Lecture # 22 – Technology in Emerging Countries

I. Innovation in Emerging Economies

- Background on emerging economies
  - Home to 40% of world population, 13% of income
  - Income is rising at a pace similar to Japan and Korea when they took off
    - Average growth rates in China over 9% during past 30 years
      - Because of their large size, GDP is high relative to other countries
        - By 2007, China had the fourth highest GDP in the world
- Because technological change is uncertain, poorer countries may benefit from letting others do the research and benefiting from technology transfer. However, technology must also fit local needs
  - Leads to the possibility of leapfrogging
  - Leapfrogging avoids the need to "re-invent the wheel."
    - Keeping up with developed country technologies is expensive. Thus, companies in India and China make use of imported technologies
      - China makes computers, but imports computer chips
        - China demands $62 billion worth of chips per year, but supplies just $3.1 billion
      - India produces drugs, but often copies the compounds
      - India writes software, but rarely owns the results.
    - Patent data suggests most innovations in India are coming from outside the country.
      - In 2004-05, 17,000 patent applications filed in India. Only 3,500 by Indians.
      - 44 of the 49 most prolific filers in the past decade were foreign companies or subsidiaries.
      - The five Indian firms are all government sponsored institutes or generic drug companies.
  - As such, while products are made in India and China, value is added elsewhere
    - About 15% of the value of Chinas IT and electronic exports is added in China
      - In 2006, China had a trade surplus in computers, video cameras, TVs and telephones, but a trade deficit in electronic components, such as semiconductors, integrated circuits, and audio and video parts.
    - The top 10 electronic firms in China are foreign.
    - India exported $18 billion in IT services in 2006, but only $450 million of its own software.
      - Note that services are labor intensive.
        - This limits the potential productivity growth of service industries.

        - Why doesn't India create more software?
            - Creating software requires capital.
            - More risk involved, as new products require an up-front investment that might not work out. Services are done via contracts, and so paid for up front.
            - To develop new products, it helps to be close to customers. India is not.
                - Indians only purchased $1.6 billion of software in 2006
                - Piracy rates are as high as 72%
    - The iPod is an example.
        - 30GB video version, manufactured in China, sells for $224 in 2005
        - But most parts cost one cent or less.
            - Display module costs $20, but made in Japan
        - China's assembly accounted for $3.70 of the iPod's value.
        - $80 in profit went to Apple for designing the iPod.
- While metrics suggest the level of innovation in China is increasing, there are concerns about quality
    - Chinese patent applications grew 26% per year between 2003-2009
        - Compare to 6% in US, 5% in South Korea, 1% in Japan
        - However, most are minor utility patents, rather than invention patents
            - Utility patents in China now equal the number of invention patents
                - 2005: Less than 85% of foreign applications for invention patents. Less than 25% of domestic applications were for invention patents
                - Foreigners patented more after 2000, presumably in anticipation of China joining the WTO
                - Hu/Jefferson (2009): Domestic firms patent more in industries with more FDI, suggesting they learn from foreign firms
        - Moreover, Chinese patents often perceived to be of lower quality
    - Policy plays a role
        - China's patent law was amended in 1992 to broaden the scope and extend the length of patent protection
            - Coverage for things such as pharmaceuticals and chemical processes began at this time.
            - Coverage extended from 15 to 20 years for invention patents, and from 5 to 10 years for utility patents
        - Further amendments in 2000 to comply with TRIPS, primarily strengthening enforcement
    - However, perverse incentives encourage the patent explosion
        - Patent examiners are paid more for approving patents
        - Successful patenting helps professors get tenure

            - Recall our discussion after Bayh-Dole. Is this the right metric?
        - Workers and students who file patents more likely to get residency permits for desirable cities.
        - Firms that patent get corporate income tax breaks
        - Hu and Jefferson (2009) find the R&D-patent elasticity is low in China, supporting the notion that the patent explosion is the result of more than just increased R&D.
    - "Bamboo innovation" suggests that we shouldn't look at the usual measures of success to evaluate Chinese innovation. What else might matter?
        - Process innovation: improving factories and distribution systems
            - As an example, China became a leader in solar PV manufacturing by developing new production techniques that were more labor intensive to take advantage of cheap labor.
        - Adaptive product innovation: adapting existing goods to local requirements

II. Technology Leapfrogging? Wind Energy in India and China

- Both India and China went from having no wind turbine manufacturing capacity to almost complete local production of turbines in less than 10 years' time.
    - In both cases, a combination of local energy policy that created demand for wind energy and efforts of the leading local firms to gain new skills were important.
        - New companies are competing against established companies that have been in business over 20 years.
    - Lewis' paper provides a case study of how India and China developed local production capacity of this emerging technology.
        - An example of energy leapfrogging – moving from a path of development using fossil fuels to one using advanced, cleaner technologies
        - Lewis notes that empirical work does not necessarily support this.
            - As this is a successful case, tries to find lessons for when such leapfrogging may be possible.
    - Case focuses on the leading wind turbine manufacturer in each country
- Background on wind in India and China
    - As of 2006, 74 GW of wind worldwide
        - 8% in India
        - Just 3% in China
    - 75% of turbine sales from four leading manufacturers
    - Vestas (DK), Gamesa (ES), GE (US) and Enercon (DE)
    - India has 8% of market, China 3% in 2006 (note similar to share of installations – are they focusing on local markets)
    - China's electricity capacity growing rapidly, but most new capacity from coal

        - Wind represented just 1% of China's generation capacity in 2005
    - Wind was 2% of India's electricity capacity in 2005. Most generation also from coal
- Policy support for wind
    - India
        - Since 1990s, has had a government ministry devoted to renewables: Ministry for Non-Conventional Energy Sources (MNES)
        - However, policy has been unstable
            - Note that unstable policy hurts development of wind
        - National Guidelines for Clearance of Wind Power Projects: 1995
            - Mandated state electricity boards ensure grid compatibility with wind
            - Provided financial incentives
                - 100% depreciation in first year
                - 5 year tax holiday
        - India's Electricity Act of 2003
            - Requires all state-level energy regulatory commission to encourage minimum % of electricity from renewables
            - Different states have established different renewable targets
    - China
        - Government has provided R&D funding for wind since 1996
        - Wind concession program
            - Government-selected sites auctioned to potential wind developers
            - Local content requirement
                - Must be 70% local
                    - Generally calculated according to cost
                - As a result, companies that want to sell in China must establish local production facilities
                - However, often avoided establishing partnerships with smaller companies to avoid technology transfer
        - 2005 National Renewable Energy Law
        - Requires concession-based pricing for wind
        - Occasionally, fixed feed-in tariff prices allowed for specific projects
- Suzlon
    - Indian owned, by a family that started in textiles and diversified in 1995.
        - Grew quickly within its first 5 years
            - 8% global market share in 2006
            - Holds 52% of Indian market share
    - Both supplied equipment and develops and operates wind power sites
    - Note that it owns subsidiaries in developed markets
        - Includes technology development centers in Germany and the Netherlands
    - In 2004, established international headquarters in Aarhus, Denmark

        - Able to hire workers recently laid off from leading Danish companies after a merger of Vestas and NEG Micon
        - Note importance of human capital for technology transfer
    - Note diversification of international portfolio
        - Established R&D facilities in the Netherlands and Germany to take advantage of the expertise from these countries
        - Most production occurs in India
            - Cheaper labor
            - Lower manufacturing costs
            - Better access to capital
    - How Suzlon obtained expertise
        - Technical collaboration agreements
            - 1995: entered a technical collaboration agreement with Südwind GmbH Windkrafttanlagen (became Südwind Energiesysteme GhbH in 1996)
                - Südwind was to share technical know-how for turbines in return for royalty payments for each turbine sold in the first five years of the agreement
        - Licensing
            - 2001: Obtained license to manufacture rotor blades from Aerpac B.V.
            - 2001: Obtained molds, production line, and support from Enron Wind Rotor Production B.V. to produce blades in India
        - Own R&D
            - Built upon licensing agreements by using their own R&D
            - Focus on design and development of new turbine models and advanced blade technology to improve efficiency
                - R&D facilities located in Netherlands and Germany take advantage of local specialties (blade design in NL, engineering in DE)
            - More so than established firms, made use of learning networks
    - Focused on local production
        - Allowed it to respond to demand quickly and to not rely on a supply chain of components
- Goldwind
    - Established in 1998 as a subsidiary of Xinjiang Wind Energy Company
        - 55% state owned
        - Market share in 2006
            - 2.8% of global market
            - 31% of Chinese market
    - Local production content increased quickly over time
        - 1998: 33%
        - 1999: 72%
        - Won a high-profile government contract in 2003
            - One of two of the first government concession projects

            - Were able to offer prices 25% lower than European manufacturers working in China
        - By 2006, approaching 100% local content
            - However, quality and reliability of local suppliers is a concern
            - Chinese government established a technology certification program in response
                - Goldwind's 600kW turbine ISO 9001 quality certified in 2000
    - How Goldwind obtained expertise
        - First purchased a license from two small German wind manufacturers
        - Believes that "holding trademarks and property rights improves 'progressive production engineering'" (p. 223)
            - Registers for patents on new products as soon as possible
        - Sends employees abroad for training, but has no overseas facilities
            - Includes events for technical exchange, training at foreign companies, and foreign MBAs
- Lessons from the cases
    - Similarities
        - Both countries had supportive national policies
            - Particularly important for environmental technologies, where externalities (e.g. concern over pollution) are a concern
            - But, as noted below, the specific policies varied by country
        - Both used licensing to obtain technology
            - Large international companies avoided licensing agreements so as to avoid helping the development of international competitors.
            - Instead, licensing agreements reached with smaller companies that had little international presence.
                - Had little to lose from competition in China and India, but gained from royalty payments.
    - Differences
        - China policy required local content, India did not
            - Local content requirement encouraged foreign owned companies to shift production to China
            - Primary beneficiary is companies like Goldwind that can meet the requirements
            - But, local production emerged in India anyway as a way to meet local demand
                - Raises the question if the local content requirement is necessary
                    - Does the nature of the product matter?
                        - Turbines are large – shipping long distances would be expensive
        - India used fixed tariff prices, China had competitive bidding
            - Fixed tariffs provide stability for the industry

        - Different learning networks
            - Suzlon: international R&D facilities
                - Brings this knowledge back to India through its local production facilities
                - This given them an advantage over global firms operating in Indian and allows it to maintain control of IP
            - Goldwind: sent researchers abroad
                - Also hires workers from foreign firms working in China
                - Example of potential spillover
            - Suzlon moved beyond licensing and has purchased majority control of several component suppliers
                - One company purchased was a supplier for Goldwind
                - May make it difficult for Goldwind to expand globally

III. Biotechnology in India

- Biotech in developing countries can find more appropriate solutions to developing country problems
    - Local diseases may not be of interest to western researchers
        - Brazilian researchers publish often on tropical diseases
        - Rich country pharmaceuticals tend to think of poor country consumers in terms of philanthropy, rather than good business.
            - However, in richer countries, such as China and India, there is a concern that generics cut into the market for developed country products.
            - Indian and Chinese health care markets growing at a rate near 10%/year
- The Indian case suggests that developing countries can succeed in the pharmaceutical market.
    - While India's biotech industry serves the local market, it is also beginning to focus on the global marketplace.
- Where do Indian firms come from?
    - Some grew out of larger parent companies that decided biotech investments were viable.
    - Some smaller niche companies began as biotech firms.
    - Sources of funding
        - Venture capital scarce, so most adopt a revenue-generating growth model.
            - Rely on production of generics and/or contract services to generate funds to use for R&D.
            - Thus, competition can lower the revenues available for R&D.
        - Funding partnerships from both government and NGOs
        - The little venture capital that is available seems to come from the US, rather than India
            - Indian venture capitalists do not seem to identify biotech as an area of interest.

            - However, smaller firms often need too little money to be of interest to international investors
- What products and services do Indian biotechnology firms provide?
    - Affordable vaccines
        - Several firms do this.
        - First domestically produced and marketed recombinant DNA product developed in 1997.
        - Competition leads to lower prices
            - Entrance into local market for Hepatitis-B vaccines, as well as competition among Indian firms, led to a 30X decrease in the price compared to imported vaccines ($15 => $0.50)
        - India is a major supplier for other developing countries
            - Shantha Biotechnics supplies nearly 40% of the UNICEF global requirement for Hepatitis-B vaccine.
                - The company devotes about 25% of its revenues to R&D.
                    - This is high, even for US firms.
                - Funding came from long-term low-interest loans and from private equity, including money from Morgan Stanley.
                    - In 2006, Merieux Alliance of France purchased a 60% share of the company.
                - Works collaboratively with foreign firms to develop new products.
                - Because of the lack of government support for private research, the company entered into several private-public partnerships.
            - Serum Institute of India is the world's largest exporter of vaccines.
        - India able to be prominent in vaccines because they tend to sell at lower prices and are not under patent.
    - Nonvaccine therapeutics
        - Among the 21 companies surveyed, 6 produce recombinant drugs.
            - The global market for these drugs is expected to increase as several blockbuster drugs go off patent.
                - Several Indian firms are investing in new manufacturing facilities to scale-up production.
                - Facilities are being built to comply with standards of international regulatory agencies such as the U.S. FDA
            - Biocon has developed a proprietary process for manufacturing recombinant insulin.
                - Even before the product entered the market, foreign companies lowered their prices by 40% in response. Biocon's price is even lower.
    - Novel product development

- India changed its patent law to allow product patents on January 1, 2005. As a result, many firms are now doing innovative research.
    - Some focus on developing country markets, while others focus more broadly.
        - Only 10% of Indian biotech R&D focused on local needs
        - Ranbaxy and Dr. Reddy's have begun to challenge key patents in the US
            - In the US, the first generic company to succeed in a patent challenge gets a six month head start
            - However, the legal costs are high ($12 million/year for Dr. Reddy's, or ¼ of its R&D budget).
            - Ranbaxy is challenging the patent for Lipitor
- Subsidiaries outside of India
- Companies pursuing R&D for several diseases, such as Dr. Reddy's Laboratories, have set up subsidiaries or research groups outside of India.
    - Dr. Reddy has an agreement to purchase a Mexican firm, and a joint venture with a Chinese company.
    - Some companies have subsidiaries in the US or Canada
        - Shantha Biotechnics has a US subsidiary, Shantha West
        - These subsidiaries both facilitate tech transfer and help Indian firms break into new markets.
    - GangaGen Biotechnologies is itself a subsidiary of a US company.

o Contract services
- Avesthagen, in Bangalore, uses contract services to become a fully integrated drug company.
    - Started in Patell's laboratories in 1998.
        - Patell was supported by grants from both India and abroad, including the Rockefeller Foundation.
    - Because of financial limitations, relies on both foreign and domestic collaboration.
    - Avesthagen is a private spin-off company from the National Center for Biological Sciences and the University of Agricultural Sciences in Bangalore.
        - Initial focus was agricultural biotech, but now does pharmaceuticals as well.
        - In addition to research, has facilities for production and clinical trials.

        - Some Indian companies contract capacity to do clinical trials to multinationals.
            - They claim that the low cost of doing preclinical and early clinical trials in India can reduce risk of larger investments in later trials.
            - To do so, firms must have practices that meet international standards.
            - Infrastructure is an issue. Not all hospitals are equipped for trials
            - Tracking patients for follow-ups can be difficult.
- Partnerships in innovation
    - In general, Indian firms are at an early R&D stage.
    - They have yet to produce something truly innovative on their own.
    - Types of partnerships
        - Local collaborations with domestic research institutes
            - Similar to firms working with US labs.
            - Companies get access to in-house staff, research facilities and equipment, and can perform clinical trials.
            - Many of these focus on local health needs.
            - Example
                - Nicholas Piramal (NPIL), India's fourth largest pharmaceutical firm, built a research center in Mumbai
                - The company is testing extracts from India's flora for medicinal uses
                - The laboratory partners with the National Institute of Oceanography in Goa and eight other research institutes.
                - Indian government provided 70 million rupees ($1.8 million) of funding.
                - They have been successful.
                    - Have at least seven new drugs in development
                    - 6% of revenues go to R&D
            - Partnerships between multiple Indian firms less common.
        - International collaborations with other firms
            - Both licensing and joint ventures are used
            - Several firms are developing vaccines based on technologies transferred from abroad
            - License technology from firms in the US, Canada, or Netherlands

        - International collaboration with other institutions
            - Biological E working with the International Center for Diarrheal Disease Research, a UNICEF organization, to develop a vaccine for cholera.
            - Bharat Biotech is developing vaccine candidates for the Malaria Vaccine Initiative.
            - The new patent laws make India more attractive to MNCs.
- Barriers to development of the Indian pharmaceutical industry
    - Multiple regulatory agencies delay commercialization
        - These agencies also lack experience with biotech
            - Leads to a lack of credibility with international regulatory bodies.
    - Shortage of advanced training programs and scarcity of qualified personnel
        - Many talented Indian PhD students migrate abroad
            - Greater opportunities for training and research funding abroad
            - However, the success of the Indian industry can help prevent brain drain
    - Public-private collaborations are ineffective
        - The Indian government is trying to improve this by promoting policies that support cooperation, rather than competition, among science agencies, research institutions, universities, and industry.
    - Few Indian academics show entrepreneurial ambition in biotech
        - Only 4 of the 21 firms surveyed were founded by Indian academic scientists
        - Weak technology transfer between public research institutes and private firms cause this.
            - Includes weak policies for encouraging entrepreneurial ventures by academics.
            - Proposals to remedy include the possibility of dual positions, including joint salary support
    - Lack of financial resources
        - Many companies seek foreign funding, because domestic funding, both public and private, is still small.
        - Applying for domestic funds often time consuming due to bureaucracy.
        - Some companies have declared themselves 100% export-oriented, so as to avoid tariffs on imported equipment.
            - This leads to significant cost savings, as tariffs can be as high as 45%, and much of the equipment needed for a research facility must be imported.
            - Does this send the wrong signals to Indian firms? Does this hurt development of drugs for the local market?
    - Lack of national focus on domestic health needs
        - Profits are low in Indian market, due to high competition.

        - Makes it difficult to support the fixed cost of R&D.
        - Note that this is the same problem faced by developed country firms when they choose not to develop drugs for developing countries.
        - There is limited public funding available for R&D focusing on local needs.
    - High costs of domestic distribution
        - Particularly an issue for rural markets
        - Many firms rely on the Indian government to distribute vaccines
        - Indian Immunologicals, owned by the National Dairy Development Board, uses franchise clinics and refrigerated vehicles to deliver vaccines to rural areas.
- Lessons from the case
    1. Many local firms started small and used revenues generated by early sales to support later growth.
        - Note how this substitutes for venture capital, for example.
    2. Many firms get funding from both domestic and foreign sources.
        - Unlike firms in developing countries, most grow without surrendering equity in their firms.
    3. Successful firms have been proactive establishing collaborations
    4. Indian firms aim to become more competitive by patenting technologies globally.
    5. Successful firms have been able to establish international reputations.
        - Many of these firms had senior managers who had worked abroad.
        - Nice example of tacit technology transfer.

IV. General Lessons

- Emerging countries are starting to do their own research, rather than just depend on technology transfer via FDI.
    - Fu *et al*. summarize recent work on the relative role of local versus foreign innovation on the efforts of emerging economies to catch up with high income countries.
    - Overall, the research suggests that local innovation is necessary to fully take advantage of technology transfer.
- Four key lessons
    - Technology diffusion is not costless and unconditional
        - Depends on a firm's absorptive capacity and complementary assets
            - Li (2011) finds that investing in foreign technology does not enhance productivity unless accompanied by in-house R&D.
                - In contrast, domestic technology purchases alone can enhance productivity. No additional R&D is necessary.
            - Fu and Gong (2011) decompose TFP growth into technological change and efficiency improvements
                - They find that FDI was a vehicle for technology transfer

            - However, foreign R&D had a negative impact on technological change in local firms
            - Instead, indigenous innovation needed to push local firms to the technological frontier
    - Local innovation necessary to encourage MNEs to develop linkages to the local economy
        - Optimal production processes vary under different economic conditions
            - Factor endowments in the North and South differ
            - These differences induce innovations to take advantage of local conditions (Acemoglu 2002)
        - Note that this also implies that foreign technology becomes more appropriate as an economy grows and becomes more industrialized
            - Studying Chinese manufacturing firms from 2001-2005, Fu and Gong (2011) find that local firms dominate the technological frontier of low and medium technology industries, but foreign firms dominate the frontier of high technology industries
            - Suggests a two-tiered strategy for developing countries
                - Optimal technology depends on labor/resource endowments
    - Greater use of external knowledge accompanied by decrease of internal R&D
        - That is, crowding out is a problem
            - Fu and Gong (2011) find that foreign R&D labs crowd out research in local labs
            - Zhou (2006) reports that foreign R&D labs do not intend to collaborate with local labs
    - Inappropriateness of foreign technology in local markets may explain poor results of FDI found in many studies
        - FDI may help improve basic capabilities, but not help deepen capabilities
        - When is FDI most likely to be effective?
            - Investments from R&D intensive firms more likely to involve technology transfer
            - Recipients need sufficient absorptive capacity
            - Clustering of innovation is important
                - Li and Shapiro (2008) find spillovers from FDI greatest in locations with clusters of innovative foreign firms
                    - Local firms in these areas more likely to introduce new product innovations
                    - Doesn’t occur when foreign firms have large employment, but are not innovative

- Finally, what about the role of state-owned enterprises (SOE)?
  - Good at infrastructure
    - Both transportation and, more recently, high tech infrastructure
  - Have produced national champions that compete globally
    - Able to provide needed resources
  - But, can they produce innovation?
    - Governments good at providing support (e.g. funding), but not good at turning research into new products
  - Evidence suggests SOE are less productive than private competitors
    - Note more likely to survive despite poor performance