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The University-Science Model and Global Megascience: 100 Years of Advancing Research

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Global megascience highlights the transformative role of universities in driving global knowledge production through collaborative scientific networks. Rooted in the twentieth-century educational revolution and the global diffusion of the "university-science model," universities evolved into pivotal research hubs, reshaping science beyond national borders. Since 1900, expanding scientific output and cross-disciplinary collaborations have spurred discoveries and addressed global challenges, even as sustainability questions remain.

The extraordinary velocity of contemporary scientific discovery was showcased by the COVID-19 pandemic—in particular, how researchers worldwide collaborated to understand the novel coronavirus and develop vaccines rapidly. This swift acceleration of research was no isolated phenomenon; rather, it represents the culmination of decades of investment in worldwide scientific infrastructure characterized by collaborative, networked, and often cross-border research efforts—a form of scientific engagement that we refer to as "global megascience."

Our recent book, *Global Megascience: Universities, Research Collaborations, and Knowledge Production* (Stanford University Press, 2024), traces the historical evolution of a transformative idea: expanding universities and actually merging teaching and research missions toward fostering a global, highly collaborative, and unexpectedly powerful research capacity. We integrate historical narratives of twentieth-century university development with scientometric analysis based on unique data from a vast sample of the world's scientific journal papers, spanning from 1900 onward. Along the way, we explore counterfactual models, examine the ironic outcomes of excellence initiatives, and confront the major challenges threatening the sustainability of the global spread of the university-science model.

The exponential surge in research output, notably in 2023 when around four million studies were published with almost all including university-based scientists, evidences the largely university-based research capacity and collaborative potential of the international scientific community. Originating from a handful of the earliest research-active universities in 1900, these scientists have both taught and undertaken research at over 38,000 universities and other postsecondary schools educating growing proportions of the world's youth. Still far from the predicted limits to growth in science, the contemporary scientific landscape continues to flourish, fueled by an educational and cultural revolution that links higher education and science.

The Educational Revolution and Megascience

At the heart of the megascience phenomenon lies a cultural shift—the education revolution—that transformed universities from teaching institutions into centers of research, solution-seeking, and public engagement. Over the past century, the inclusion of broader segments of society in education has driven a remarkable rise in university attendance, with nearly 40 percent of young people worldwide now enrolled in postsecondary education. Combined with the extraordinary mobility of (graduate) students and growing gender equality in many fields, this democratization of access has produced generations trained in and committed to advancing scientific inquiry—and to crossing boundaries.

As universities evolved to integrate teaching and research, they prioritized research as a primary mission. This shift established universities as key sites of scientific investigation and created a forum for the free exchange of ideas across disciplines and borders, as well as the intergenerational transfer of cutting-edge knowledge.

This alignment of mass education with scientific advancement has built an unprecedented global network of research and development. Alongside the formation of national research universities, many countries now emphasize publishing cutting-edge research in specialized journals. STEMM (science, technology, engineering, mathematics, and medicine) fields alone feature nearly 10,000 high-impact journals that provide access to the latest discoveries, upholding research quality and ensuring the global exchange of knowledge.

Universities Providing the Research Platform for an Era of Global Science

Universities remain central to scientific discovery, with their faculty contributing to an estimated 85 to 90 percent of the millions of scientific publications produced annually. These institutions

foster collaborations across disciplines and borders, often partnering with other research entities or industries.

The advent of the internet—a technology born in universities to enhance global research collaboration—has revolutionized international and interorganizational partnerships. Today, scientists collaborate in real time across continents, overcoming traditional geographical boundaries. This connectivity has rapidly expanded research capacity, supported by a global pool of hundreds of thousands of scientists. The growing number of active researchers, combined with technological advancements, has driven exponential growth in scientific output and enabled breakthroughs at an unprecedented pace.

While some critics describe the surge in publications as "hyperinflation," analyses suggest that it reflects a genuine expansion in research capacity rather than diminished quality. The immense growth does pose challenges, such as the need to efficiently synthesize and replicate findings across millions of publications. However, advanced artificial intelligence tools offer transformative ways to navigate these vast knowledge networks, highlighting the potential and far-reaching implications of such tools.

The Scientization of Society

A symbiosis between the ascendent education revolution and research at universities has the broad consequence of "scientizing" society, meaning the development of science's capacity to inquire into ever more aspects of human affairs, life, the planet, and the cosmos. Through the growing institutionalization of scientific endeavors, research-oriented universities worldwide have adopted a common organizational framework, spreading from Germany to North America to East Asia and everywhere else, too. As a result, universities in diverse regions have come to play similar roles in knowledge production, blending aspects of their national histories and cultures with this global model of scientific organization.

This "university-science model" has inspired countries around the world to invest in science and contribute to the global pool of knowledge, sometimes for the first time in their history. Universities in Brazil, Iran, and Turkey, for instance, now contribute to major science journals, most often in English. Even small countries, such as Luxembourg and Qatar, have made significant investments in their scientific capacity, with their research universities acting as nodes within this vast global research network. Over the past several decades research activity has grown significantly at originally low-research universities and other postsecondary schools. This activity includes a steady stream of collaborations with faculty at two-year institutions. Lastly, although basic research is also undertaken at a growing set of noneducational institutions, even these tend to collaborate heavily with university-based colleagues, tapping into university access to and leadership of global hubs of joint research.

The scope of scientific research has extended beyond traditionally strong research nations and the usual research-intensive universities as even newer research universities contribute to the growing body of scientific knowledge. The world today, as a result, is arguably richer in scientific knowledge than ever before, with universities serving as epicenters of discovery and collaboration on a global scale.

The Journey of Megascience: Global Dissemination and Local Contexts

An earlier companion book—*The Century of Science* (Powell, Baker & Fernandez 2017)—describes case studies of selected countries' capacity-building of megascience and examines how the knowledge-production systems adapted to different cultural, historical, and political contexts. The university-science model that emerged in German-speaking regions and spread to the United States is now embraced worldwide, extending from Europe to Asia and beyond. Each region has adapted parts of the model, emphasizing particular national or regional priorities and particularities, with different mixtures of public and private funding. Countries that historically lacked research infrastructure before the 1980s now contribute regularly to the global flow of scientific knowledge, underscoring the potential of higher education to support knowledge transfer and foster scientific communities worldwide.

The analysis of this global flow of scientific research offers profound insights into the collective enterprise of megascience, further illustrating a durable and influential network of discovery. Overall, the collective enterprise stands as a testament to higher education's transformative power and the ongoing relevance of universities in facilitating knowledge production.

Sustaining Megascience for the Future

Megascience represents the cumulative achievements of scientists worldwide who continue to seek answers to complex questions. Understanding its roots and trajectories allows us to appreciate its monumental accomplishments but also today's challenges—replication and synthesis of knowledge, the ethical dimensions of artificial intelligence in science, and maintenance of high research standards amid increasing output. As we navigate contemporary global challenges, from public health crises to the climate crisis, understanding the cultural and educational foundations that support megascience is essential for its sustainability. Ultimately, megascience exemplifies the potent interplay between education and scientific discovery, highlighting the pivotal role of universities in global knowledge production and the potential for continued, collaborative advancements in our collective pursuit of knowledge.

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