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STATE, SELF-ORGANIZATION, AND IDENTITY IN THE BUILDING OF SINO-U.S. COOPERATION IN SCIENCE AND TECHNOLOGY*

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Cooperation in science has become an important part of the relations between China and the United States, and is usefully seen in the context of the worldwide phenomenon of increasing international scientific cooperation. Attempts to explain this increase in international scientific cooperation have called attention to the importance of government-to-government agreements and to self-organizing tendencies within the international scientific community. In the China-U.S. case, however, co-ethnic identity, manifested in coauthoring patterns, seems to be an especially important factor in cooperation as well. This article explores these patterns with an eye toward understanding the complex relationships between transnationalism and our understanding of Chinese nationalism and multiple Chinese identities.

Key words: U.S.-China relations, nationalism, science and technology, cooperation in East Asia

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Introduction

The development of scientific and technological cooperation between the United States and China has been an important and enduring theme in China-U.S. relations since Richard Nixon visited China in 1972. Following that visit, an era of exchanging scientific delegations ("scientific tourism" to the disparaging observer) led to a series of important agreements at the end of the 1970s, including the Agreement on the Exchange of Students and Scholars in 1978 and the Agreement Between the Government of the United States of America and the Government of the People's Republic Of China on Cooperation in Science and Technology (S&T Agreement), which subsumed the former, in January 1979. The S&T Agreement became an umbrella under which a large number of agency-to-agency agreements (more than twenty-five protocols with over sixty annexes) were signed between the technical agencies of the U.S. government and their Chinese counterparts. Although activities under these agreements have ebbed and flowed during the intervening two and a half decades, overall, cooperative activities under the S&T Agreement have remained reasonably robust in the service of both science and of China-U.S. relations, and are now poised to expand.

These early government-to-government agreements helped set the stage for the rapid growth of students and scholars coming to the United States during and after the 1980s. Over time, this trend took on a life of its own. Largely independent of the formal agreements, the numbers began to swell during the course of the 1980s as Chinese and U.S. individuals and organizations forged ever more dense ties. The high absorptive capacity of the U.S. university system, the flexible ways in which government research funding could be used to support Chinese graduate students, and the abundant supply of Chinese candidates for research and training opportunities in the United States fueled the growth of the relationship.

Over time, of course, many of the Chinese students and scholars took employment in the U.S. research enterprise, became citizens or permanent residents, and launched professional careers and established families in the United States, thus contributing to China's brain drain, and the enlargement of the Chinese scientific diaspora in the United States.[1] As of 2003, there were an estimated 294,800 China-born residents (excluding Taiwan) in the United States with university-level science and engineering (S&E) degrees, second to the 448,700 from India. Among the Indian population, only 43 percent of the degrees were from the United States; for the Chinese, on the other hand, the figure was approximately 72 percent. At the master's degree level, there were 115,500 China-born S&Es in contrast to 172,700 from India, with approximately 85 percent of the Chinese having received their degrees in the United States; the figure for the Indians was 62.5 percent. At the doctoral level, though, the China-born degree-holders numbered 62,500 (again, this figure excludes the estimated 12,400 Taiwan-born S&E doctorate holders) in comparison with 41,300 for the India-born, with roughly 76 percent of the doctorates received in the United States (in contrast to the 66 percent for the Indians). Of the 62,500, 74 percent were between the ages of 30 and 49, 37 percent were employed in educational institutions (with 49 percent in industry), and 30,000 had become U.S. citizens (with 17,000 of the remainder being permanent residents). (See the Appendix.)[2]

My purpose here is not to revisit the brain drain issue, which has received, and continues to receive, expert study and assessment. It is, rather, to explore the growth of research collaboration between the United States and China in light of the more general phenomenon of the expansion of international scientific cooperation that has occurred over the past twenty years, and to assess the role of common ethnic ties, facilitated by diasporic expansion, in the growth of this scientific cooperation.

Explaining International Cooperation in S&T

Much has been made in recent years of the globalization of science and technology. "Globalization," of course, must be used

1. "Stay rates" for Chinese (and Indian) recipients of U.S. doctorates in science and engineering (S&E) have remained higher than those of citizens of other countries. U.S. National Science Foundation, *Science and Engineering Indicators*, 2006, appendix 2-33.
2. U.S. National Science Foundation, *Science and Engineering Indicators, 2006*, appendix 3-18.

advisedly since modern research and technological development activities clearly remain unequally distributed around the world, with large portions of the global south excluded from them. Nevertheless, there is abundant evidence that international cooperation in science and technology (ICST) has grown dramatically over the past fifteen years, and that even countries on the periphery have not been untouched by this growth. Many governments around the world have increased expenditures on science and technology, thus contributing to the international diffusion of technical capabilities. The growth and global expansion of multinational corporations, especially those active in high-technology fields, has been a second powerful force for the diffusion of technologies, and research and innovation capabilities. And, of course, the spread of the Internet has dramatically changed the conditions under which scientific communication occurs. The case is often made, therefore, that science is becoming "de-nationalized" as research collaborations cross borders with increasing ease.

One consequence of these developments has been the remarkable increase in research collaboration, as seen in the growth of international coauthorship of professional publications.[3] As seen in *Figure 1*, coauthorship has increased in all scientifically active regions of the world over the past two decades (with China being a special case).[4] A variety of hypotheses have been offered to explain this growth in international collaboration.[5]

According to "center-periphery" arguments, modern scientific development has been characterized by shifting "centers of

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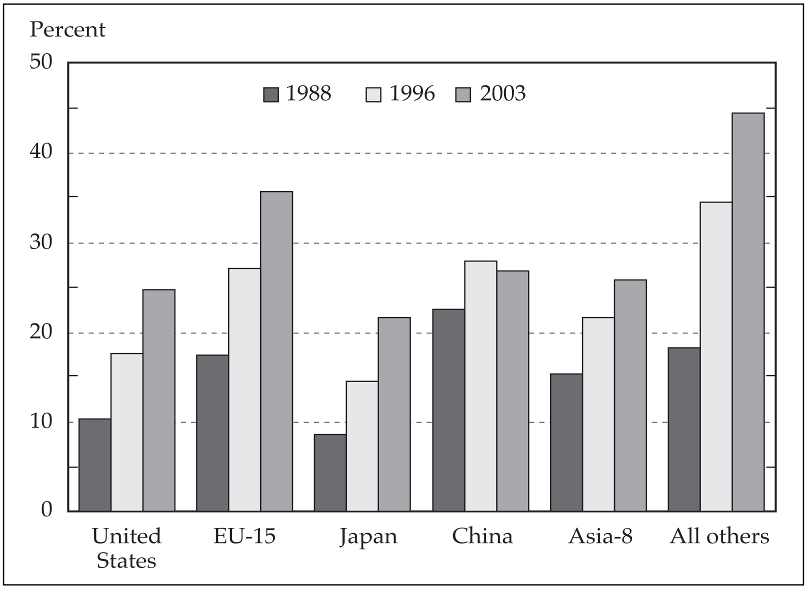
3. Coauthorship, of course, is not the only measure of collaboration, but it is relatively accessible through data collected and archived by the Institute for Scientific Information (ISI) in Philadelphia and other such organizations.
4. As discussed further below, the number of internationally coauthored papers from China continues to increase, but the number of Chinese papers in SCI journals without international coauthoring has increased more rapidly.
5. These are reviewed in Caroline Wagner and Loet Leydesdorff, "Network Structure, Self-Organization and the Growth of International Collaboration in Science," *Research Policy*, vol. 34 (2005), pp. 1608-18. See also Wagner and Leydesdorff, "Mapping the Network of Global Science: Comparing International Co-authorships from 1990 to 2000," *International Journal of Technology and Globalization*, vol. 1, No. 2 (2005), pp. 185-208, and National Science Foundation, *Science and Engineering Indicators, 2004*, chap, 5.

Figure 1. Share of Scientific and Technical Articles with International Coauthorship, by Country/Region: 1988, 1996, and 2003



EU = European Union

Note: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

Source: National Science Board, *Science and Engineering Indicators 2006*.

science," with countries on the periphery seeking to cooperate with, and learn from, the centers. In the process, capabilities diffuse to the periphery and collaboration increases, largely as a function of processes internal to science. A variant of that view focuses more on public and private policy decisions to enhance scientific and technological capabilities through significant increases in support for research and development and advanced education. This might be termed the "S&T for Development" thesis, which emphasizes the building of national scientific and technological capabilities through investment strategies that include the active encouragement of international scientific cooperation.

A third, "specialization" thesis, focuses on the differentiation of scientific disciplines and the need to bring together complementary specialized knowledge for scientific progress. The specialization thesis recognizes considerable cross-field variation. A special application of this hypothesis would be the mobilization of different specializations in support of megascience projects. Finally, some explanations have emphasized various extra-scientific factors promoting collaboration. These could be based on history (for instance, colonial legacies), geographic propinquity, or convenience. The growth of information and telecommunications technologies to facilitate interactions also falls within this category, as would the growth of international trade and investment.

In spite of the *prima facie* plausibility of these explanations, and evidence in their support in some circumstances, Caroline Wagner and Loet Leydesdorff have argued that a better explanation for the growth of ICST is to be found in theories of self-organizing systems. In their work, international collaborative networks expand through processes of "preferential attachment," either by adding new members to a network or by adding more links among existing members. Borrowing from the literature on scientific collaboration, Wagner and Leydesdorff suggest that we can think of the international scientific community as populated by four types of scientists: "terminants" (those at the end of their careers), "newcomers," "transients" (those coming into one field from another, typically on a short-term basis with typically only one publication resulting from collaboration), and "continuants" (the most active publishing scientists).[6] According to Wagner and Leydesdorff:

> In network terms, . . . continuants play a role as "hubs" to which others connect. A large number of members within the network are competing for reputation and reward in terms of international coauthorship relations using the mechanism of preferential attachment. However, some become so well-connected that they no longer compete for reputation, rather they compete to build networks of intellectual followers of the next generation . . .

They go on to note that,

> Hubs dominate the structure of the networks in which they are

6. Wagner and Leydesdorff, "Network Structure," p. 1615.

> present, and they play a specific structuring role. Theory suggests that within networks, actors display preferential attachment: when choosing between two possible links, they will seek to connect to the more connected member. In other words, when someone is seeking a collaborator, they will seek someone who's already highly connected . . .

Thus:

> The more senior (or reputed) members of a group hold privileged social and technical information. . . . Newcomers and transients seek access to this information as well as recognition within their field. As a result, the continuants (and perhaps the terminants) acting as hubs within their scientific networks, are attractive collaborators. The sought after partner, in turn, can choose carefully among the many opportunities to collaborate. As Melin (2000) found, senior researchers work with junior people to gain higher productivity and credibility within their field. The costs of collaboration are borne by the newcomers and transients who potentially gain greater visibility by working with a well-known person. . . . This would suggest that in certain fields, there may be a different pattern of preferential attachment for junior and senior scientists respectively. . . . In general, the continuants and terminants act as gatekeepers to newer entrants into the network, creating a social dynamic within the network . . .[7]

The Wagner and Leydesdorff thesis is an intriguing one in a variety of ways. It returns to strong traditions in the sociology of science, which emphasizes reputation building through peer recognition as a powerful motivation in science, and the strong forces of relatively autonomous community building through self organization. It is a view that treats science as a quasi-market system built around agent-like individuals. It also has interesting policy implications that are not entirely consistent with the kinds of structured, programmatic initiatives in support of international cooperation that one finds in varying degrees in the more scientifically active countries.[8] In the Wagner-Leydesdorff view, the best explanation for the growth of international

7. Wagner and Leydesdorff, "Network Structure," p. 8.
8. Caroline Wagner, "International Collaboration in Science: A New Dynamic for Knowledge Creation," Ph.D. dissertation, School of Communications Research, University of Amsterdam (2004).

collaboration is found in the growth of a network of scientists which is truly international and which rests uneasily with ideas of *national* science and technology policies or *national* systems of innovation.

However, the thesis also raises a number of questions about the nature of the actors in the network and on the processes facilitating or inhibiting network formation and growth. In particular, one wonders about the size and distribution of the transaction costs faced by members of the network and how these affect the "market failures" (i.e., failures of expected collaboration) in this quasi-market system.[9] This, in turn, raises questions about the means available to network members, or prospective members, for overcoming transaction costs and market failures, questions that inevitably take us back to government policies in support of collaboration. We should also note that although Wagner and Leydesdorff do disaggregate their analysis to regional networks of collaboration, their approach is one of aggregate data analysis, which is insensitive to the particularities of individual cases of collaboration. For our purposes here, this includes cases of collaboration involving co-ethnic scientists in diasporic communities, as one finds in the China-U.S. experience (and, of course, in the India-U.S. case as well).

Thus, while the Wagner-Leydesdorff thesis offers an appealing motivational theory for international collaboration, it does not fully address the fact that network formation is not costless. Accounting for those costs is necessary to support the plausibility of the motivational theory. Government interventions (and

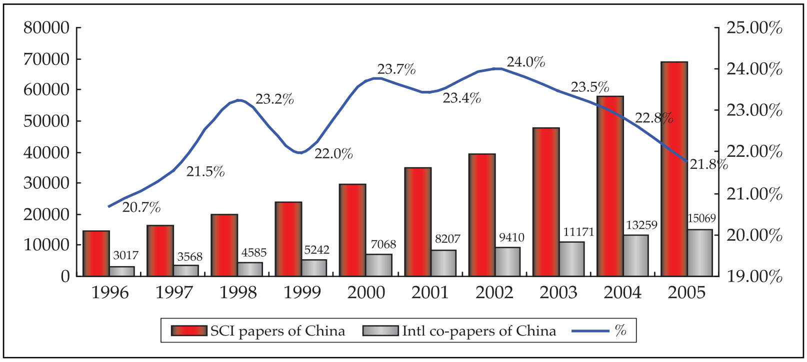
9. Market failure problems are often behind active government policies in support of scientific research, classically with regard to basic research. In developing countries, government support for R&D more generally—in addition to basic research—is often justified by the belief that markets cannot be counted on to generate scientific and technological capabilities at an appropriate level. Debates in China today about the proper role of government in promoting science and technology turn very much on this issue, with Chinese economists sometimes questioning the wisdom of many government science initiatives, while representatives of the technical community push the need for ever more ambitious national science and technology programs, including the active promotion of international scientific and technological cooperation, as discussed further below.

policy interventions from private organizations as well) clearly would represent one approach to the management of costs, but so would the exploitation of common identities built around shared language and cultural traditions. Let us explore the relative importance of these factors in greater detail.

Patterns of Chinese Coauthorship and Cooperation with the United States

In keeping with international trends, Chinese international coauthorship has also increased substantially in recent years. As seen in *Figure 2*, internationally coauthored papers involving China-based researchers increased from 1,860 in 1991 to 15,069 in 2005.[10] At the same time, given the rapid rise in the number of Chinese papers in the international science and engineering literature, the percentage of internationally coauthored papers has actually declined somewhat after rising between 1996 and 2002.

Figure 2. Patterns of Chinese International Co-Authoring, 1996-2005



As *Figure 3* indicates, Chinese coauthoring with colleagues in the United States notably exceeds coauthoring with researchers

10. All data on Chinese coauthoring, unless otherwise noted, are based on unpublished analyses performed by Jin Bihui et al. of the Library of the Chinese Academy of Sciences. I am grateful to Professor Jin for sharing this data with me.

Figure 3. China's Top 5 Co-Authoring Partners, 1996-2005

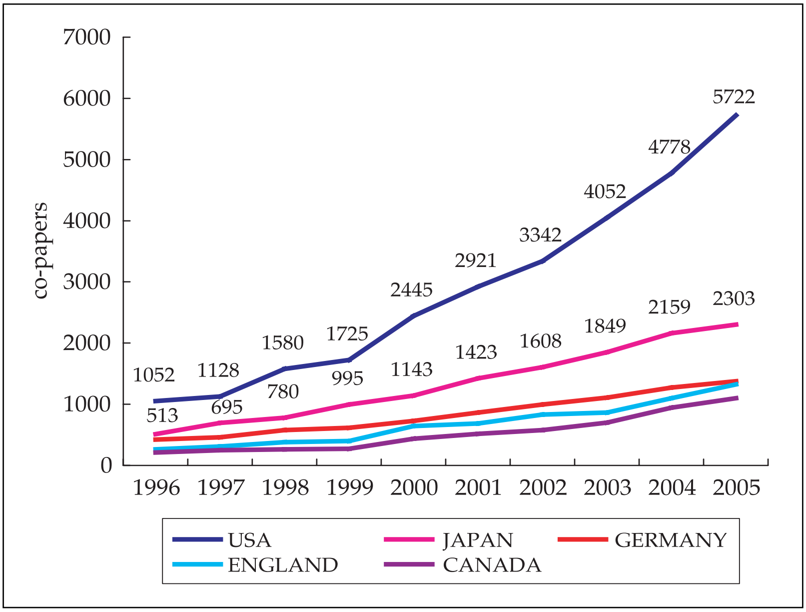
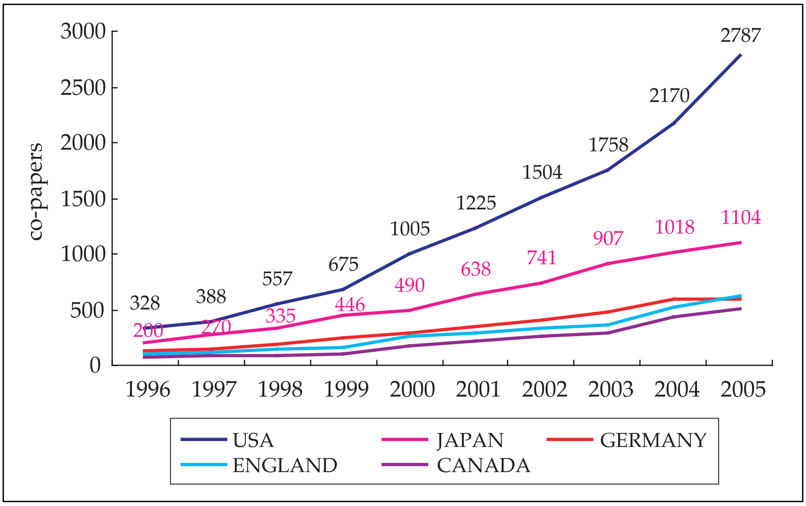


Figure 4. China's Top 5 Co-Authoring Partners, 1996-2005;
Chinese First Authors



in other countries. This is true in cases where the China-based scientist was the first author as well (see *Figure 4*).

Jin Bihui and her colleagues at the Library of the Chinese Academy of Sciences recently studied Chinese international cooperation in four fields in depth and have discovered that the strength of the ties with the United States—and of the United States with China—has deepened in all four (chemistry, nano-science, genetics, and cell biology) even as the number of countries with which significant cooperation occurs has expanded.

In 1996, for instance, the United States had only sixteen coauthored papers with China in nano-science but had eighty-six with Germany, sixty-five with Japan, and forty-three with Russia. By 2005, however, the U.S.-China number had grown to 293, which surpassed 269 with Germany, 202 with Japan, and 195 with South Korea (which took over third place from Russia). In 1996, the sixteen papers with U.S. authors represented the second most active link for Chinese scientists after the twenty-one with Japan. Germany was third with eleven papers. By 2005, however, cooperation with the United States dominated Chinese international coauthoring in nano-science; that year, the number increased to 293, with Japan a distant second with 129 papers, and Germany again third with 88.

Of particular interest in *Figures 3* and *4*, and in the more in-depth analyses of the four fields, is the rapid rise in China-U.S. coauthoring after 2000, a time when official China-U.S. relations were sometimes tense, when the Chinese government was encouraging expanded scientific cooperation with Europe and other countries, and after 9/11, when new U.S. visa requirements introduced new complications in China-U.S. cooperation.

How do we explain this striking growth in China-U.S. collaboration even in the face of increasing political complexities? How does the China-U.S. case fit with explanations for the growth of ICST more generally?

Public Policy and State Interventions

Most western interpretations of the development of China-U.S. S&T relations call attention to the seemingly critical initiatives of the two governments in both the pre-normalization, post-Shanghai Communiqué era (1972-1978), and in the post normalization period (after 1979) in providing for the development of collaborative ties.[11] On the other hand, there has long been a skeptical, somewhat libertarian, interpretation with regard to the diplomatic framework for the collaboration, and more specifically for the active government-to-government programs. In this view, once the political *obstacles* to collaboration were removed through the normalization of diplomatic relations, it was possible for researchers in the two countries to find their common interests and allow collaboration to develop on the basis of these interests—a view that accords with the Wagner-Leydesdorff perspective. An active government role in promoting collaboration through political agreements, and expenditures in support of those agreements, is seen in this view as a less than efficient utilization of resources and would be inconsistent with the dynamic processes of science.

The U.S. government has sought to find equilibrium between active programmatic support for the relationship with China and a far more laissez-faire approach to scientific collaboration. Since the signing of the S&T Agreement there has long been dissatisfaction in some quarters (including among Chinese government officials and scientific partners from China) that, on the U.S. side, the relationship is underfunded and lacking in strategic vision and effective central coordination; market failures were keeping the activities at a suboptimal level with reference to the social benefits that would accrue from more active government intervention.

With few exceptions, however, from administration to administration the United States has taken the position that the technical agencies had to assess their interest in collaboration with China and then find the resources to support that collaboration. This has resulted in the application of "hard budget" constraints on most activities; collaboration with China would be supported if it served the technical mission of the agency and the science sup-

11. Of course, in the development of the Sino-American scientific relationship following the 1972 Nixon visit, a critical role was played by the Committee for Scholarly Communication with the People's Republic of China (CSCPRC), a nongovernmental organization representing the U.S. scholarly community, and by the nominally nongovernmental China Association for Science and Technology (CAST). Both organizations, however, were closely linked to government policy.

porting that mission.[12] Ultimately, this tended to drive collaborative decision making to heavier reliance on the scientific merit of proposed activities.[13]

On the Chinese side, on the other hand, the approach has been different—partly, one suspects, because of its relative economic and scientific underdevelopment, but also because of strong (pre- and post-1949) traditions of state control and direction of knowledge. Chinese science, we should recall, had been terribly disrupted by the Cultural Revolution at the time that active collaborative activities with the United States began in the 1970s. As various students of China-U.S. relations have noted, one of the appeals of normalization of relations with the United States in 1979 was to gain access to the American system of science as well as to American technology.[14]

From the beginning, therefore, the state took an active role in planning and coordinating collaborative activities with the United States. These activities were included in formal plans, resources were set aside to fund them, and a cadre of administrators was recruited to manage the relationship. Over time, the strategic importance of this relationship became increasingly refined, with increasingly clearer formulations of strategic objectives and increasingly sophisticated mechanisms for incorporating scientific judgments, all in the hands of seasoned adminis-

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12. Historically, the most notable exception has been the Department of Agriculture, which has international outreach as part of its defined institutional mission.
13. But it may also have led to missed opportunities. In recent years, China's S&T cooperation with Europe has had a different cast, being far more structured and directed by governments. It remains to be seen which approach is more productive over the longer term.
14. But Chinese appreciation for the importance of science in its international relations, and of international scientific cooperation for Chinese interests, goes back before the Cultural Revolution. Wang Zuoyue, for instance, calls attention to a talk given by then Premier Zhou Enlai to Chinese diplomats in 1966 in which they were instructed to "learn enough science and technology to be able to coordinate the process of absorbing scientific and technological information from the countries where they were stationed." See Wang Zuoyue, "U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond," *Historical Studies in the Physical and Biological Sciences*, vol. 30, Part 1 (Fall, 1999), pp. 249-77.

trators who had "worked the issues" with the United States for many years. In the United States, of course, administrative leadership for the relationship has changed with the political cycles resulting from elections and from normal career rotations in the State Department.[15] For better or worse, however, the government-to-government framework has persisted and has had some achievements. Nevertheless, as the data on coauthored papers clearly indicates, there is a vast realm of collaborative activity among China-based and U.S.-based scientists outside of direct governmental purview.

This brief administrative overview suggests that one cannot understand the development of China-U.S. scientific cooperation, including the growing coauthorship, without paying attention to the role of government. There is considerable room for debate, however, as to the nature and effectiveness of government initiated activities in comparison with the more self-organizing activities of members of the scientific communities themselves.

Ethnicity and Identity in the Relationship

The Crucial Place of Ethnicity in Collaboration

Conceptually, somewhere between the idea of a self-organizing system and government planned and coordinated collaboration, there is room for common identities in energizing international cooperation in science. And, empirically, it is not difficult to miss the fact that Chinese ethnicity has been, and continues to be, an important factor in the development of collaboration. C. N. Yang (Yang Chenning), T. D. Lee (Li Congdao), and other American scientists of Chinese descent played important roles in the early years of reestablishing scientific contacts and in making those contacts serve the process of reestablishing diplomatic ties.[16] The CUSPEA (China-U.S. Physics Examination and Application)

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15. Although one sees some continuity in the staffs of the technical agencies themselves, at the policy level U.S. programs with China are directed by the White House Office of Science and Technology Policy and by the Bureau of Oceans, International Environmental, and Scientific Affairs at the Department of State.
16. Wang, "U.S.-China Scientific Exchange."

program, started by T. D. Lee, which brought almost 1,000 of China's best physics students to the United States for graduate training during the course of its existence, was a highly visible effort at building cooperation. It was by no means the only initiative from ethnic Chinese scientists in the United States, however, to help train a new generation of scientists from China and lay the foundation for future cooperation. Early on, ethnic Chinese in the technical agencies of the U.S. government were recruited to help manage the developing relationship and bridge civilizational differences. U.S. corporations brought—and continue to bring—their ethnic Chinese scientists and engineers into important roles for opening up business contacts with China.

Co-ethnic professional societies, whose numbers have grown over the past twenty-five years, have also played an important role in developing China-U.S. cooperation. For example, the Society of Chinese Bioscientists in America (SCBA), founded in 1984, now has thirty local chapters in the United States, Canada, Hong Kong, Singapore, Taiwan (Taipei and Tainan), and China (Shanghai and Beijing). At its tenth international conference in Beijing, co-hosted with the Chinese Academy of Sciences (CAS) and the Ministry of Science and Technology (MOST), topics ranged from reports on cutting edge basic research to new trends in the biotechnology industry, to the "how-to's" for applying and being accepted into U.S. graduate programs. A review of the SCBA website shows a remarkable membership of researchers in Chinese communities on both sides of the Pacific.[17]

In spite of its evident importance, systematic study of Chinese co-ethnic scientific and technological cooperation is only beginning.[18] The following discussion represents a preliminary

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17. See www.scba-society.org.
18. There are exceptions. AnnaLee Saxenian's important work has called attention to the importance of co-ethnic ties in building communities of industrial technologists, and recent work using patent data by William Kerr has shown the importance of co-ethnic technical communities for the spread of tacit knowledge in the processes of technological diffusion. See William Kerr, "Ethnic Scientific Communities and International Technology Diffusion," unpublished paper, online at http://pine.hbs.edu/external/facPersonalShow.do?pid=337265. See also Xiang Biao, "Promoting Knowledge Exchange Through Diaspora Networks (The Case of the People's Republic of China)," Report to the Asian Develop-

approach to analyzing this phenomenon by looking at patterns of coauthorship between ethnic Chinese researchers in the United States and those in China. The data is drawn from the Web of Science maintained by the Thompson Institute for Scientific Information on a subscription basis. The database includes publications from most of the world's major professional journals from 1975 to 2004. Searches conducted solely by the addresses of the authors (e.g., "China," "USA") yield 36,674 records of internationally coauthored articles during this period (36,285 in English), again indicating that there has been a fairly robust pattern of coauthoring going on between China and the United States.[19]

Unfortunately, it is not possible, electronically, to determine from this population how many coauthorships are co-ethnic, and a manual review of the total number of records would be impractical. It was therefore decided to choose a series of fairly narrow subfield designations, based upon a subjective sense of subjects that are "hot," and search the database using both the "subject" entries and "addresses." The subfield designations included "grid computing," "thin film materials," "bioinformatics," "ceramics," "superconductivity," and "condensed matter."[20] The number of records returned is shown in *Figure 5*.

From the coauthorship records identified, a manual search was conducted matching Chinese surnames with Chinese addresses and Chinese surnames with U.S. addresses. While the results vary

ment Bank, ESRC Centre on Migration, Policy and Society (COMPAS), University of Oxford, March, 2005. For a recent treatment of the Indian case, see Ajay Agrawal, Devesh Kapur, and John McHale, "Birds of a Feather, Better Together? Exploring the Optimal Spatial Distribution of Ethnic Inventors," National Bureau of Economic Research Working Paper No. 12823, online at www.nber.org/papers/w12823.

19. Searches were limited to published articles only, not notes, proceedings, and others forms of published communication. This total can be compared with the total of 32,857 papers identified by Jin Bihui and her colleagues for 1991-2005.

20. It should be noted that the use of the subject designations will not exhaust the possibilities for collaboration in these fields. For instance, there may be more work going on in the area of bioinformatics than is captured by searching by that category. Thus, if one wanted a comprehensive view of China-U.S. coauthoring in bioinformatics, a different search strategy would be required. My purpose, however, was to generate a small population that could be analyzed in a nonelectronic fashion.

Figure 5. Co-Ethnicity in Chinese Publication Activity in Selected Fields

	All languages	In English	U.S.-Coauthor	Co-ethnic	% Co-ethnic
GridComp	129	129	2	1	50.00%
Thin Film	23	17	0		ERR
Bioinfo	207	164	39	36	92.31%
Ceramics	1073	923	155	106	68.39%
Supercom	1920	1853	179	137	76.54%
Con Matt	74	65	10	8	80.00%

with subfield, the strength of the co-ethnic common identity is evident. For instance, for the new field of "bioinformatics," thirty-six of the thirty-nine records considered were co-ethnic publications. The records which were not co-ethnic were publications resulting from multilateral cooperation from a number of countries, with a non-Chinese identified as "reprint author."[21]

Web of Science allows for some additional analysis of the data, including the frequency of author names, institutional affiliations, and years of publications in five-year increments. In the bioinformatics case, two authors ("continuants"?) accounted for approximately 50 percent of the coauthoring, and over the five-year period during which bioinformatics emerged as a field, they had multiple affiliations: the Gordon Life Science Institute in San Diego, the Chinese Academy of Sciences, the Shanghai Center for Bioinformatics Technology, the Tianjin Institute for Bioinformatics and Drug Discovery, the University of Manchester, and a private U.S. company.

The "condensed matter" designation also led to a manageable population of records. Again, we see co-ethnic collaboration as a dominant feature in coauthorship. In the ten records reviewed, only three had non-Chinese authors; in one case the non-Chinese was in Canada, and in one case, Poland. The one U.S.-based non-Chinese was the reprint author, with the coauthors being one China-based Chinese and one U.S.-based non-Chinese. Although the sample is small, we can again see one or two individuals being well represented.

In the case of ceramics and superconductivity, we have

21. In most cases, but not all, the reprint author was also the first author.

somewhat larger populations, but the strong co-ethnic pattern is still evident. Of 179 superconductivity records, 137 had ethnic Chinese reprint authors and at least one ethnic Chinese coauthor. In this field, an ethnic Chinese, C. W. Chu, has been an international leader in the field and, not surprisingly, he is listed as a coauthor on forty of the papers. Until becoming president of the Hong Kong University of Science and Technology (HKUST), Chu had been at the University of Houston, which shows up as the leading address (n=42) for work in this field (followed by CAS, with thirty-seven records, and HKUST with twenty). Many of the other frequently appearing authors, ethnic Chinese and non-Chinese, are associated with the Houston and HKUST groups.

The Changing Research Environment in China

These findings, however preliminary, point to the strength of co-ethnicity as a factor in collaboration and suggest that issues of identity warrant more attention in discussions of ICST. If one subscribes to social constructionist views of ethnicity, however, it is also necessary to probe more deeply into the social settings in which identity is constructed and comes to shape international collaborations. This is especially true with regard to Chinese science, given the sizable numbers of ethnic Chinese in the U.S. technical community and the significant changes that have occurred in the Chinese research environment over the past fifteen years.

With regard to the latter, we have seen major reforms in the Chinese research system and the infusion of financial resources to support scientific development. The combination of these two factors has made the Chinese research environment exceedingly competitive and has put a premium on publication-based success measures. The awarding of advanced degrees, promotions and salary increases, and success in competition for research funding have all been linked to publication in SCI journals. The rapid growth of Chinese-authored papers in the international technical literature noted above is in part a reflection of the incentive structure at work in China as well as a measure of increased Chinese research productivity. The strong emphasis placed upon publication is also thought to contribute to the problems of Chinese research misconduct that have attracted international attention in the last few years.

The emphasis placed upon building a successful publication record in China may help explain the growth of Chinese internationally-coauthored papers, especially when the impact factors of the papers is considered. In keeping with the logic of the Wagner-Leydesdorff thesis, it would be reasonable for Chinese scientists to seek to build collaborative relationships with scientists abroad who, as coauthors, could facilitate the successful placement of papers in prestigious international journals. When impact factors are introduced, the value of international coauthoring may increase.

For instance, Robert Kostoff has shown in a recent study that international coauthoring can have a major positive effect on the citation rates of papers by Chinese authors.[22] In the Wagner-Leydesdorff scheme, Chinese scientists thus might be thought of as seeking "preferential attachments" with "continuants," those at the hubs of professional networks, to enhance both the prospect of publications in prestigious journals and to enhance the impact factors of their publications. As the quality of research in China improves, the number of China-based continuants is likely to increase; the notable increase in first authorship seen in *Figure 4*, for instance, would support this view. At the same time, as China-born scientists in the United States establish careers and reputations there, they are becoming a larger proportion of the continuants working in the United States (the data on the age structure of China-born doctorate holders in the Appendix indirectly supports this view).

Thus, if co-ethnic coauthoring is as prevalent as our preliminary analysis suggests, we may be seeing the interactive effects of self-organization and ethnicity, i.e., the emergence of an ethnically-based transnational technical community in which common identities facilitate self-organization. The early cohorts of U.S.-based ethnic Chinese have moved from graduate students to established "continuant" scientists who become the targets of "preferential attachment" of Chinese scientists working in China, who face a demanding reward structure emphasizing SCI publications and high impact factors. On the other hand, Chinese research in China

22. Kostoff et al., "The Structure and Infrastructure of Chinese Science and Technology," *DTIC Technical Report*, No. ADA 443315 (2006), online at www.dtic.mil/.

is maturing and producing both domestically-trained research leaders and an increasing number of foreign-trained researchers who have returned to China; they are gradually establishing themselves as hubs in international research networks, but ones which seem to be facilitated by common ethnic ties.[23]

The analysis above suggests that in the China-U.S. case of international scientific cooperation, ethnic ties play a very important role in facilitating cooperation. At the same time, such ties are influenced by the contingencies of the research environments in the two countries. This suggests that notions of "international," "transnational," and "national" science and technology require reconsideration.

Ethnicity, Identity, and the Play of Nationalism(s)

A useful place to start might be in reviewing recent writings about "techno-nationalism" and "Chinese nationalism." Sandro Montresor has suggested in a recent paper exploring the relationships between nationalism and science and technology that it is important to distinguish between state-oriented conceptions of nationalism and those that focus more on ideas of common identity. In his discussion of techno-nationalism, for instance, he argues that in its conventional usage, distinctions between "nation" and "state" often are blurred, such that the concept may obscure as much as it clarifies. He therefore proposes a definition that distinguishes between what he calls "techno-statism" and "techno-nationality."[24] The former encompasses the state's control over the spatial dimensions of innovation systems (referred to as "techno-territoriality"), the nature and extent of the state's

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23. In some cases, returnees who networked successfully with continuants while abroad may find that the challenges of establishing professional identities in China, through the initiation of new lines of research, make it *less* desirable to collaborate with overseas continuants. This, in turn, may be a factor in the declining share of internationally coauthored papers from China noted above. I am grateful to Shi Bing of the Evaluation Research Center of the Chinese Academy of Sciences for this observation.
24. Sandro Montresor, "Techno-Globalism, Techno-Nationalism and Technological Systems: Organizing the Evidence," *Technovation*, vol. 21 (2001), pp. 399-412.

control over governance structures for technology-related policymaking and implementation ("techno-sovereignty"), and the nature of obligations and accountability regarding research and innovation ("techno-citizenship").

Though linguistically awkward, the concept of "techno-nationality," on the other hand, calls attention to the relevance of ethnicity, language, and the grounds for "socio-culture sharing" in the development of technologies. It is also a particularly suggestive term for thinking about the kinds of diasporic technical communities that we are considering here, those transcending the political jurisdictions of the state, but which are nevertheless socially integrated—at least to some extent—by common ethnic and cultural ties.

Recent writings about nationalism in China have also pointed to such distinctions. William Callahan, for instance, by identifying four different possible usages, calls attention to the ambiguous nature of the concept of "Chinese nationalism" as it is used in various narrative circumstances. He sees, first, a "nativist" manifestation of "China" as *Zhongguo*, where China is treated as a threatened territorial entity needing protection from a hostile outside environment. This can be distinguished from a second "conquest" narrative, linked more to China as a strong empire (*da Zhongguo*) that has experienced "a century of humiliation" and is now reclaiming its rightful place in the world, especially in East Asia. A third expression—*da Zhonghua*—focuses more on ethnicity and culture. For Callahan, this "conversion" narrative refers to a self-confident China dealing with its environment through civilizational power; nationalism here is less associated with territorial protection or integrity and more with a variety of exchange relationships with the outside world that extend the values of Chinese civilization to the international environment. Finally, there is the nationalism of the Chinese diaspora in which a core of Chinese identity helps structure and is maintained in complex transnational relations in which diverse civilizational elements are flexibly mixed together.[25]

All four elements can be found in the China-U.S. scientific cooperation experience generally, and in the co-ethnic coauthor-

25. William A. Callahan, "Nationalism, Civilization and Transnational Relations: The Discourse of Greater China," *Journal of Contemporary China*, vol. 14, No. 43 (May, 2005), pp. 79-99.

ing phenomenon more specifically, although the fourth diasporic expression (oriented to transnational Chinese civilization) is perhaps the most widely accepted. As seen in the activities of organizations such as the SCBA and other transnational professional associations, for instance, membership organizations with bases in different political jurisdictions and members with different citizenship come together around "a core of Chinese identity." The 2004 SCBA meeting in Beijing was not, seemingly, celebrating Chinese bioscience but rather a more universalistic cultural practice, albeit one with both Chinese- and U.S.-inspired "civilizational elements" (among these, the "how to get into U.S. graduate schools" conference panels!).

On the other hand, the cosponsorship of this particular event by a Chinese state that has often linked scientific and technological development to the ideas of "a threatened territorial entity needing protection from a hostile outside environment" (the nativist narrative) and, more recently, to a political entity "which has experienced 'a century of humiliation' and 'is now reclaiming its rightful place in the world'" points to a "scientific statism" at work in the cultivation of international collaboration. This is occurring even as many of the researchers who are partners in collaboration might wish to distance themselves from state focused scientific and technological nationalism of this sort.[26]

Callahan's "conversion" narrative of *da Zhonghua* ("in which a self-confident China" deals with a potentially hostile environment "through it civilizational power") is one which is also inclusive of the state and non-state actors involved in co-ethnic international scientific cooperation. The appeals of *da Zhonghua* undoubtedly also include the possibility of reconciling ideas of the universalism of modern science with universalistic beliefs associated with Chinese cultural nationalism, thus resolving one of the cultural dilemmas of modern Chinese history, i.e., the perceived antipathy of modern science and Chinese culture.[27]

The *da Zhonghua* narrative may also play a special role in the

26. For a good discussion of the importance of state initiatives in promoting scientific cooperation through diasporic networks, see Xiang, "Promoting Knowledge Exchange through Diaspora Networks."
27. Suisheng Zhao, *A Nation-State by Construction* (Stanford, Calif.: Stanford University Press, 2004).

United States. As Wang Zuoyue has noted, the growth of scientific ties between China and the United States in the post-Shanghai communique era coincided with the growth of collective identity and activism within the ethnic Chinese community in the United States. Chinese-American scientists played important roles in the development of that relationship, as noted above, but the rising profile of China and Chinese science in the United States also tended to reinforce a sense of confidence about ethnic identity within the Chinese community in the United States.[28]

On the other hand, awareness of the *da Zhonghua* narrative outside the Chinese community in the United States may also fuel concerns—many of which carry the scent of racism—that co-ethnic ties supporting scientific and technological cooperation with China may be aiding the development of Chinese national power to the detriment of U.S. power. The Wen Ho Lee case readily comes to mind.[29] While these concerns have been more in areas of strategic high technology rather than in scientific research, as the relationships between science and high technology become ever more intimate, the more specific concerns for "technology leakage," especially through espionage, have evolved into a more generalized set of concerns which, as we know, have led to more restrictive immigration practices and the extension of an export controls mentality into university laboratories.[30]

Conclusion

The discussion above leads to two seemingly disparate con-

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28. Wang, "U.S.-China Scientific Exchange" and "Chinese American Scientists and U.S.-China Scientific Relations: From Richard Nixon to Wen Ho Lee," in Peter H. Koehn and Xiao-huang Yin, eds., *The Expanding Roles of Chinese Americans in U.S.-China Relations: Transnational Networks and Trans-Pacific Interactions* (New York: M. E. Sharpe, 2002), pp. 207-334.
29. Ibid.
30. See Commission on Scientific Communication and National Security, "Security Controls on the Access of Foreign Scientists and Engineers to the United States," Homeland Security Program, Center for Strategic and International Studies, October, 2005; Committee on Policy Implications of International Graduate Students and Postdoctoral Scholars in United States, *Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States* (Washington, D.C.: National Academies Press, 2005).

clusions. With reference to the conditions under which international cooperation in scientific research occurs, a preliminary conclusion is that the argument in favor of self-organizing systems is a bit too simple; it seems highly unlikely that the patterns of co-ethnic coauthoring we see would result solely from the mechanisms that Wagner and Leydesdorff identify. That said, however, it also seems that some form of "preferential attachment" is at work, and that ethnic-Chinese with both United States and Chinese addresses are important "continuants" in some fields of international science. It will be useful to further explore through interviews and surveys the reasons ethnic Chinese scientists collaborate the way they do.

The degree to which co-ethnicity seems to drive coauthoring also points to the need to think further about the nature and role of nationalism in international science. Here, evolving concepts of nationalism that recognize its complex and contingent nature may be useful, especially in identifying the ways in which a sense of nationality as a basis for identity may differ from nationalism as the basis for political organization and state coherence. The China-U.S. case illustrates very nicely the ways in which shared identity bolsters international cooperation. At the same time, the complex, crosscutting nature of nationalism can also lead to perceptions of co-ethnic scientific collaboration supporting state projects of scientific and technological nationalism in China. Such projects might, in turn, unleash forces antithetical to scientific cooperation.

The discussion above points to the messiness of transnational relations in an era of globalization. It is highly unlikely that trends toward increasing international cooperation in science will be reversed any time in the future, and there is a need for better understanding of what motivates and facilitates this important force for globalization. Our preliminary findings here are that co-ethnicity can be a very important factor in some circumstances. At the same time, the underlying ambiguities of nationalism mean that co-ethnicity as a base for scientific collaboration sits uncomfortably in a world where identity is more than citizenship, where global processes erode state prerogatives, and yet where, as a consequence, states seek to enhance their power and legitimacy by appeals to nationalist sentiments.

Appendix. Characteristics of China-born Holders S&E Doctorates, 2003

Employment	**Percentage**
Education	37
Industry	49
Government	5
Field of Degree	
Computer/Math	8
Bio, Agric., Environment	30
Physical	21
Social	6
Engineering	27
S&E Related	5
Occupation Category	
Computer/Math	18
Bio, Agric., Environment	25
Physical	11
Social	2
Engineering	18
S&E Related	8
Non-S&E Related	8
Unemployed/NILF	10
Age	
70+	2
65-69	4
60-64	6
55-59	7
50-54	5
45-49	13
40-44	25
35-39	20
30-34	16
25-29	2
Citizenship	
US	30,000
Chinese	28,000
Other	4,500
Perm Res.	17,000
Temp.	13,000

Source: US NSF, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT)

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