1.117	0.085	5.331
Log of per-worker GDP, 2011	98	10.251	0.979	7.761	12.311
Higher education quality, 2011-18	98	1.219	0.071	1.054	1.443
Log of distance to nearest top 20 global university	98	-6.170	1.880	-13.816	-4.408
Diffusion distance index top 20 global university	98	0.010	0.086	0.000	0.843
Tertiary enrollment / working age population, 2011-18	98	0.038	0.018	0.006	0.087
Population growth rate, 2011-2018	98	0.010	0.012	-0.014	0.053

Table C. Cross-sectional regression for log of per-capita GDP (OLS and IV estimates)

	(1) OLS	(2) 2SLS	(3) 2SLS	(4) 2SLS	(5) 2SLS
Higher education quality, 2011-22	1.181**	3.034**	1.918*	2.537*	2.440**
	(0.548)	(1.215)	(0.979)	(1.314)	(1.173)
Initial log of per-capita GDP, 2011	0.855***	0.784***	0.787***	0.803***	0.768***
	(0.044)	(0.060)	(0.050)	(0.077)	(0.063)
Tertiary enrollment rate, 2011-22			1.406		1.633
			(1.277)		(1.225)
Population growth rate, 2011-2022			-9.224***		-8.711***
			(2.031)		(2.093)
Constant	1.019**	-1.373	0.115	-0.476	-0.156
	(0.506)	(1.593)	(0.977)	(0.897)	(0.768)
IV		Log of distance to nearest top 20 global university		Diffusion distance index	
First-stage F-statistics		28.61	14.96	37.28	21.86
Observations	98	98	98	98	98

Notes: This table presents cross-sectional regression results for the log of per-capita GDP (current international $) in 2022. Robust standard errors are reported in parentheses. Significance levels are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.