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Environmental Sustainability and Economic Development

——Transferring Energy Efficient and Clean Emissions Technology from Japan to China——

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Global warming is the most pressing issue of our day, next to nuclear arms control. Global warming—caused by excessive greenhouse gas emissions (*GHEs*) —may well be our doom, less dramatic than a nuclear cataclysm, but equally disastrous nonetheless. 5% of global GDP will be lost annually and forever as early as 2035, according to the most comprehensive study of the problem (*Stern Review,* ix).

Moreover, unless carbon emission levels can be stabilized at or below 550 ppm in the next 10-20 years, annual global GDP losses due to global warming will increase to 20% or more. Stabilization at 450 ppm emissions is already almost out of reach (*Stern Review,* xv). In addition, the costs associated with stabilization will increase steadily because marginal damages rise with the stock of GHEs, which is rising constantly. Abatement efforts need to intensify over time.

Mitigation and adaptation are the two means to arrest global warming. Proposed mitigation methods, like carbon sequestration, however, are unproven and alternative energy regimes are as yet far-fetched.

For now, adaptation alone can harness climatic reversal. Adaptation includes emissions trading schemes, innovations, such as new crop varieties, reducing deforestation, and technology cooperation.

For two reasons, technology cooperation is the most interesting. First, the International Energy Agency (*IEA*) believes that energy, efficiency will be the single biggest source of emissions savings, generating both economic and environmental benefits (*Stern Review,* xiii). The most significant savings will occur in energy generation and transmission where 24% of energy losses occur, and in industry and transport, each accounting for 18%. The IEA further points out that Japan is the only economic power that has increased research spending on energy efficiency in recent decades.

Second, Japanese industrial firms are the most efficient and cleanest in the world (*see below*). I have spent many years trying to understand and analyze the high performance of Japan's industrial firms. Based on what I am able to learn, I want to facilitate the transfer Japan's know-how to China and the U.S., the two countries most responsible for global warming. Transfer hinges on creating favorable conditions for international collective action. In this paper and related presentation, I attempt to enumerate and examine what those favorable conditions may be.

The Problem

For every $1 of economic output, Chinese industrial firms, as compared with Japan's, produce eight times the greenhouse gas emissions at six times the cost. American firms do better, but not by much. U. S. firms produce six times the GHEs at twice the cost (*Sakamoto, 2003,* *2005*). Given the size of the U. S. and China's economies, their energy use and emissions, America and China would have to become twice as energy efficient or lower carbon emissions by fifty percent to avoid permanent damage to world economic and environmental systems.

Fortunately, the means to be twice as energy efficient and halve carbon emissions are available: set efficiency and emissions levels at Japanese standards. Unfortunately, high standards without the means to realize them will not work. Transfer of efficient, low-emission technologies, even a phased, programmatic transfer, is not simple. Numerous barriers exist, including identifying and generalizing embedded process know-how, valuing of firm-specific intellectual property, making energy and carbon credit markets, and institutionalizing industry, local, national and international government cooperation.

What We Know Country-level Issues

Differences in country of origin have been shown to be significant in terms of the consequences of foreign direct investment (*FDI*), especially with respect to energy efficiency and fossil fuel emissions. FDI from Western economies, including Japan, is not pollution haven-seeking, but FDI from Chinese origin-countries, Singapore, Taiwan, and Hong Kong, often is (*Eskeland and Harrison, 2003; Dean, Lovely, and Wang, 2003*) .

Research show that Western FDI goes to provinces and special economic zones characterized by environmental stringency, high wages, skilled labor, investment incentives, and agglomeration benefits (*Head and Ries, 1996; Fung, Iizaka, and Parker, 2002*). But Chinese origin-investment often goes to places of lower wages and environmental stringency; it is also smaller scale and more export-oriented, factors linked to inefficiency and pollution output (*Head and Ries, 1996; Cheng and Kwan, 2001; Fung, Iizaka, and Parker, 2002; Dean, Lovely, and Wang, 2003; Zhang and Markusen, 1999*).

Country-level differences, such as these, depend little if at all on government policies. Instead, they stem from where firms are headquartered, a different sort of country consequence. That government policies have not impeded flows of China-bound investment and technology transfer is advantageous to international technology transfer. However, this also suggests some likely barriers to effective collective action. Getting diverse firms and countries to agree on standards and performance targets for FDI in China may prove difficult. Aside from country-level differences, industry-and company-level differences are also important.

Industry-and Firm-level issues

The energy efficiency and low emissions technologies of which we are speaking are not really Japan's, except in an associative sense. Such technological capabilities are industry-and firm-specific and, in this sense, they grew out of Japan's economic history of late development, scare natural resources, high costs of imported energy, and associated industry structure (*Brooke, 2001*). This makes them hard-to-identify because they are wedded to particularly evolutionary pathways, hard-to-isolate because they are decentralized and idiosyncratic, and hard-to-imitate because they are part of largely tacit knowledge, know-how and knack.

Research suggests that such capabilities are rooted in three strong forms of organization and management—focal factories, strategic firms, and interfirm networks—that characterize Japan's industrial organization and constitute multiple layers of organizational embeddedness (*Abo, l994; Aoki, 1988; Aoki and Dore, 1994; Fruin, 1992, 1997; Gerlach, 1992; Taniguichi, 2006*). Focal factories are management intensive, multi-function, often multi-product, manufacturing-engineering organizations designed to shorten time to market, reduce costs, and develop new products in rapidly changing markets. The bulk of Japan's energy efficient, low emissions technologies are localized at the factory level of organization.

Strategic firms capture share in high-growth markets by tying together the resources of focal factories with the production and distribution capabilities of interfirm networks. Interfirm networks are decentralized organizations where information exchange and mutually beneficial relations between nodes (*subsidiaries, affiliates and suppliers*) lead to complex adaptive routines, such as innovation in production and distribution capabilities (*Aoki and Dore, 1996; Gerlach, 1992; Fruin, 2007*).

In sum, the technological capabilities of Japan's firms are based on country-specific models of industrial organization and industry-leading best practices; some of these are:

(1) High levels of managerial and technical talent concentrated in factories,

(2) High levels of factory performance in terms of quality assurance, manpower training, and total productivity improvement,

(3) Firms that are adept at connecting and coordinating the activities of focal factories and interfirm networks,

(4) Networks of subsidiaries and affiliates to carry out Production

and distribution activities, facilitating technology diffusion, information exchange, and stimulating innovation,

(5) Subsidiaries and affiliates that deploy the most advanced technologies and organizational practices possible because their profitability depends on doing so.

The most important barriers to the transfer of energy efficient, low emission technologies from Japan to U. S., China, and the rest of the world are their origin and evolution in the crucible of Japan's economic development. In effect, such capabilities are part of the deep structure of Japanese industrial organization expressed in firm functions, boundaries and linkages to other firms.

Autos and Electronics as Exemplars

Firms in the motor vehicle and electronics industries are widely studied as the industries are characterized by global competition and the volume and frequency of FDI in these industries are significant. Japanese firms have performed well on an international basis in these industries although their record in terms of energy efficiency and pollution abatement in these industries has not been the main thrust of research to date (*Lieberman and Dhaman, 2005; Sakamoto, 2005 ; Womack, Jones, and Roos, 1990*). Research on the auto industry suggests three sources of Japan's competitiveness: operational efficiency, product development, and supplier management practices (*Womack, J. P., D. T. Jones, & D. Roos, 1990; Lieberman and Dhawan, 2005*).

Operational Efficiency

Producing more value added for less energy embodies energy saving and enhanced managerial practices. Substantial labor productivity differentials characterize GM and Toyota, the largest auto makers in the U. S. and Japan (*Lieberman and Dhawan, 2005*). On average, GM's output (*value added*) per worker was only 62% of Toyota's. GM had 13 times as many employees, but only 79% as much investment per worker. GM's plants enjoyed only one-fourth the average volume of Toyota's but maintained about 10 times more work in process inventory (*WIP*) . Internal operations represented 46% of final sales revenue for GM, but only 18% for Toyota (*Lieberman and Dhawan, 2005*).

Product Development Efficiency

According to MIT's International Motor Vehicle Research Project, Japanese companies develop products faster, cheaper, and better (*Womack, J. P., D. T. Jones, & D. Roos, 1990; Takahiro Fujimoto, 1999*). Codesign and development activities with subsidiary and affiliate firms are major reasons why. High-knowledge content, frequent interactions between core and subsidiary/affiliate firms result in autos developed quickly, with high quality, and high customer satisfaction.

Supplier Management Practices

Outsourcing to affiliates, good supplier relations, and focused use of the best available patents, technologies, and organizational practices are positively related to total factor productivity growth among small and medium-sized firms in Japan (*Nishiguchi, 1994; Urata and Kawai, 2001*). Differences in human resource practices coupled with supplier relations help explain substantial, sustained performance differences between U. S. and Japanese auto firms (*McDuffie and Helper, 1999; Helper, S. R. and M. Sako, 1995*).

Embedded Capabilities

The magnitude and persistence of these differences suggest that high-level organizational capabilities are not easily imitated, even when the bases for them are well known (*Lieberman and Dhaman, 2005; Liker et al., 1999*). This runs counter to the received wisdom, popularized by Michael Porter (*1996*) and others, that argues that operational effectiveness is not sufficient to maintain competitive advantage.

This difference of opinion hinges on the durability of high-performance organizational capabilities. Porter and like-minded scholars believe that they are imitable and, thus, not durable sources of long-term competitive advantage. Others believe that high-level capabilities are not easily copied because they are organizationally-embedded, meaning they are embodied in work-based social relations, likely to be tacit and proprietary in character (*Granovetter, 2004*).

They are embedded because they evolve through the interrelated efforts of many individuals and organizational sub-units. They persist because, once put into motion, it is easier to continue with them than to abandon them. As countless minor adaptations and incremental innovations occur, they become increasingly wedded to and expressed through social and work relations, making them tacit and, thus, hard to imitate. They differ from firm to firm because they are based on firm-specific relations, routines, and practices. Research likewise confirms that when firms like Toyota and Toshiba go abroad, such capabilities are maintained, substantiating that they are firm-based and organizationally embedded (*Fruin, 1997; Liker et al., 1999*).

What We Don't Know Transferring Embedded Capabilities

The technology transfer literature to date has not distinguished between the transfer of non-embedded and embedded capabilities, such as high performance best practices. Because embedded capabilities are anchored in work-based social relations and likely to be tacit and proprietary, they cannot be transferred easily.

Non-embedded capabilities are much easier to move overseas, and their transfer blends foreign and indigenous elements in organizations often described as hybrids. "Hybrid organizations" in such cases mean organizations that combine foreign and local practices. This approach to technology transfer was described in Abo's Hybrid Factory. However, we prefer to avoid the term "hybrid" because hybridization has particular meanings in biology. It occurs when genetic materials from two parents are combined; offspring are typically stronger than either parent, indicating that while hybrids combine parental qualities, they have unique qualities, superior to either parent (*donor*).

Hence, using the term "hybrid" is confusing. The term is used in a straightforward way, meaning "a combination" and nothing more, and in a more sophisticated way, meaning the diffusion and domination of superior traits, which is closer to the biology model. We believe that the transfer of high-level embedded capabilities is closer to the biological model, which has not been discussed widely in the literature.

Fujimoto is the exception. His work, The Evolution of a Manufacturing System at Toyota (*1999*), indicates that what Toyota does so well —operational effectiveness-developed as problem-solving capabilities with respect to particular work practices. These firm-specific capabilities, analogous to the energy efficient and pollution abatement technologies under discussion, are quintessential embedded capabilities.

By their nature, embedded capabilities cannot be transferred. They are embodied in tacit, work-related social relations. If transferred, they have to be re-created. The process for doing so involves five steps.

(1) embedded capabilities in home organizations have to be identified;
(2) processes by which embedded capabilities appeared and evolved are analyzed;
(3) embedded capabilities are removed from the social and organizational contexts in which they appeared. Typically, this involves moving both people and practices from one context to another;
(4) facilitative organizational practices and repertoires with supportive social networks are established in new contexts;
(5) new embedded work practices (*that mirror those at home*) are developed and nurtured. Home practices are templates against which new capabilities are measured but, as a rule, embedded capabilities cannot be transferred, only recreated.

What is being Transferred

In order to know if Japan's firms in the motor vehicle and electronics industries are taking their most energy efficient and environmentally friendly technologies to China or anywhere else, we need to assess:

・ is the factory-firm-interfirm network model being re-created in

China;

- which models are being made and which production processes are being implemented;
- what organization process capabilities are being created, and how are they normalized against organizational practices in Japan;
- are production volumes similar to those in Japan—scale-related issues affect the costs and methods of getting the most advanced products to markets;
- is Japanese FDI oriented towards producing goods for China or the domestic market, in which case production is more likely to conform to environmentally stringent standards, or for export (*Antweiler et al., 2001; Dean et al., 2003; Eskeland and Harrison, 2003; Zhang and Markusen, 1999*).

By focusing on one or a limited number of special economic zones (*SEZs*) in China, interprovincial differences with respect to relative factor abundance, numbers of suppliers, industry policies, and special incentives in environmental stringency are ruled out as explanatory variables (*Head and Reis, 1996; Cheng and Kwan, 2001*). Also, research suggests that development planning is more likely to succeed when local government policies and corporate commitment are integrated (*Jacobs, 2002*); this will be most easily achieved in SEZs, like the Tianjin Economic Development Area (*TEDA*).

Conclusion

Given the short time frame—one to two decades—within which effective international collective action for mitigating global warming must occur, all possible means to identify, isolate, generalize, and transfer the organizational knowledge that Japanese firms possess in terms of energy efficient and low emissions technologies is called for. Given that the transfer will take place across firm, institutional, and national boundaries, however, transfer will be difficult and transformations of organizational knowledge in new environments should be expected.

Notes

Abo, Tetsuo, 1994. Hybrid Factory, New York: Oxford University Press.

Antweiler, Werner, Brian R. Copeland, and M. Scott Taylor, 2001. "Is Free Trade Good for the Environment," American Economic Review, vol. 91, 4, 877-908.

Aoki, Masahiko, 1988. Information, Incentives, and Bargaining in the Japanese Economy, Cambridge: Cambridge University Press.

Aoki, Masahiko and Ronald Dore, 1994. The Japanese Firm――Sources of Competitive Strength, Oxford: Clarendon Press.

Brooke, James, "Japan Squeezes to Get the Most of Costly Fuel." New York Times, June 4, 2005, on-line edition.

Cheng, Leonard K. and Yum K. Kwan, 2000. "What are the Determinants of the Location of FDI? The Chinese Experience," Journal of International Economics, 51, 370-400.

Dean, Judith M., Mary E. Lovely, and Hua Wang, Dec. 2003. "Foreign Direct Investment and Pollution Havens: Evaluating the Evidence from China," unpublished paper, presented to Midwest International Economics Meetings.

Eskelalnd, Gunnar S. and Ann E. Harrison, 2003. "Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis," Journal of Development Economics, 70, 1-23.

Fruin, W. Mark, 1992. The Japanese Enterprise System――Competitive Strategies and Cooperative Structures, Oxford University Press.

Fruin, W. Mark, 1997. Knowledge Works――Managing Intellectual Capital at

Toshiba, OUP.
Fruin, W. Mark, 1998. "Smart Cards and Product Development Strategies in the Electronics Industry in Japan," IEEE Transactions on Engineering Management, 45-3 (August).
Fruin, W. Mark, 2007. "Business Groups and Interfirm Networks," in Geoff Jones and Jonathan Zeitlin, eds., The Oxford Handbook of Business History, New York and Oxford: Oxford University Press.
Fujimoto, Takahiro, 1999. The Evolution of Manufacturing Systems at Toyota, OUP.
Fung, K. C., Hitomi Iizaka, and Stephen Parker, 2002. "Determinants of U. S. and Japanese Direct Investment in China," Journal of Comparative Economics, 30, 567-578.
Gerlach, Michael, 1992. Alliance Capitalism, Berkeley: University of California Press.
Granovetter, Mark, 2004. "Business Groups and Social Organization," Handbook of Economic Sociology, 2nd edition, Neil Smelser and Richard Swedberg, eds.
Head, Keith & John Ries, 1996. "Inter-City Competition for Foreign Investment: Static & Dynamic Effects or China's Incentive Areas," Journal of Urban Economics, 40, 38-60.
Helper, S. R. and M. Sako, 1999. "Supplier Relations in Japan and the United States: Are they converging?" Sloan Management Review, 36 (3), 77-84.
Henley, John, Colin Kirkpatrick, and Georgina Wilde, 1999. "Foreign Direct Investment in China: Recent Trends and Current Policy Issues," World Economy, 22, 223-243.
Jacobs, Andrew James, 2002. "Integrated Development Planning, Supportive Public Policies, and Corporate Commitment: A Recipe for Thriving Major Cities in Aichi, Japan," Journal of Urban Affairs, 24 (2), 175-196.
Lieberman, Marvin B. and Rajeev Dhawan, 2005, "Assessing the Resource Base of Japanese and U. S. Auto Producers: A Stochastic Frontier Production Function Approach," Management Science, 51-5, July 2005, 1060-1075.
Liker, Jeffrey, M. Fruin, and P. Adler, 1999. Remade in America――Transplant-

ing and Transforming Japanese Management Systems, New York: Oxford University Press.
MacDuffie, John Paul and Susan Helper, 1999, "Creating Lean Suppliers: Diffusing Lean Production through the Supply Chain," in Liker et al., Remade in America, 154-200.
Nishiguchi, Toshihiro, 2004. Strategic Industrial Sourcing: The Japanese Advantage. OUP.
Porter, M. E., 1996. What is Strategy? Harvard Business Review, 74 (6), 61-78.
Sakamoto, Toshiyuki, 2003. "Structural Options for Future Actions in Annex I Countries――Part II: Energy and Climate Case Study, Japan." METI, October.
Sakamoto, Toshiyuki, 2005. "Japanese Climate Technology Policy――Encouraging Technology Development and Diffusion," May 11, 2005, Climate Policy in the US and Japan: Prospects in 2005 and Beyond, Workshop, METI.
Stern, David, 2006. Stern Review on the Economics of Climate Change, London: Exchequer; Cambridge University Press will be publishing the report in hardcopy in 2007.
Taniguchi, Kazuhiro, 2006. Boundaries and Organizational Architecture of the Firm: Toward a Theory of Business Institutions, Tokyo: NTT Publications.
Urata, Shujiro and Hiroki Kawai, "Technological Progress by Small and Medium Firms in Japan," World Bank Institute, 2001, Stock number 27193.
Womack, J. P., D. T. Jones, D. Roos, 1990. The Machine that Changed the World: The Story of Lean Production., Rawson Associates, New York.
Zhang, Kevin Honglin and James R. Markusen, 1999. "Vertical Multinationals and Host-Country Characteristics," Journal of Development Economics, 59, 233-252.