# Lecture # 18 – International Technology Diffusion

## I. Channels of Technology Diffusion

*A. Theory*

- The previous lectures focused on technology diffusion within a country. Today we begin to look at diffusion across countries.
- An important consideration is the ability of a country to absorb new knowledge. Technological capability can be divided into three areas. Trade can provide the elements of technology, but these other elements must also be in place for technology transfer to be successful.
    - Production capabilities
    - Investment capabilities: does the country have the ability to expand production facilities and build new ones.
    - Invention capabilities: the ability of the local efforts to adapt, improve, and develop technology.
- Two basic mechanisms for international economic activity to lead to technological diffusion:
    1. Direct learning about foreign technological knowledge.
        - This means learning about the blueprint of the technology, so that the recipient country can reproduce the technology.
        - If the cost of obtaining the knowledge is less than the cost of invention, a *spillover* has occurred.
            - Such spillovers should increase the productivity of domestic inventive activity. It becomes part of the domestic knowledge stock off which inventors build.
        - No purchase is necessary for active spillovers. They can be transferred via blueprints.
            - Such transfer can be low-cost.
            - However, without licensing agreements, the inventor may choose to keep the blueprints secret.
            - Although no direct purchase is required, activities such as trade or FDI can help create and maintain communication channels.
        - However, active technology transfer doesn't require blueprints. Tacit knowledge can also be transferred.
            - Tacit knowledge can be transferred by:
            - Demonstrations
            - Personal instruction
            - Provision of expert services
            - Hiring workers away from the innovating firm.
                - To avoid this, multinationals may pay workers a wage premium to keep them from switching jobs.
    2. Employing specialized and advanced intermediate products that have been invented abroad (passive spillovers).
        - Here, the technology is *embodied* in the product that is being used.

            - Its use should make production more efficient.
                - However, no new knowledge is passed on to domestic inventors.
                - Thus, the productivity of domestic R&D does not increase.
            - If the product is purchased for less than the opportunity cost of producing the product, including R&D costs, a spillover occurs.
                - Keller calls this a passive spillover.  Griliches calls this a pecuniary externality.
            - For passive spillovers (embodied technological change), a purchase must occur.  Passive spillovers are transferred via:
                - International trade
                - Foreign direct investment (FDI)
- The costs of technology transfer
    - Technology transfer is not free.
    - Although knowledge is a public good, that only means that it is available to anyone willing to pay the costs of transfer.
        - New products must be adopted to fit each market.
        - There are costs involved in exchanging designs, setting up training, etc.
    - Three types of transfer:
        1. Material transfer
            - The simple import of materials (e.g. seeds, machines)
            - Local adaptation not attempted
        2. Design transfer
            - The transfer of designs in the form of blueprints, handbooks, formulas, etc.
            - Foreign equipment may be imported to be reverse engineered, so that domestic engineers can learn about the technology.
        3. Capacity transfer
            - The transfer of scientific knowledge and technical capability.
            - Often requires strengthening of education and technical capacity.
            - Firms are better able to adopt complex innovations if they can do R&D to adapt the technology to local conditions.
    - Over time, a country may experience all three levels.
        - Consider the example of Hewlett-Packard in Singapore.
            - They began by doing simple production in Singapore in the 1970s.
                - The products were designed in the US and shipped to Singapore for production.
            - Later, they moved production of more complicated products, such as programmable calculators, to Singapore.
                - Before this was possible, engineers came to the US for a year to learn about chip design.

        - Finally, when production of ink jet printers was transferred to Asia, most of the parts came directly from Asia, rather than from the US and Europe.

*B. Empirical Evidence*

- Empirical evidence: trade
    - Why trade matters
        - Technology transfer via embodied technologies
        - Brings increased awareness of new goods
            - Can lead to direct spillovers
    - Coe & Helpman (1995) estimate the effect of both domestic and foreign R&D on TFP growth for 22 countries.
        - Model:
            - $\ln TFP_{it} = a_i + a_t + b_R \ln R_{it} + b_S \ln S_{it} + e_{it}$
            - R = domestic R&D
            - S = foreign R&D
                - They use trade-weighted foreign R&D measures. Other work shows this might not be correct
        - Results:
            - Domestic R&D more important for larger countries, foreign R&D more important for smaller countries in the sample.
            - Competition may play a role here. There are two competing possibilities. Foreign knowledge:
                - Increases productivity through spillovers.
                - Competes with domestic products.
                    - For a technology leader, competition is likely to be more important.
            - Domestic R&D elas. 0.08 for smaller countries, 0.23 for G-7 countries.
            - Foreign R&D elas: 0.12 for smaller countries, 0.06 for G-7 countries.
            - Note that these results are for developed countries.
                - For developing countries, an important question is whether capabilities exist to take advantage of direct spillovers.
        - Other work: Eaton and Kortum's general equilibrium model
            - Productivity growth due to domestic, rather than foreign, R&D:
                - 11-16% for Germany, France, and UK
                - 35% for Japan
                - 60% for the US
    - Keller (2001): technology from the G-5 countries contributes to almost 90% of the total R&D effect on productivity in nine other OECD countries.

    - Sjöholm (1996) finds a correlation between Swedish patent citations and bilateral imports, suggesting that imports contribute to international knowledge spillovers.
    - Capacity of local firms matters
        - In the mid-1980s:
            - In Taiwan, 50% of engineers left MNCs to join local firms
            - In Kenya, only 16% left MNCs to join local firms
                - In such a case, local competitors may be disadvantaged
    - Inter-industry differences
        - R&D spending varies across industry. In the OECD, 80% of all manufacturing R&D is in four industries: chemical products (includes drugs), electrical machinery (includes computers), non-electrical machinery, and transportation equipment.
        - There is evidence that the elasticity of TFP with respect to R&D is higher for these industries.
        - Blyde (2001) finds OECD imports have a stronger effect on TFP than Latin American imports.
            - Explanation: more R&D is embodied in OECD imports.
    - General lessons:
        - International technology diffusion plays an important role in economic growth.
        - This role is inversely related to:
            - Economic size
            - The level of development
- Geographic considerations
    - The more global that technological diffusion is, the more likely that convergence of incomes will follow.
        - However, geographic considerations affect technology transfer.
    - Things that affect technology transfer:
        - Physical constraints, such as soil & climate conditions
        - Economic constraints
            - For example, relative factor prices affect the profitability of various technologies.
        - Social factors such as legal systems, transaction costs, etc.
    - Empirical studies
        - Evenson looked at technological distance and rice across different regions of India.
            - Technological distance = (cost of using the optimal technology for region *j* in region *i*)/(cost of using the optimal technology for region *i* in region *i*).
                - Equals 1 if the technologies are perfectly interchangeable.
                - Greater than 1 if the technology for region *j* does not work perfectly in region *i*.
            - Found technological distance between 1.05 – 1.67.

            - Note that this is within one country!
    - Jaffe et al. find that US patents are more likely to cite US patents than foreign patents.
    - Keller (2001) finds that the R&D spillovers in the Coe & Helpman model are a function of geography. They are stronger for countries that are closer together.

**II. Firm-Level Technology Transfer**

- Firms that wish to serve foreign markets must choose between producing the good at home and exporting it or setting up production abroad.
    - If they set up production abroad, they can use FDI through a subsidiary, or they can license their technology to another firm.
    - Two key choices
        - Export vs. Production Abroad
            - Empirical evidence suggests these are complementary processes
                - Likely because intermediate goods must be exported to subsidiaries.
            - FDI can help a firm avoid tariff barriers.
            - FDI has a larger fixed cost, but lower marginal cost, than exporting.
                - Thus, the decision to export or use FDI may depend on the size of the fixed cost.
                - Information is important. Firms are less willing to invest large fixed costs in uncertain climates, like new market economies.
        - FDI vs. Licensing
            - Licensing typically comes through a joint venture with a local firm.
            - Firms typically choose FDI when they want to protect intellectual property.
                - More likely to use FDI for new technologies & license older ones.
                - Firms that do lots of R&D more likely to use FDI than license.
            - Many times, firms first use a licensing agreement with local companies to learn about the market.
                - After learning, they may switch to FDI.
- What drives the internationalization of R&D?
    - Compared to other transnational activities, R&D is not very mobile.
        - Complex, tacit nature makes it difficult to fragment.
            - Can't locate different segments in different places.
        - Face-to-face collaboration important.
        - Develops in a cumulative manner.
        - Keeping R&D at home allows firms to maintain control.
            - Particularly want to avoid areas with weak IPR.

- Why outsource R&D?
    - When complex innovations require diverse skills, one company may not possess all the necessary skills to complete an innovation.
    - Need to get products to market quickly
        - Can take advantage of a partner's strengths, rather than taking the time to learn on your own.
- Trends
    - Internationalization of R&D is increasing. R&D performed overseas by US MNCs:
        - 2000: 12%
        - 2010: 16%
    - Most internationalization in chemicals and pharmaceuticals
        - Percent of foreign R&D in host countries varies by country (2003 data):
            - Exceeded 50% in Ireland, Hungary and Singapore
            - Exceeded 40% in Brazil, the Czech Republic, Sweden, the United Kingdom and Australia
            - Below 10% in Republic of Korea, Japan, India, Chile and Greece.
    - Overall, R&D in developing countries, particularly China, is growing
        - R&D in East and Southeast Asia was 25% of global R&D in 2001, is 34% in 2011
- Reasons to move R&D abroad
    - Adaptive R&D
        - When need to customize product to local conditions or support foreign production.
        - This is the dominant form of R&D done abroad.
        - Necessary conditions:
            - Host country must be sufficiently different from home country
            - Scale of operations must be large enough to support the cost
            - Host country must have sufficient human capital and institutions to support the R&D effort.
        - Technology sourcing or monitoring
            - Allows firms to track new technological developments
                - E.g. electronics firms have facilities in Silicon Valley
        - Access to skilled workers
            - Costs of these workers becoming more important.
            - Particularly in high-tech industries, where there is a shortage of skilled workers.
                - Note that the cost of a chip design engineer in Asia is 10-20% the cost of one in Silicon Valley.

          - A study in India found proximity to market main reason for firms in conventional technology industries to locate there.  For new technologies, availability and low cost of R&D workers was important.
- Host country determinants affect the decision to move R&D abroad
  - Depends on R&D type
    - Adaptive R&D
      - Dominant R&D in Latin America and Africa
      - Closely related to production needs
        - To be close to customers
        - To improve local image
        - To cooperate with local partners
        - To overcome protectionist barriers
      - More likely to do if market is large
      - At times, a country can become the base for R&D for a regional market
        - Thus, being a good fit for the region becomes important.
    - Innovative R&D
      - Done in some parts of South and Southeast Asia, as well as some transition economies.
      - Here, skills matter
        - Availability of well-trained S&E workers important
        - Note countries such as China are expanding tertiary education
          - 19 million enrolled in 2003
            - 100% increase over 2000
        - In contrast, Latin America lags behind
        - However, not all tertiary graduates appropriate
          - Having skilled engineers in technology-intensive areas is important
          - Recent survey of TNCs:
            - 50% of engineers in Hungary & Poland suitable
            - 25% of engineers in India suitable
            - 10% of engineers in China and Russia suitable
        - Skilled workers tend to be concentrated in specific areas
    - Willingness to come depends on national innovation system
      - Science parks can be helpful, as they foster collaboration
      - Institutions also important
        - Research institutes such as Indian Institute of Technology help draw firms to India.
          - Some firms outsource R&D to these institutes.

            - IPR protection essential for innovative R&D
                - However, if the product will be sold in other countries, it is the IPR in those countries that matters.

**III. Implications for Developing Countries**

- Effects of R&D internationalization on host countries
    - Potential benefits
        - Improved structure and performance of the NIS
            - Foreign firms performing R&D interact with local firms, government agencies, and universities.
            - In developing countries, public institutions are an important part of the NIS, as private enterprises do less R&D than in developed countries.
                - Thus, there are fewer links between private and public sector R&D in developing countries.
                - Private foreign firms can help provide these links.
                    - For example, can help make use of basic R&D performed by universities or governments.
        - Contribution to human resource development
            - Increased R&D employment
            - Many TNCs provide in-house training to employees
            - Support to higher education
                - This may include research collaborations
            - Reverse brain drain
                - Newly available jobs can bring back engineers who have left.
        - Knowledge spillovers
            - Depends on type of international activity (e.g. FDI vs. licensing)
            - More likely when linkages between institutions are present
        - Contributions to industrial upgrading
            - Adaptive R&D typically leads to process and/or product upgrading
            - Functional upgrading: upgrading capabilities (e.g. moving from assembly work to R&D)
            - Chain upgrading: developing countries moving from simple low-tech products to more advanced high-tech
    - Potential costs
        - Downsizing of existing local R&D or losing control of technology
            - Some internationalization comes from TNCs acquiring control of local companies that perform R&D.
            - In other cases, acquiring firms may shut down R&D operations.
                - Depends on whether R&D operations are complements or substitutes for the parent.
                - Often the case for Latin America, where R&D is rarely the main reason for acquiring a firm.

        - Unfair compensation for locally developed intellectual property
            - Concern over unfair bargaining power
        - Crowding out in the labor market, potential harm to basic research
            - Foreign firms competing in local market may make it difficult for local firms to compete for skilled workers.
        - Technology leakage
            - Fragmentation of R&D (e.g. different parts done in different countries) minimizes possibilities for meaningful spillovers.
        - Race to the bottom and unethical behavior
            - E.g. using lower local standards to attract workers.
                - For example, will pharmaceutical companies want to do clinical trials where standards are lower?
                - Counterpoint: won't they need to meet high standards to be able sell in markets such as the US?
- Empirical evidence: foreign direct investment
    - Lichtenberg and van Pottelsberghe de la Potterie (1996):
        - Find a country's outward FDI gives access to foreign technology
            - This is FDI going from the country to a second country
        - Do not find significant effects from inward FDI
            - Inward FDI is FDI coming into a country
    - Xu (2000) finds outward US FDI increases productivity growth in the recipient country
    - Aitken and Harrison (1999) find a negative correlation between FDI and TFP of domestic plants in Venezuela.
        - Competition may be a factor.
        - It may also be that foreign firms look to move into sectors where the domestic firms are weak.
    - Liu (2008) finds differences in the short-run and long-run effects of FDI
        - Looks at the effects of FDI on Chinese manufacturing firms
        - An increase in FDI leads to lower short-run productivity, but higher long-run productivity
            - Short-run costs come from devoting scarce resources to learning
            - Long-run gains come from spillovers that enhance local production capabilities
    - Keller (2001) finds that language skills help technology transfer.
        - For example, he finds that if the share of English speakers in Spain (currently 17%) rose to the level in the Netherlands (77%), Spain would experience a 15% boost of technology diffusion form English-speaking countries.
    - Lipsey and Sjöholm (2003)
        - Foreign owned firms pay higher wages
        - Wages increase after acquisition, suggesting foreign ownership => learning

- General lessons:
    - FDI does not necessarily lead to strong positive spillovers.
        - Firms choose to operate through a fully-owned subsidiary (FDI) rather than through joint ventures or technology licensing because FDI helps keep the private returns of technology internal to the firm.
    - Firms that choose FDI concentrated in industries with high R&D/sales ratios.
    - Evidence of positive effects of FDI stronger for developed countries.
        - Less outsourcing of low-skill labor jobs to developed countries.
        - These jobs may have less learning opportunities.

- General lessons on what makes technology transfer successful
    - Newly acquired technologies are rarely used at their peak productivity.
        - Both the initial productivity and the time it takes to master the technology depend on the starting level of ability.
        - Three key factors:
            - Labor cannot be effectively trained without experience with the activity.
            - Technologies usually need to be integrated into larger systems. Such integration takes experience.
            - Technologies are sensitive to local circumstances.
    - An important factor is the ability of the country to absorb new knowledge. This can be affected by:
        - Human capital
            - This may explain why rich countries benefit more from FDI.
        - R&D
            - R&D may be necessary to adapt technology to local conditions.
    - Geography matters
        - Features that affect technology transfer include:
            - Physical constraints, such as soil & climate conditions
            - Economic constraints
            - Social factors such as legal systems, transaction costs, etc.

- Effects of R&D internationalization on home countries
    - Potential benefits
        - Improved overall efficiency of R&D
            - Lower costs in developing country
            - Can tap a larger range of knowledge sources
        - Reverse technology transfer and spillovers
            - Only significant if the host country is technologically advanced
            - For example, companies from Korea, China, India, and Taiwan have located R&D centers in US and Europe to gain access to new technologies.
        - Market expansion effects
            - Adaptive R&D allows firms to sell in new markets
    - Potential costs
        - "Hollowing out" of domestic R&D base
            - However, this seems to be small
        - Disappearance of certain R&D jobs
        - Technology leakage