Hegemony and Inequality in Global Science: Problems of the Center-Periphery Model

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The autonomous global system of science, grounded in collegial networks of scientists, publishing, and cross-border papers, is expanding rapidly and spreading to a growing number of countries. Strong national science systems have emerged outside Euro-America. Yet the multipolarization of economic capacity and scientific output plays out within a continuing Euro-American science world regulated by an inside/outside binary. Global science remains primarily Anglo-American in language, leading institutions, disciplinary and publishing regimes, agendas, and topics. Non-English and endogenous knowledges are excluded. The article critiques the world-systems theory interpretation of relations of power in science. The determinist center-periphery model fails to grasp the growth and pluralization of global science and its relation with national science systems. It normalizes the Eurocentrism it opposes, radically underestimating agency outside the "center" countries. The article argues for a more ontologically open theorization of global power in science, in terms of cultural hegemony, and for an ecology-of-knowledges approach.

Introduction

In the last 3 decades, basic science centered on universities and research institutes across the world has been transformed, in some but not all respects. A distinctive global science system has formed, with partial autonomy in relation to nation-states and connections into the local scale (Marginson and Rhoades 2002). Science has become networked, much larger, and more distributed and diverse. Yet it has changed little in language and agendas. It remains monocultural in process and content.

This article is focused on relations of power in science and the drivers of inequality and suppression of diversity. It considers the nature of the emergent global science system and interpretations of science, which shape understandings and affect practices. An explanation of relations of power in global science

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must include three elements: (1) the dynamism of its material growth and diversification, (2) relations between global science and national science and the interstate order, and (3) global homogeneity and inequality. The article reviews each in turn, followed by a critical review of one explanation of power, world-systems theory and its center-periphery model (Wallerstein 1974; Wallerstein et al. 2013). The fixed world-systems hierarchy of nations bolted down by political economy closes off the potential of national and individual agents. It cannot explain the evolution of science.

In developing alternatives to the vortex-like compulsion of the center-periphery model of science, the article works with an open ontology in which change is continuous and reality is not fixed but emerging (Sayer 2000). Each of the four domains of structure (material and institutional factors), the "ideational" (knowledge, ideas, ideologies), social relations, and human agency is autonomous, and they continually interact (Archer 1995, 2000). The article draws on Gramsci's (1971) discussion of cultural hegemony in the national and international scales and the counterhegemonic decolonizing perspective of Santos and his "ecology of knowledges" approach (2007, 2014).

Global Science

After World War II, science evolved within nationally normed and funded systems. On the world scale it was an uneven Euro-American ("Western") duopoly, dominated by the United States, with Japan as outlier and Soviet Russia fenced off behind the Cold War barrier. Epistemologies, assumptions, and mechanisms were Eurocentric (meaning the European civilizational bloc, including North America) and, within that, primarily Anglo-American.

From the 1990s onward two changes occurred. First, there was the development of a discrete internet-based global communications system in science, a synchronous professional community grounded in networked interaction and collaboration between scientists and a single pool of publications in bibliometric collections. By "global" is meant activities and relations that constitute a planetary ontology and tend to the evolution of the world on an integrated basis (Conrad 2016). The internet accelerated intersubjectivity according to a network logic, in which each node is added at negligible cost while augmenting the existing nodes by expanding their connections. Networks extend toward every possible connection, growing more rapidly than linear forms (Castells 2000). Wagner et al. (2015) describe global science as a "dynamic" open communication system, developing endogenously, an "emerging organization" in its own right (11–12). Second, there was a partial shift in the geopolitics of science toward multipolarity, as in political economy (Pieterse 2018), with large national systems emerging outside Euro-America and rapid growth in emerging countries.

These transformations fed each other (Marginson 2021, 2022a, 2022c). The collegial global science system catalyzed investment in national science (OECD

2021), as nations accessed the common pool of knowledge. Growing national infrastructures were materially essential to global collaboration and output growth. There was an evolving symbiosis.

Between 2000 and 2018, papers in Scopus increased by 4.94 percent a year. That is, codified knowledge was doubling every 15 years (NSB 2020, table S5A-2). The proportion authored in more than one country grew from 1.9 percent in 1970, before electronic networks, to 22.5 percent in 2018 (Olechnicka et al. 2019, 78; NSB 2020, table S5A-32).

University science, research centers, and doctoral training have spread to middle-income and some low-income countries. Wagner et al. (2015, 12) find that global science is increasingly open to new members, and "network betweenness" has declined, meaning a declining proportion of communications pass through the leading countries: there is less gatekeeping. Choi (2012, 34) finds that links between scientists in emerging countries are the fastest growing connections. Of the 20 countries whose scientists produced more than 5,000 papers in 2018 (and whose papers grew most rapidly in 2000–2018), 12 had per capita incomes below the world average of $16,635 in purchasing power parity (PPP). They included India, Indonesia, Brazil, Iran, Nigeria, Pakistan, South Africa, and China, which was just below average income (NSB 2020, table S5A-2; World Bank 2020). Since 2016 China's scientists have produced the most papers in English, and India is now the third largest producer. East Asia outproduces Europe. In China, India, Iran, and South Korea science grows more through national collaboration than international links (NSB 2020, tables S5A2, S5A32, S5A36-49). The Euro-American duopoly is not as central as it was.

In 2019 the United States spent £78.7 billion PPP on research in higher education compared to China's £42.7 billion and Germany's £25.8 billion (OECD 2021). The United States is a strong overall leader in high citation science and far ahead in biomedicine. The quality of the newer producers is often questioned. However, there is no context-free "quality," and as discussed below, both paper counts and citation rates—a questionable proxy for quality (Tahamtan and Bornmann 2019)—are loaded in favor of the duopoly. Even so, citation of non-Euro-American papers grows rapidly. China is first in high-citation papers in mathematics and approaching this in computer science. Its top university in physical sciences, Tsinghua, is ahead of MIT and all other US universities in high-citation papers. Singapore's citation rates are well ahead of the United States and similar to Switzerland (Leiden University 2020).

Data and Interpretations

These data on the tendencies in global science are sourced from national comparisons of research resources (OECD 2021); secondary compilations (Leiden University 2020; NSB 2020) developed from the main bibliometric collections

on scientific papers and citations, those of Scopus/Elsevier and Web of Science (WOS)/Clarivate Analytics; and papers in science policy and scientometrics that draw on the bibliometric data. Bibliometric collections in science (Waltman 2016) have normative, practical, and empirical-analytic functions. They set the boundaries of recognized knowledge, facilitate epistemic collaboration and exchange, and source investigations of global science. They enable the categorization and analysis of papers, authors, scientific groups, and citations by discipline, topic, institutional affiliation, author demographics, and geographic location. Bibliometrics also determine hierarchies and exclusions, as will be discussed.

The current article is in social theory, not scientometrics, and sees bibliometric data as indicators of the materiality of global science, not as the science itself. Numbers of papers and collaborations are partial proxies for knowledge, practices, and social relations. However, not all aspects of social relations are quantifiable or even empirically observable. Theorization has an irreducible role in explanation, including causal explanation (Marginson 2022b). At the same time, data summaries, theorizations, and narratives of science are forms of discourse, and discourses can have effects, colonizing the practices of agents. The choice between world-systems theory and other interpretations is consequential.

National and Global Systems

As the above account suggests, networked science has evolved into two orthogonal systems, heterogeneous and coupled: the global science system and national science systems. National science systems are normed by governments and structured by laws, policies, resources, and institutions. Their mission is to advance national security and economic capability. They do not contain or control global science. Global science has no normative agent: its mission is knowledge creation, and it is regulated by the accumulated interactions of scientists. Scientists bring to bear their individual and collective goals, cognitive cultures, knowledge, imagination, associations, beliefs, and habits. Studies of science (e.g., Winkler et al. 2015; Chen et al. 2019) discuss motivations for collaboration, including cognitive affinity, excitement at the cutting edge, friendship, proximity, cultural affinity, shared values, and preferential attachment for status and career benefits (Marginson 2021).

Resource allocations are necessary to scientific creativity but not in themselves sufficient. Because scientists mobilize across borders, they are not limited by national affiliation. Many move freely between global disciplinary links and their national institutional systems. For some, the disciplinary loyalties are stronger (Adams 2013).

The dual global/national system structure in science fosters a double set of world relations. First, there are international relations in the interstate

system, in which zero-sum nations alternately cooperate and compete and where neoimperial Western configurations of power openly influence the whole. Second, there are the primarily collaborative global relations pursued by autonomous scientists. Both sets of relations feed the growth and diversification of global science. If national ambition helps to explain the spread of capacity, much of the rapidity of growth and ease of diversification derives from the autonomous global network.

Haas (1992) refers to cross-border "epistemic communities" (see also Jerdén [2017] on "epicoms"), which highlights the role of agents while acknowledging systemic conditions. Here science parallels transnational advocacy networks, which likewise gained impetus after 1990, forming global norms and feeding back to national practices (Keck and Sikkink 1999). Critics note that such networks may adapt to dominant national cultures and reproduce knowledge hierarchies (e.g., Dunlop 2000; Shahjahan 2016; Koskinen 2017). Individuals are free to bring any identities into cross-border communities, but when autonomous global systems are filtered through neoimperial relations of power, the new potentials opened up by global convergence are partly closed again.

Inequality and Homogeneity in Science

Thus it is in global science. Its foundational assumptions and culture have changed less than its membership. US-based scientists were at the forefront of the internet, and the early global science system was shaped by that nation's strong universities, talent concentration (including immigrant talent), and federal research system. These largely American origins, in faculty cultures normally free of direct state intervention, fostered open-ended freedoms and autonomous growth. On the debit side, global science was patterned by US hierarchies of value, local norms, and monolingualism that have changed little since the 1990s.

Unregulated global science is both open to all and notably constrained—any outside agents can enter, provided they adopt the culturally specific rules within. As a result there is a poor fit between the wide global distribution of capability in science, in terms of economic capacity and scientific output, and the global narrowing of intellect and imagination. A science system patterned by a single exclusive culture sharply reduces global potential.

Mechanisms of Exclusion

Global science creates common knowledge in relation to shared human problems, for example, global climate change and COVID-19 vaccines. Yet public and common goods can be captured by powerful interests and their commonality stymied in distribution (Marginson 2016). The potentials of global science are limited by inequalities and cultural homogeneity. Conrad (2016)

remarks that networks do not operate in a vacuum. They are "embedded in structural inequalities." Hierarchies also shape networks inside, although network diagrams typically underestimate internal stratification (127). Network analyses highlight nodes and edges and miss the dark spots: connections not made, conversations untranslated, knowledge undervalued, agents that are excluded by rules, protocols, and agendas.

Science combines the horizontal with the vertical. Cognitive accumulation, knowledge building, is partly collective. There is an irreducible moment of equality in every research conversation. There is often also hierarchy. As well as the epistemic distinctions between truth/untruth and strong/weak explanation, there is stratification of status/resources and structured injustice between national systems, universities, and disciplines in journal rankings and inside academic professions. These modulate epistemic distinctions: all else being equal, a Harvard professor's paper has authority. Ideas matter, and some subaltern scientists break through, but this does not negate the two meta-inequalities in the global system: the exclusion of knowledge in languages other than English and expectations that universal global knowledge is framed by Anglo-European and primarily Anglo-American norms.

Global science is structured by a Euro-American (mostly Anglo-American) inclusion/exclusion binary that operates at two levels: in the determination of what is included in the global system and in the ordering of value inside it. Why does this matter? Because beyond the codified science in bibliometric collections there is a wealth of other knowledge. It is often different to recognized knowledge. As with bibliometric knowledge, not all of it has lasting importance. The point is that it is hidden.

English is the first language (L1) of 378 million people, 5 percent of the world, and the second language of 750 million (Ethnologue 2018). Yet because of 200 years of British-American military, political, economic, and cultural primacy, it dominates science, having displaced Latin, French, German, and Russian as world scientific languages. Of the 300,000 periodicals in Ulrichs's comprehensive directory, 69 percent are in English (UlrichsWeb 2021). English constitutes 80 percent of indexed journals in Scopus, 89 percent in the WOS Science Citation Index Expanded, and 90 percent in the Social Sciences Citation Index (Elsevier 2020; WOS 2020). Ulrichs lists 9,857 scholarly journals in Chinese; only 42 are in WOS (UlrichsWeb 2021). In WOS, 95.37 percent of all publications are in English; in Scopus it is 92.64 percent. Spanish is second in WOS with 1.26 percent, and Chinese is second in Scopus with 2.76 percent (Vera-Baceta et al. 2019).

English rules also in translation. Almost half of all translations are from English to other languages, while less than 1 in 10 are from other languages to English (Naravane 1999). Again, little non-English knowledge enters the common pool. In a triumphal account of global English, Crystal (2003) remarks that "it is possible that people who write up their research in languages other than English will have their work ignored by the international community" (16).

Good that he noticed. L1 speakers of Mandarin Chinese and Spanish, both outnumbering L1 English speakers, must be bilingual to fully share in global science. The asymmetry is stark. English-speaking scientists move smoothly between the local national and the global. Other scientists must deal with friction or outright barriers.

The global science that functions as universal knowledge is culturally specific, and its claim to universality is naturalized as normal business. Euro-American organizations control knowledge formation, circulation, and codification. The top 10 publishers share over half the global market (Wischenbart and Fleischhacker 2020). They are all in Europe or the United States, as are Clarivate/WOS and Elsevier/Scopus. The United States dominates editors, reviewers, and reviews despite the diversity of contributors, particularly from emerging countries (Mazov and Gureev 2016; Publons and Clarivate Analytics 2018). Global intellectual property is Western in legal form, and Anglo-European scientists lead disciplinary standards and conventions.

The homogeneity of language, norms, and knowledge is powerfully sustained by Anglo-American universities. The Leiden University (2020) ranking carries data on 2016–19 WOS papers in the top 5 percent by citation. Of the leading 50 universities, 48 percent were in the United States, and 70 percent were Anglophone. Global university rankings are grounded in the customary profiles of the top US and UK universities: bibliometric papers, citations, number of leading researchers, Nobel Prizes, and surveys of university reputation (Marginson 2014). Ranking defines, affirms, and recycles the Anglo-American control of science (Shahjahan et al. 2017). Institutional science is more unequal than the global economy. The United States had 20 percent of world gross domestic product in 2018 (World Bank 2020) but half the universities leading high-citation science.

The forms of global science are installed not through coercion by neoimperial states but in day-to-day institutional practices and autonomous professional habits. In science "normative processes may be as 'closed' to outsiders as are state power and commercial markets, and may not be quite as illustrative of meritocracy as Merton and others assumed" (King 2011, 369). Whether scientists across the world are motivated by curiosity and cognitive accumulation, or status and preferential attachment, they are pulled gravitationally to the familiar hierarchy and the works fashioned at its peak.

Pushback against Monoculture

Control systems based on language and cultural uniformity can persist for long periods. Consider the Qin dynasty's (221–206 BCE) standardization of written language in China, which facilitated a unified polity that, with breaks, has survived since, or, in Europe, the universalizing role of Latin in the cultural-political authority of the medieval Catholic Church. However, there is nothing

inevitable about this. Other states, empires, and civilizations have been multilingual and fostered intercultural mixing and diversity.

The current Euro-American centrism and hierarchy in knowledge draw trenchant critiques from non-English-speaking and postcolonial countries (e.g., Posholi 2020). Vessuri et al. (2014) states that journal lists in bibliometric collections are composed by "self-selection," while work in national languages is rendered invisible. Non-English-speaking jurisdictions appear as intellectually impoverished yet are not (654). "The mainstream has been self built on the supposition that outside there was backwardness and lack of academic value" (Beigel 2014, 619). Santos (2007, 48) describes a "radical denial of copresence," an inside/outside dualism that maintains the intellectual outlook of the colonial period, creating a distinction between universal science and local nonscience—although all knowledge begins as local, and, as Mato (2011) puts it, intercultural collaboration is "indispensable" (409).

Non-English-speaking science systems face a recurring dilemma of inclusion versus identity. Ministries and universities "internationalize" research by incentivizing publications in internationally indexed journals (Xu 2019), but this is a double-edged sword (Yang 2014). Theories, methods, and topics are reworked for Anglo-American journals. Articles that do not tick standard boxes are desk rejected as nonrigorous. National agendas are displaced by "global" topics localized to American society. Subaltern universities contribute to "problems affecting mostly rich countries (a kind of foreign aid in reverse)" (Vessuri et al. 2014, 649). Ostler (2006) states that "the world has as yet exacted no price" for Anglophone monolingualism (542). Not so. The price of cultural uniformity is the loss of diverse knowledge, including endogenous (indigenous) knowledge (Connell 2014, 212; Nyamnjoh 2019, 2).[1]

Critical scholars adopt differing positions, although all want to advance subaltern agency. Some reject existing science wholesale as an act of decolonization, demanding its replacement by alternative knowledges, a position critiqued in Roy (2018). Others call for not the abolition or subordination of monocultural science but its dethroning and supplementation by knowledges previously marginalized or ignored, in an open framework. "We don't want another system of intellectual dominance" (Connell 2014, 218). Many just want a broader inclusion of voices and localities.

Non-Anglo-American systems and persons have much greater agency than bibliometric collections acknowledge, but in global relations they can exercise it only in Anglo-European science, radically reducing the potential

[1] *Endogenous* "emerges from a society," while *indigenous* is "inherent to a given society" as innate and instinctive (Murithi 2008, 17). Devisch and Crossman (2002) note that indigenous knowledge has been applied in Western development discourses in restrictive ways, such as the exclusion of modern forms. They advocate endogenous knowledge, meaning "a community-, site- and role-specific epistemology governing the structures and development of the cognitive life, values and practices shared by a particular community (often demarcated by its language) and its members, in relation to a specific life-world" (108).

of multipolarity. For Beigel (2014) the goal is not to build autonomous science and social science in subaltern sites. That already exists. It is global plurality in models, standards, institutions, professional practices, and values. In identifying the potential of epistemic plurality, the scholarship of science has a role.

The Center-Periphery Model

How are unequal relations in knowledge understood in the scholarship of science? Most studies are in scientometrics, which conducts quantitative analyses of bibliometric data (Mingers and Leydesdorff 2015; Chen and Chen 2016). Although scientometric papers are rarely highly theorized, the most used framework is world-systems theory. While world-systems theory acknowledges a monocultural hierarchy, it sees this as inevitable.

Wallerstein's Theorization

The global structure of center-periphery or "core-periphery" relations originated in the dependency theory of Argentine economist Raul Prebisch who headed the 1950s UN Economic Commission for Latin America (Wallerstein et al. 2013, 44–45). However, it has become largely associated with Immanuel Wallerstein.

In this narrative, over time all nations become incorporated into an expanding Euro-American world system grounded in the capitalist world economy (Wallerstein 2006, 1). "The only kind of social system is a world-system . . . a unit with a single division of labor and multiple cultural systems," states Wallerstein. Power is calibrated by the strength of states and grounded in the economy. There is a three-way division between the world "center" of strong states in the United States, parts of Western Europe, and Japan; nations on the "periphery" whose states are endemically weak or nonexistent; and the intermediate "semi-periphery" (Wallerstein 1974, 390). The center countries command advanced technologies and manufacturing, while in colonial fashion periphery countries provide raw materials and cheap labor and purchase the center's manufactured goods at exploitative prices.

World-systems theory is statist. It sees only nation-states. There are no autonomous global relations crisscrossing nations. Yet, remarkably, within the world system nations do not have even partial autonomy. For countries in the periphery and semiperiphery it is very difficult to move between categories (Wallerstein 1984, 7). The world "totality" locks them in. They exist only within the rigid mosaic of nations that is the world system. As Wallerstein puts it bluntly: "There is no such thing as 'national development'" (1974, 390).

To support his premise of a largely closed world system, Wallerstein scales up Marx's idea of the class struggle over surplus value to relations between national economies. There is a limited political-economic "surplus" at the world level subject to zero-sum competition between countries. To reach the core,

a "semi-peripheral" country "must garner a heavy portion of the collective advantage of the semi-periphery as a whole to itself," at the expense of core countries and all other semiperipheral countries. "This is not 'development' but successful appropriation of world surplus" (Wallerstein 1976, 466). On the periphery, states are weak because foreign capital controls local elites and blocks development (Wallerstein 2004, 23–41). It is impossible for multiple countries to rise together.

In 1974 Wallerstein saw no end of his world system for another century (Smith 1979, 251). He assigned a long list of countries to the semiperiphery, including those in Eastern and Southern Europe, Norway, Finland, parts of Latin America, Anglo settler states including Canada and Australia, Israel, Turkey, Iran, stronger Arab countries like Egypt, Nigeria, Zaire, Indonesia, India, China, Vietnam, and South Korea (Wallerstein 1976, 465). Three decades later, after state strategy and advanced manufacturing had secured for South Korea a spectacular global role as a research-and-development powerhouse, knowledge-intensive exporter, and cultural leader, it was still stuck in Wallerstein's semiperiphery (2004, 30).

Wallerstein is not Eurocentric by conviction. He began with Africanist critiques of colonialism (Wallerstein 2013, 196), and his later work endorses Said's decolonial critique of Orientalism and multiple and subaltern perspectives (Wallerstein 2006). He wants "universal universalism" in place of "Eurocentric universalism" in science (71–84). But he argues that major change in the world system can occur only when global capitalism is abolished (Wallerstein et al. 2013, 30–31). His rigid economic determinism and statism parallels neorealism in international relations theory, which also imagines the absolute predominance of the whole over the parts (Ashley 1984, 235, 283). This helps to explain the wide take-up of the center-periphery model. Inevitable Eurocentrism is readily endorsed by those who, unlike Wallerstein, support Euro-American domination, bask in the alleged cultural primacy of the center, and see capitalism as not just inevitable but desirable.

In an early and prescient critique, Smith (1979) takes issue with Wallerstein's "insistence that it is not internal characteristics of particular countries so much as the structure of the international system—particularly in its economic aspects—that is the key variable" (248). "Part and whole must be comprehended at the same time as an aspect of each other and as analytically autonomous." Change can come not only from the evolution of the whole but endogenously, from individual parts (259). Determination by the "totality" leads Wallerstein to underplay contextual variations and the potential of national agency to escape the dependence trap, especially through "the organisation of the state" (260). The state is not necessarily reducible to either national class interests or the world system (270–71). Strong states can precede economic development, as in nineteenth-century Meiji Japan (264), and peripheral economies do not always remain captured by foreign capital. Within a

decade Wallerstein's world system was being remade by multinationals, global supply chains, the move of manufacturing to emerging countries, and an uneven surge of state building, industrialization, modernization, and growth in science.

Center Periphery in Science

The broad theoretical sweep of Wallerstein 's theory, with determination at a world level, seems to resonate with the worldwide scope of bibliometric collections. "Center/core" and "periphery" in world-systems theory also seem to match corresponding terms in social network analysis. It looks like a short journey from Wallerstein to scientometrics. It is not, and the transfer creates ambiguities. Nonetheless center periphery is often referenced in studies of science and of higher education (e.g., Altbach 2009). Not all studies using these terms conform with Wallerstein. In some, center and periphery are just tiers of a hierarchy.

Schott (1998) uses mobility patterns and citations to describe worldwide stratification. Ties accumulate at the center. Scientists from the periphery gain status by visiting the center, which is inwardly focused and complacent. In social science, papers from outside Euro-America have a weak presence in global publishing, and critical scholars reference center periphery (e.g., Helibron 2014, 685). Xu (2020) defines it as a West/non-West dual.

In scientometrics, an influential paper by Leydesdorff and Wagner (2008) adopts a center-periphery framework, although other papers by these scholars reject this and assert openness and dispersed agency (e.g., Wagner et al. 2015). Chinchilla-Rodriguez et al. (2019) use world-system concepts to investigate agency and dependency in emerging national systems. They find that citation counts, author order, and the international share of papers are blunt tools for studying relations of power. Choi (2012) frames a social network analysis in center-periphery language, although his focus on newly rising science in Turkey and South Korea undermines Wallerstein's fixed positions. Similarly, in a study of high-energy physics Jang and Ko (2019) point to advantages that "core" countries gain from international collaboration, but they note the often successful strategies of "latecomer countries" (440).

Here is the ambiguity between Wallerstein and scientometrics. The "center" in world-systems theory is not equivalent to the concentrated connections in social network diagrams (Scott 2017, 95–111). The latter are not necessarily one-half of a dominance/subordination dyad or an exploitation/dependence dyad. Network analyses permit multiple centers. Here center-periphery relations are not always zero-sum. However, when scientometrics buys into world-systems theory, it can also slip into assumptions about a locked-down world order, inevitable Eurocentrism, and weak agency in "the periphery."

Olechnicka and colleagues (2019) name Wallerstein (102) and apply his theorization closely. "The world of science reproduces the global structure of

center and periphery. . . . New ideas are generated predominantly in the center and then imitated in the periphery." There are "horizontal relations" among core countries, while "core and periphery relations tend towards domination and subordination" (102). It is not explained how that science is patterned by the center periphery in the political economy. What are the mechanisms of correspondence? Is science tied to the economy through the platform capitalism of publishing companies or commercial research and consultancy? Or do states pattern science as the servant of corporations? What of the fact that scientists retain collegial forms and agendas and mostly shape their own projects?

Olechnicka et al. (2019) want to explain the "increasingly central role of collaboration" (2). Because they cannot see an autonomous global science system with distributed agency, they have no plausible explanation for the rapid growth and spread of science and collaborative papers. They follow other studies in arbitrarily splitting collaborative papers on the basis of author nationality as if only the national scale exists (Marginson 2022b). Remarkably, they explain the exponential growth of networks as unconscious acts of neoimperial power. "Research collaboration is one of the means that the center uses—even if unintentionally—to ensure its scientific domination over the periphery" (102).

Everything is run through the world-systems idea. Center countries "control knowledge flows and thus maintain a competitive advantage," set the rules and "the institutional framework" of science, and impose a research agenda "not necessarily consistent with the needs and wants of the periphery." Center countries attract and hold "talented scholars from peripheral countries." Peripheral researchers become "subcontractors or routine research providers for core countries." Authors from the periphery network upward for jobs, publications, citations, and finance (Marginson 2022b, 103). Although the authors miss the language factor, the description of inequality is valid in itself. Yet it is not the sum of the actual or possible.

Domination for its own sake does not wholly explain networking downward from research-strong countries (Chen et al. 2019, 158). Not all collaboration fosters hierarchy, not all motives are transactional, and Olechnicka and colleagues (2019) underplay the emergent agency and potential of emerging countries and their scientists, for example, in first authorship and nation-only collaborations (Chinchilla-Rodriguez et al. 2019; Jang and Ko 2019), and the links into other emerging systems (Choi 2012).

Changing World, Unchanging Paradigm

The pellucid imaginary of center periphery negates the autonomy of global relations, the autonomy and agency of nations and persons, and the potency of context and culture as distinct from uniform economic drivers. It denies the possibility of any autonomy for science, including national science

policy. This prevents it from explaining global science in three areas that have been discussed. First, there is the mobilization and collaboration of active scientists who network freely across borders. Second, there is the simultaneous construction of science systems in many countries categorized as semi-periphery and some on the periphery. The differing strategies, from emphasis on international partnerships (e.g., Singapore) to national collaboration (e.g., Iran) or a mix (e.g., China), are not inhibited by a zero-sum battle over a fixed "surplus." Third, there is the growing multipolarity in science and the emerging disjunction between economic capacity and cultural power in science.

Olechnicka et al. (2019) struggle with the pluralization of science, which violates the fixed Euro-American centric order. Their data plainly indicate pluralization. There is "a great shift of world-wide knowledge flows" (93), in East Asia, India, and secondary regional nodes (92–93). "The recent examples of Singapore, South Korea and, in particular, China indicate that transfer from periphery to semi-periphery, or even to the core, is possible" (105). Is the Eurocentric world system (and world-systems theory) finished? Not quite yet.

China is "a new scientific superpower" state the authors. Yet this rests on "massive investments from the Chinese government," and "cultural and organizational obstacles to scientific collaboration" may hinder "further expansion of the research sector" (Olechnicka et al. 2019, 177). "The Confucian tradition does not support collaborative behavior. It attaches great importance to the social hierarchy, loyalty, and subordination to authority. Chinese education traditionally does not encourage critical thinking" (155). Rules, centralized funding, and "all-pervasive bureaucracy and central planning" inhibit Chinese science. It is not meritocratic. *Guanxi* networks shape collaboration and determine access to resources. "The political system . . . hampers the freedom of choice of scientific topics and partners for collaboration, and the freedom of speech. . . . It is in conflict with the notion of innovativeness and creativity" (156).

In short, science in China is not bona fide, not genuinely collaborative, and not creative in a Euro-American sense. Amid this barrage of othering, the empirical weight of China's science evaporates. Eurocentrism is briefly dethroned and almost immediately reinstated.

Olechnicka and colleagues join the long list of Western commentators who forecast a "glass ceiling" that will block further improvement of science in China (e.g., Altbach 2016). Such predictions have a poor track record. Again, some of their points are right, like the role of *guanxi*, rules, and lack of freedom in some disciplines, but these insights are embedded in a normative and selective picture that protects the world-system vision. Olechnicka and colleagues expect to find a Wallerstein world, and, despite their own data, they succeed.

World-system explanations fail to grasp the potency of political-cultural factors, except for European-heritage culture. Post-Confucian statecraft and

self-cultivation in China, South Korea, and Singapore have been not a weakness but a strength, facilitating accelerated science building (Marginson 2011). Olechnicka and colleagues are likewise uncurious about relations between global scientists and nation-state policy, a pivotal issue. There can be tensions between global networks and national agendas (Wagner et al. 2015, 11–12), but structuring those relations effectively is one of the keys to science in China. This national/global congruence is achieved within a specific political culture (Marginson 2022a).

Others puzzle about reconciling world-systems theory with the observable realities. Mulvey (2021) discusses China in higher education in Africa. World-systems theory says China is semiperipheral, not part of the colonizing North, but its relations in Africa are asymmetrical. Mulvey suggests "semi-peripheral (post) coloniality" (441) to explain this. This protects world-systems theory by adding another layer of complexity, but the term is ambiguous and opaque. Some scholars fragment the definitions. Helibron (2014) asserts a global social science system whose "predominant characteristic" is "a core-periphery structure with a duopolistic Euro-American core, multiple semi-peripheries and a wide range of peripheries" (685). At this point it is better to talk in terms of cases, not categories. Gymnastic redefinitions and applications, with concepts alternately too rigid and too loose, are signs of a paradigm in decay. It is not worth the effort made to preserve it.

World-systems theory emerged during the Cold War. Because of its ontological closure it cannot comprehend post-1990s globalization, networks, and the new Eurasia. It has long been decoupled from the history of science. It is a dangerous obsolescence, normalizing received hierarchies by diminishing the potential of agency. A new approach is needed.

Cultural Hegemony in Science

How is it that while economic and scientific capacity is spreading across the world, the near absolute dominance of Euro-American knowledge is undiminished? The trajectory of global science has inverted the world-systems assumption that political economy necessarily drives culture. Here it is cultural factors that sustain control. This challenges perceptions of the drivers of inequality. Resources matter, but they are not the only factor.

Richer insights into power in science can be gleaned from the conceptual toolbox of Antonio Gramsci (1971). Gramsci breaks with the "standard economic determinism and philosophy of actor-less historical necessity" (Fonseca 2016, 24) exemplified by world-systems theory. He does not provide an account of world relations parallel to world-systems theory, or specifically focus much on science, but provides a nuanced account of processes of hegemony and of sectors like science that lie outside the core machinery of state. Gramsci shows how relations of power in science are partly autonomous and also how ideological

leadership in this sector contributes to the overall configuration of power. He takes these ideas to the international as well as national fields.

Gramsci's hegemony is more than simple dominance, the main usage of the term in neorealist theory (Ashley 1984). Relations of power have two modes: coercion or force exercised directly by the state and hegemony, the fostering of active agreement in the state and civil society. "The ruling class not only justifies and maintains its dominance, but manages to win the active consent of those over whom it rules" (Gramsci 1971, 178). Its vision of the world is diffused through the capillaries of social networks and secured in subjectivity and day-to-day conduct. Here Gramsci anticipates Foucault. Hegemony is the "glue" binding the leading socioeconomic group to the rest of society (Fonseca 2016, 80). It requires strenuous investment in normative processes, including law, schooling, media, publishing, and the arts. Intellectuals, who articulate universalizing ideas, play a key role in the formation of hegemony and in moments of counterhegemony.

Gramsci extrapolates these ideas to "combinations of states in hegemonic systems" (1971, 176) and the "colonial subjection of the whole world to Anglo-Saxon capitalism" (1977, 79–82, 89–93). Writing 60 years before the internet, he does not discuss autonomous global systems. "International" power is seen as an outgrowth of the strongest nation-states (arguably, global science began like this but has evolved beyond it). International consent is engineered by the same processes as at a national level. In his passages on "Americanism and Fordism" Gramsci highlights the universalizing element in American culture, propagated worldwide in industrial production, mass consumption, and ideologies of individualism and "internationalizing" associations like Rotary and the YMCA (1971, 277–318). The sciences are especially fitted for universalization: "Every relationship of 'hegemony' is necessarily an educational relationship and occurs not only within a nation, between the various forces that comprise it, but in the entire international and world field" (Gramsci 1995, 156–57). "Up to now experimental science has provided the terrain on which a cultural unity of this kind has revealed its furthest extension. This has been the element of knowledge that has contributed most to unifying the 'spirit' and making it more universal. It is the most objectified and concretely realized subjectivity" (Gramsci 1971, 446).

No country other than the United States allows its intellectuals greater freedom to "detach themselves from the dominant class." Mostly they choose to "unite themselves to it more closely" (Gramsci 1996, 355), but they are also central to counterhegemony.

Gramscian hegemony is readily seen inside science. Lukes (2005) discusses "the mobilization of bias" (20–21) and control over processes and agendas (25–29). Ordorika (2003) refers to "shaping and incorporating perceptions, cognitions and preferences into a dominant ideology" (27) in higher education in Mexico. Leading institutions sustain authorities and processes (e.g., journal

hierarchies and topic selection) that calibrate value in science on the basis of the hegemonic order.

The Gramscian theorization understands power in systems such as science as grounded in voluntary consent, the investment of subjects. This explains how dominant forms and ideas are bedded down in global science without the necessity for an interventionist state. Hegemony explains how scientists outside Euro-America "consent to the terms of the game as if they were their own" and invest in their own subordination (Fonseca 2016, 81).

Gramsci's open ontology enables a more comprehensive and supple explanation of power in science than that of world-systems theory. He recognizes the distributed character of agency, knowing that subaltern nations and persons have scope for action, and understands the fluidity of relations between national and international activity. Today's multipolarity and growing science on the "periphery" would not have phased Gramsci. He would have been fascinated by the possibilities opened up by global science.

World-systems theory sees inequality and homogeneity as inevitable and cannot grasp the main tendencies in global science. Gramsci understands relations of power as open to challenge and sees intellectuals, not only states, as key to transformation.

Conclusion: The Ecology of Knowledges

The purpose of cognitive accumulation is building knowledge, not systems of power. Yet science and other knowledge can be annexed to one or another configuration of power. The question is how to develop their potentials for openness, democratization, and equalization.

Those potentials are always there. Globalization fosters both cultural homogenization and cultural heterogenization, bringing people face to face with difference on the basis of common templates. The present global science works only the homogenizing side of the globalization dyad. Is it possible to evolve science with multiple centers, national-cultural diversity, and continuous intercultural conversations, as in some interpretations of the Chinese *tianxia* 天下? The multipolarization of capacity encourages a move to unity in diversity—from centripetal and stratified knowledge to a system that recognizes and respects a fuller corpus of languages, concepts, theories, methods, and topics.

"In history, in social life, nothing is fixed, rigid or definite. And nothing ever will be. New truths increase the inheritance of knowledge" (Gramsci 1985, 31). Creating an accessible shared diversity entails significant work, as the European Union experience shows. The first and crucial step is the will to make it happen. In emerging countries there is a continuing need to materially strengthen science, but if multiple agential perspectives are to be valued in science and social science, this requires not just resources but cultural freedom.

A Gramscian understanding of hegemony emphasizes that the struggle to pluralize knowledge is partly about language, institutions, and processes. Mbembe (2016) suggests a "pluriversity" in place of a university, with "a process of knowledge production that is open to epistemic diversity. It is a process that does not necessarily abandon the notion of universal knowledge for humanity, but which embraces it via a horizontal strategy of openness to dialogue among different epistemic traditions" (37). "Pluriversal" knowledge recurs in decolonial literatures in Latin American and Africa.

Santos (2007) proposes an "ecology of knowledges" in place of "the monoculture of modern science" (66). He emphasizes "sustained and dynamic interconnections between" heterogeneous knowledges, "without compromising their autonomy" (66), and also intercultural translation. "This requires renouncing any general epistemology. . . . Not only are there very diverse forms of knowledge of matter, society, life, and the spirit, but also many and diverse concepts of what counts as knowledge and the criteria that may be used to validate it" (67). Santos does not want to weaken scientific knowledge but to promote "the interaction and interdependence between scientific and non-scientific knowledges" (70), including endogenous knowledges. This does not mean that all truths have equal status. It means that structural exclusion is discarded. There is cosmopolitan openness: "The novelty of subaltern cosmopolitanism lies, above all, in its deep sense of incompleteness without, however, aiming at completeness. . . . The diversity of the world is inexhaustible and . . . such diversity still lacks an adequate epistemology. In other words, the epistemological diversity of the world does not yet have a form" (64).

One step toward epistemological diversity is to move from sole reliance on global English to a multilingual publishing and translation regime as the primary repository in each field. English would remain the shared language, but every effort would be made to bring knowledge in diverse languages to the common pool. All global field journals, and leading national language journals, would be available in the major languages (some journals already do this). Citation counts would aggregate different versions of one text. Book publishers would facilitate online translation of books, from all languages to each other.

Developments in technology can facilitate multilingual publishing: software should include scientific languages. Languages with over 100 million L1 speakers or 130 million L2 speakers are English, Mandarin Chinese, Spanish, Hindi, French, Arabic, Russian, Bengali, Portuguese, Indonesian, Urdu, and German (Ethnologue 2018). In some fields the normalization of translation would encourage open source modes. Resources would still be unequal, but multilingual publishing would be a game-changer, fundamentally extending the common pool to knowledges outside the English-dominated academic world.

The crucial agents are not just publishers and bibliometricians but scientists themselves, their collegial networks, universities, and potentially

supportive non-English-speaking governments (e.g., Helsinki Initiative 2019). Science will not move as a whole. The path to structured plurality is via individual disciplines. New norms in one field can trigger change elsewhere.

Before that much can be done. The habits of self-regulating scientists reinforce structural injustice but can also transform it. It is difficult to enter the imagination of another community. A first step is reflexivity about the ordering of value: Why elevate our own cultural practices above others? Each monocultural scientist who starts to work across language divides or draw on endogenous insights, each editor curious about diverse papers, each cross-cultural group embodying equality of respect, each person who reflects on Eurocentrism and unlocks the imaginary of "centers" and "peripheries," and each new voice and way of seeing has unanticipated effects. In the multiplication of these small steps, the ecology of knowledges begins.

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