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Global Webs of Knowledge

Education, Science, and Technology

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Knowledge is globally institutionalized as three differentiated and interpenetrating social institutions: education as a social institution for transmitting humankind's existing knowledge, science as a social institution for creating new knowledge that becomes a global public good, and technology as a social institution for creating new knowledge that becomes privately appropriated. These three social institutions are governed by a global regime that is anchored in a web of organizations that through an epistemic community of analysts of knowledge, formulates and promulgates policies for knowledge. In education, the regime promotes transmission of existing knowledge to youth through schooling and also through the movement of students around the world. In science, the regime supports creation and diffusion of new knowledge around the world through open publication. In technology, the regime promotes private appropriation of new knowledge through property rights in the form of patenting, which is increasingly global.

This article addresses how knowledge is institutionalized around the world, how it circulates around the world, and how circulation is variously enabled and limited by institutional arrangements. Among the many traditions of knowledge, a few are especially global in their institutionalization, namely education, science, and technology (Stiglitz, 1999).

Education as a social institution for transmitting humankind's existing knowledge is organized as formal training of the youth of humankind, with the crystallization of the social roles of student and teacher and the kind of organization called a school, which has been built throughout the world. The content of schooling comprises increasingly instrumental knowledge and is increasingly similar from place to place (Meyer, Kamens, & Benavot, 1992). Science as a social institution for creating new knowledge that becomes a global public good

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is organized throughout the world in the form of professional academic research, with the crystallization of the social role of scientist, and conducted mainly in the kind of organization called a university (Münch, 1983; Schott, 1998b). Technology is a social institution for creating new knowledge that becomes privately appropriated is organized around the world in the form of a professional inventive work, with the crystallization of the social role of inventor. It is conducted mainly in research and development laboratories in industry, agriculture, and the military (Collins, 1986; David, 1993; Schott, 1994).

Social relations among cultivators of these three traditions of knowledge are wide ranging, even globe spanning. In education, textbooks, curricula, instructional principles, teachers, and students circulate around the world. In science, new knowledge is published; the publication transfers the knowledge to a common pool that is available to humankind for further use. In technology, new knowledge is often patented; the published patent announces the innovation to humankind but also makes it private property. The private appropriation is global insofar as an invention made almost any place can be patented nearly everywhere.

These institutionalized traditions of knowledge are governed by a global regime. The governance works through an epistemic community of analysts of knowledge. The analysts form a community organized as a network that extends around the world. The epistemic community is supported by a web of organizations, notably the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the Organization for Economic Cooperation and Development (OECD), the World Bank, and the World Trade Organization. The community analyzes knowledge and theorizes about its dynamics and benefits, and it formulates and promulgates policies (Burch, 1995; Drori, 1997; Finnemore, 1993; Meyer, Boli, & Ramirez, 1997; Mörtz, 1998).

Knowledge is widely considered not to be an end in itself; it has been rationalized as a means to other ends, mostly some kind of social progress, for example, modernization and economic growth. Support for knowledge is treated as an investment in economic production and is often measured as a percentage of gross national product (GNP). The epistemic community advocates that an increasing percentage of GNP be spent on education and on R&D. In the 1960s, when the United States was the most economically productive nation and was the exemplary model for the world, it spent about 3% of its GNP on R&D, and this figure has become a global standard for the support of science and technology.

Support for knowledge can be indicated by public expenditure on education and on R&D, both as percentages of GNP (Table 1). The public expenditure on education does not greatly differ from one nation to another. Over time, nations have tended to increase their public spending on education and R&D, and they have become more similar in their level of support. The isomorphism among nations in their institutionalization of knowledge, and specifically in their similarity of support, does not entail an equalization in their intensity of benefit but

TABLE 1: The Global Institutionalization of Knowledge (in percentages)

	Population ^a	Education ^b	Science ^c	Technology ^d	Public Education Expenses ^e	Research Expenses ^f
United States	4.7	16.9	32.8	37.4	5.4	2.5
Japan	2.2	4.8	8.2	28.7	3.6	2.9
France	1.0	2.6	7.2	3.4	6.1	2.4
Denmark	0.1	0.2	0.8	0.4	8.2	1.9
Russia	2.6	5.5	2.0	0.2	4.1	0.7
South Korea	0.8	3.1	0.8	3.0	3.7	2.8
China	21.5	3.6	1.1	0.1	2.3	0.5
India	16.3	7.0	1.2	0.1	3.4	0.8
Brazil	2.8	2.0	0.9	0.1	5.2	0.6
Egypt	1.1	1.0	0.2	0.0	4.8	0.5
Other nations						
World total	100	100	100	100		

a. Country's percentage of world, 1995; Source: United Nations Educational, Scientific, and Cultural Organization (UNESCO), 1998, *Statistical Yearbook*, Table 1.1.

b. Country's percentage of students in higher education, about 1995; Source: UNESCO, 1998, *Statistical Yearbook*, Tables 2.4 and 3.11.

c. Country's percentage of world's scientific articles, 1996; Source: Institute for Scientific Information, Science Citation Index 1996.

d. Country's percentage of world's technological patents, 1998; Source: Patent and Trademark Office, Patent Counts by Country/State and Year, 1963-1998 (<http://www.uspto.gov>). Technological patents refers to the utility patents granted by the U.S. Patent and Trademark Office, with the modification that the overrepresentation of domestic inventions for this indicator of inventive activity is corrected for by halving the number granted to U.S. residents.

e. Expenditure on public education as a percentage of GNP, about 1995; Source: UNESCO, 1998, *Statistical Yearbook*, Table 4.1.

f. Expenditure on R&D as a percentage of GNP; Source: UNESCO, 1998, *Statistical Yearbook*, Table 5.1.

may actually entail a widening of their inequality. When support, as a percentage of GNP, is similar among nations, the expenditure is larger in rich than in poor nations; hence, insofar as the investment brings returns, the rich get richer and the poor get relatively poorer, thereby widening the gap between them.

The volume of education in a nation is indicated in Table 1 by students enrolled in higher education in the country, as a percentage of the world's enrollment. The volume of science in a nation is indicated by the articles authored by the scientists in that country, as percentage of the world's articles in major journals. The volume of technology, specifically technological inventive activity, in a nation is indicated by the patents obtained by inventors in the country, as a percentage of the patents granted inventors in the world (Dosi, Pavitt, & Soete, 1990, p. 50).

Table 1 shows that the United States has the highest volume of knowledge in the world. Note that the distribution of knowledge production is not strictly a product of size. Volume of knowledge correlates with population, but a large population is a necessary rather than sufficient condition for a voluminous cultivation of knowledge.

The intensity of knowledge cultivation, indicated by the ratio of volume of knowledge to size of population, differs among nations. The major gap is between the knowledge-intensive societies in the West (and Japan and the few other newly knowledge-intensive societies in East Asia, such as South Korea) and the more traditional societies in Asia, Africa, and Latin America. Inequality among nations in intensity of education is large, but this inequality is decreasing. In science, the inequality is larger and seems rather stable. In technology, the inequality is even larger and appears to be increasing.

Nations specialize in their cultivation of knowledge. Japan is specialized in technology (its share of technology is far higher than its share of science and its share of education in the world), and so is South Korea. France, Denmark, and Russia specialize in science. China, India, Brazil, and Egypt specialize in education. This specialization of each nation in education, science, or technology entails an international or global division of labor in the cultivation of knowledge (Schott & Monsma, 2000).

The volumes of knowledge do not indicate the web of knowledge, but they affect the flow. Notably, we should expect the high volume of knowledge in the United States to make it a center of attraction, diffusion, and dominance in the world. We now turn to mapping global webs in education, then in science, and then in technology.

THE GLOBAL WEB OF EDUCATION

The transmission of humankind's common stock of knowledge to its youth is the essence of education as a social institution. Knowledge flows around the

world through the study of nonlocal textbooks and the import of teachers. Knowledge is also carried by students returning from a sojourn of study abroad.

The global web of education can be mapped by data on the movement of students around the world. Study abroad is institutionalized; it is valued, supported, and organized. Students from one nation travel to a variety of other countries for higher education, but some destinations are especially favored.

The center of higher education is the United States. Other nations form a periphery attached to this center. U.S. educational institutions exert attraction on foreign as well as local students, so only a tiny fraction of U.S. students venture abroad, and the center itself is self-reliant (see Table 2).

The center and periphery hierarchy has been a stable formation, although there has been an expansion of the hierarchy, shifts of centers, and incorporation of new peripheries. This vertical stratification has been combined with a horizontal differentiation, where a region is a cohesive group of nations with strong relations with one another and weak relations with outsiders. The Communist bloc was such a clique in education but has largely disintegrated; the European Union is integrating as a cohesive region, and regionalization is occurring in North America and also in East Asia (Schott, 1998a).

THE GLOBAL WEB OF SCIENCE

The global web of science can be mapped by a survey of scientists and their ties. Scientists were surveyed in the 1990s in more than a dozen countries (Schott, 1998a; Schott, Kanamitsu, & Luther, 1998; Schott, Kugel, Berrios, & Rodriguez, 1998). Each scientist was asked to name the persons whose ideas had influenced his or her own research in the previous 5 years and also asked about the location of each named influence. The sources of influence on scientific research in a country can be indicated by the location of the influential scholars named by the scientists surveyed in the country, as listed in Table 3.

The first column in Table 3 shows that scientific research in the United States is influenced mostly by knowledge created within the United States and very little by knowledge from abroad. Scientific research in Japan is influenced by knowledge created within the country and knowledge from the United States. Likewise, scientific research in each other country is influenced mainly by knowledge created within the country and knowledge from the United States. Evidently, science has a center, located in the United States, from which knowledge flows and influences research in the rest of the world. The attraction to the center has accumulated over time so that it has gained a share of influence in the world that is even higher than its share of scientific research. The center is, of course, highly self-reliant, but its inwardness is even higher than expected on the basis of its high performance (Schott, 1998b).

Regionalization has been recurring. The East European societies formed a cohesive region in science for more than a generation, but this has now

TABLE 2: The Global Web of Education: Students Enrolled in Higher Education in Foreign Countries (in percentages)

Destination	Origin of students								
	United States	Japan	France	Denmark	Russia	South Korea	China	Egypt	Others
United States		70.8	14.6	16.8	26.5	50.5	59.6	15.2	
Japan	3.8		0.3	0.5	0.6	24.8	20.5	1.2	
France	11.2	1.8		7.8	3.7	2.3	1.2	5.0	
Denmark	0.8	0.04	0.2		0.1	0.001	0.07	0.05	
Russia	0.01	0.01	0.01	0.02		0.01	0.1	0.4	
South Korea	1.0	0.6	0.01	0.02	0.07		0.4	0.02	
China	7.3	13.3	1.2	0.5	1.0	9.0		0.05	
Egypt	0.01	0.003	0.003	0.0	0.2	0.002	0.0		
Other nations									
Total abroad	100	100	100	100	100	100	100	100	

SOURCE: United Nations Educational, Scientific, and Cultural Organization, 1998, *Statistical Yearbook*, Table 3.14.

NOTE: Percentage of students abroad from the nation, about 1995.

TABLE 3: The Global Web of Science: Reported Influences on Scientific Researchers Around the World (in percentages)

Source of Influence	Country of Scientists Reporting Influence							
	United States	Japan	France	Denmark	Russia	India	Brazil	Others
United States	79.4	26.7	23.8	18.6	17.0	39.1	20.8	
Japan	0.6	49.0	1.3	1.6	1.5	1.7	1.2	
France	1.7	2.2	49.9	2.9	3.8	2.0	7.9	
Denmark	0.1	0.3	0.2	46.6	0.4	0.5	0.5	
Russia	0.6	1.0	0.7	2.5	49.1	1.5	1.4	
India	0.0	0.2	0.3	0.0	0.2	27.0	0.5	
Brazil	0.0	0.0	0.0	0.1	0.2	0.0	42.3	
Other nations								
World total	100	100	100	100	100	100	100	

SOURCE: Survey of scientists in United States, Japan, France, Denmark, Russia, India, and Brazil, about 1994; scientists were asked to name scholars who influenced their work and their home country (Schott, 1998a; Schott, Kanamitsu, Luther, 1998; Schott, Kugel, Berrios, & Rodriguez, 1998).

disintegrated; the European Union is integrating as a region, and regionalization is also occurring within North America and within East Asia.

The global web of science has been undergoing a process of globalization. Not only has science been institutionalized globally, but the flows of knowledge across national boundaries have been intensifying, relative to the flows within countries (Schott, 1998b). This globalization has not entailed an equalization.

THE GLOBAL WEB OF TECHNOLOGY

Technology as a social institution includes, at its essence, public announcement of new knowledge and private appropriation of new knowledge. The public announcement of new knowledge in a patent makes the idea a source of inspiration and thus a point of departure for the creation of new knowledge. The web of technology thus comprises, as does science, a flow of knowledge. This flow of knowledge through patents is essential to technology as a social institution. The flow of knowledge is reflected in inventors' use of technical knowledge from various places. The flow is indicated in their patents' citations to patented inventions made around the world, as listed in Table 4.

The first column of Table 4 shows that invention in the United States draws mainly on inventions made previously in the United States and much less on inventions made abroad. Invention in Japan is based mainly on inventions made within that country and in the United States. The same is true for invention in other highly inventive nations such as France. Invention in Denmark is based mainly on inventions made in the United States. The same is true for invention in other small nations and in nations with little inventive activity, such as China. Evidently, the flow of knowledge in technology has a center in the United States on which the rest of the world is dependent for its inventive endeavors (Monsma, 1999).

This flow of technological knowledge has not only a center and periphery hierarchy but also a horizontal differentiation into regions. For more than a generation, Eastern Europe was a region in the flow of technological knowledge, and now regionalization is occurring in the European Union, in North America, and in East Asia. Regionalization has been accompanied by an intensification of flows, including long-distance flows, among nations relative to flow within nations (Monsma, 1999).

Technology differs from science by its private appropriation. Property rights are national in their scope insofar as they are granted by the state, and the monopoly exists within the country, but not beyond its border. An invention may be patented in some countries (in important markets, typically, and in the inventor's own country, if the home market is significant) and perhaps not patented in other countries (in small markets, typically). The ownership of knowledge in a country is thereby reflected in patents granted in the country for inventions made around the world. The web of technology thus includes a network of appropriation. The appropriation of knowledge within a country is indicated by the origins of inventions patented in the country, listed in a column in Table 5.

The first column of Table 5 shows that ownership in the United States is mainly held within the country and also extensively held by Japanese. The second column shows that knowledge in Japan is owned within the country and to a lesser extent by Americans and others. Knowledge in France is monopolized extensively by owners in the United States and France. Knowledge in smaller

TABLE 4: The Global Web of Technological Invention: Influences on Technological Invention (in percentages)

Source of Influence	Country Where Invention Was Influenced									
	United States	Japan	France	Denmark	Soviet Union	South Korea	China	India	Brazil	Egypt Others
United States	72.7	34.3	47.2	47.9	42.0	41.8	56.0	51.9	54.3	61.1
Japan	10.6	49.8	11.9	10.3	14.6	39.4	19.1	11.1	12.8	21.2
France	2.2	2.0	18.3	2.5	3.9	1.9	2.2	3.6	4.9	1.7
Denmark	0.1	0.09	0.2	12.5	0.3	0.4	0.0	0.0	0.2	2.5
Soviet Union	0.2	0.1	0.3	0.5	14.9	0.0	0.1	0.0	0.0	0.0
South Korea	0.02	0.03	0.02	0.0	0.0	2.6	0.2	0.0	0.0	0.0
China	0.01	0.01	0.01	0.0	0.1	0.04	2.2	0.0	0.0	0.0
India	0.01	0.01	0.01	0.01	0.0	0.0	0.0	3.6	0.0	0.0
Brazil	0.01	0.01	0.02	0.01	0.0	0.0	0.9	0.0	1.3	0.0
Egypt	0.002	0.001	0.002	0.04	0.0	0.0	0.0	0.0	0.0	0.0
Others										
World total (%)	100	100	100	100	100	100	100	100	100	100

NOTE: Influences are measured by citations in patents issued by the U.S. Patent and Trademark Office from 1975 to 1991, as compiled by CHI Research, Inc.

TABLE 5: The Global Web of Appropriation of Technology: Patenting of Technology (in percentages)

<i>Source of Invention</i>	<i>Country Granting Patent</i>									
	<i>United States</i>	<i>Japan</i>	<i>France</i>	<i>Denmark</i>	<i>Russia</i>	<i>South Korea</i>	<i>China</i>	<i>India</i>	<i>Brazil</i>	<i>Others</i>
United States	55.7	6.6	20.6	25.2	1.3	11.7	15.1	27.5	33.0	
Japan	21.0	87.3	18.2	6.7	0.6	28.6	15.0	3.9	7.1	
France	2.5	0.8	24.3	9.5	0.6	3.5	3.9	4.1	6.5	
Denmark	0.2	0.07	0.5	3.1	0.09	0.1	0.2	0.1	0.3	
Russia	0.1	0.01	0.02	0.02	83.8	0.05	0.1	0.2	0.0	
South Korea	1.4	0.4	0.1	0.1	0.07	50.4	1.6	2.3	0.1	
China	0.04	0.01	0.02	0.01	0.02	0.00	46.5	0.1	0.0	
India	0.03	0.002	0.01	0.01	0.00	0.01	0.00	35.2	0.0	
Brazil	0.06	0.01	0.04	0.03	0.01	0.02	0.03	0.0	12.7	
Others										
World total (%)	100	100	100	100	100	100	100	100	100	100

SOURCE: World Intellectual Property Organization, 1996, Industrial Property Statistics, Publication B, Part I, Tables I and II (B).

countries such as Denmark and less inventive countries such as China is monopolized mainly by U.S. proprietors.

The web of technology has been undergoing a process of globalization, not only in that technological invention and property rights have been institutionalized more and more globally but also in that private appropriation increasingly extends across long distances.

FORMATIONS IN WEBS OF KNOWLEDGE: CENTER-PERIPHERY HIERARCHY, REGIONS, AND GLOBALIZATION

Mapping webs in education, science, and technology and discerning the configuration of each web raise some questions: Do the webs coincide, and are their configurations similar? The webs do, indeed, tend to coincide: Typically, a strong relationship between two nations in one web coincides with a strong relationship between them in another web, and a weak relation in a dyad in one web coincides with a weak relationship between them in another web.

Each web has a hierarchy. Nations tend to relate mainly to one center, and they thus form a periphery dominated by it. Moreover, the center is the same in the various webs, namely the United States. In each web, the centrality of the United States has been declining in recent decades, whereas Japan has been rising from a peripheral to a more central position. The steepness of the hierarchy differs among the webs. Peripheries are least marginal in education; they are more marginal in science and most marginal in technology.

The center-periphery hierarchy is the vertical stratification in a web. Complementary to this is a horizontal differentiation by region. In each web, the East European nations used to form such a clique, and now regionalization is occurring within the European Union, North America, and East Asia. The webs differ in their extent of regionalization; regions are more open in science than they are in education and technology, in which, typically, a region is more cohesive.

Each web has been undergoing a process of globalization in that long-distance relations have been intensifying, especially relative to relations within nations.

SOURCES OF THE WEBS OF KNOWLEDGE: EMBEDDEDNESS IN GEOPOLITICAL WEBS

Where do the webs come from? More precisely, what makes the webs of education, science, and technology so intertwined, and what explains the configurations of the webs?

The global web of education, the global web of science, and the global web of technology are analytically distinct relations. But these distinct kinds of rela-

tions are not autonomous but are intertwined for several reasons. Students who travel to apprentice themselves to prominent scientists may become colleagues of those scientists, and their educational tie turns into an exchange of scientific ideas. Thereby, the web of education is directly coupled to the web of science. The webs are also coupled in a more spurious manner insofar as both are promoted by agreements between governments to pursue international exchanges and cooperation in education, science, and technology. Multilateral agreements such as those within the European Union, within the North Atlantic Free Trade Agreement, and earlier within the East European Communist bloc have promoted dense relations in education, science, and technology and have thus caused a regionalization in the webs. The webs of knowledge are thus not autonomous but are embedded in geopolitical webs.

The center-periphery formations are due mainly to differences among nations in their cultivation of knowledge. The cultivation of education, science, and technology is far greater in the United States than anywhere else, and this partly accounts for its centrality. But the centrality of the center has seemingly accumulated over and above its cultivation of knowledge. In science, most notably, the influence of the center exceeds its performance.

The globalization of the webs may be attributed in part to the growing ease of communication and transportation around the world. The globalization of the webs may also be attributed in part to the global regime, which strengthens long-distance relations in educational exchanges, in diffusion of scientific knowledge, in circulation of patent documents, and in appropriation of knowledge.

The attraction of the center is exerted not only on its surroundings but also within the center itself, and the inwardness of the center has also accumulated and turned into a local parochialism, a "Not Invented Here" syndrome devaluing foreign cultivation of knowledge and enhancing the value assigned to local knowledge.

CONSEQUENCES OF THE WEBS OF KNOWLEDGE: UNEQUAL OPPORTUNITIES AND RESTRICTIONS

The project of modernization that unfolded along with decolonization in the decades after World War II envisioned a world in which the modernity of the West would be a model for emulation and catch-up by other societies around the world; some eventual equality among nations was expected. But the cultivation of knowledge remains dominated by the West. The peripheries remain marginal and dependent on the West. Their dependence is more severe in science than in education and most severe in technology. Education, science, and technology are coupled to the economy within each nation with positive effects that in a wealthy nation, form an upward spiral but, relatively in a poor society, form a

downward spiral, thus exacerbating the inequality in the world in knowledge and wealth.

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