ETM 510/610 IIPM – Innovation and Intellectual Property Management – The Chinese Perspective

GROUP STUDY: ETM 510/610 INNOVATION THROUGH TECHNOLOGY TRANSFER: COMAPARATIVE STUDY ON CHINA AND INDIA

Submitted

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Contents

List of Figures and Tables

Abstract

Technology Transfer (TT) has long been used as a means for transferring explicit knowledge as well as tacit knowledge to developing countries for industrial development. Most developing countries lag in absorptive capacity in terms of human and technological capability. Hence, the path of TT was one way. In the past few years, however, TT to China and India has increased phenomenally. This has stemmed from Chinese and Indian economical growth with competent workforce that helped develop a low-cost environment to maximize company profit. Photovoltaic Cell (PV) industry is one sector where the two countries have assimilated and inndegined technology from transfer and developed innovation capability. Cases from these two countries confirm that both China and India has long been in the PV industry and they have acquired complementary technology through various means of TT. However, China is more towards ”Home based” outside-in TT while India embraces “Go global” active technology acquisition model. Although, Chinese firms are larger in terms of size, turnover and sales compared to India, both exports almost 90% of their sales. IP has not been a barrier in TT to these two countries. Both the countries have now achieved innovation capability in PV technology.

Keywords: Technology Transfer (TT), Cobentional TT, Unconventional TT, Absoprtive Capacity, Diffusion

1.0 Introduction

1.1 Background

Technology Transfer (TT) is a recognized means of economic growth for countries across the world. In most part of the history, however, TT has been a one way ticket – its track was always from developed countries to developing countries. But during the last few decades many developing countries have reincarnated themselves from economically stagnant nations to growing economic powers. Technology transfer (TT) is a process of transacting technology between businesses or agencies. Acquisition, adaptation and utilization of technical knowhow can take different time spans depending on its travel from the originating country to other countries.[1] Countries considered to be late industrializers of the 20th century has successfully capitalized TT for development. Appropriate technology transfer, under the right policy and business conditions, contributes to learning and development of capability, which in turn contributes to competitiveness in domestic and international markets.[2] Bridging the technology gap is an issue faced by most countries, but in developing countries the issue is doubly critical; not only do they lag further behind relative to other countries but they face more stringent resource constraints.[3] In general, technologies developed in industrial countries suit their conditions and objectives; rarely do they suit the needs of developing countries automatically. Therefore, adaptation is essential. Successful adaptation and assimilation of foreign technology enables a country to improve its own technological capability. Many developing countries have adapted and indigenized imported technologies, which resulted in technology exports/joint ventures from these countries to other developing countries and even developed countries.[1]

The reason for choosing PV industry is due to the fact that photovoltaics (PV) industry reached a record high of $93 billion in 2011, which is 13.4 percent more than 2010 – and 150 percent increse from 2009 – according to a recent report by EPIC, the Paris-based European Photonics Industry Consortium (Appendix I).[3] According to China Electronic Production Equipment Industry Association (CEPEA), revenue from PV manufacturing equipment sales of CEPEA member companies has grown from RMB 1.9 billion in 2008 to RMB 3 billion in 2010 (Apendix II).[4] During 2012, PV manufacturers moved to Asian economies to minimize the risk of negative demand growth in Europe. PV policies – implemented in China, India, Thailand, and Malaysia have helped the growth across the Asia Pacific region, PV project pipeline across India, China, Thailand and Malaysia reached 3.8 GW at the end of March, 2012 (Apendix III).[5]

1.2 Objective

China and India are considered to be two upcoming economic powers to watch out and hence, cases from these two developing countries are considered for comparing innovation and development from technology transfer. The paper is a postmortem of the process involving acquisition through TT, internalization, development and innovation in two of the fast growing economy of the world. The issues to be clarified are:

i) How production technology and skill are acquired?
ii) How diffusion of technology occurred?
iii) What was the impact of IP in TT
iv) Do the countries have innovation capability at present?

2.0 Literature Review

2.1 Technology Transfer (TT)

Technology transfer is the process which causes the movement of technology (knowledge, skill, tangibles) from transferor to transferee. It is a transaction or a process through which technological knowhow is transferred normally between businesses or agencies representing business. Transfer is considered to be a deliberate, systematically organized act.[1] The complexity of TT depends on the type of technology and ability of the transferee. For developing countries it is inteneded that the receiver learns to do things in a new way and develops appropriate technology for optimal performance.[6]

2.2 TT Framework

A general framework for factors affecting technology transfer and subsequent innovation is shown in Figure 1.

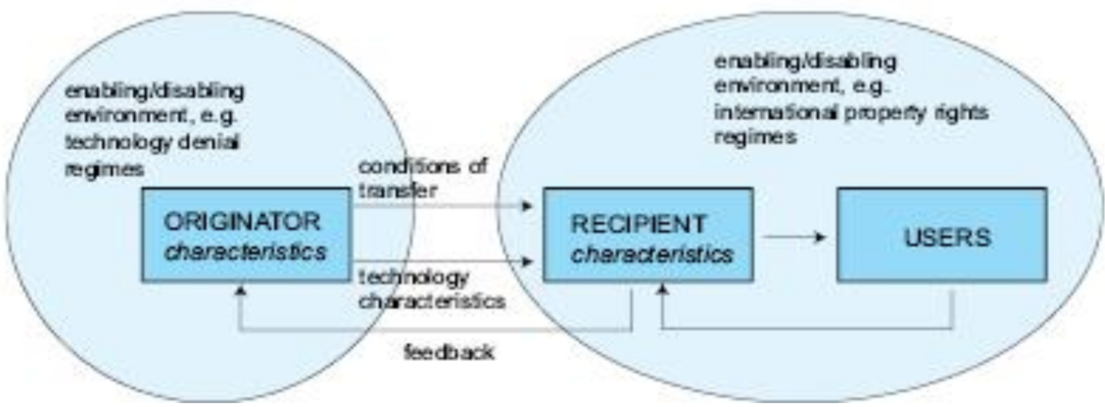

Figure 1: Framework of TT

Figure 1 shows an attempt to create a framework for all forms of technology transfer. In all forms technology transfer, especially across countries, at least seven characteristics are important. These are:

i) The characteristics of the technology.
ii) The characteristics of the originator of the transfer.
iii) The enabling (or disabling) environment in the country of origin.
iv) The conditions of the transfer.
v) The characteristics of the recipient.
vi) The enabling (or disabling) environment in the host country.
vii) The ultimately valuable post-transfer steps, i.e. assimilation, replication and innovation.

Each of these characteristics are discussed below:[7]

The characteristics of the technology

The following characteristics of technology are required for successful technology transfer:

(a) The technology must be appropriate for the proposed application.

(b) The technology must be at an appropriate level of maturity.

(c) The recipient must be at an appropriate level to apply the technology.

(d) The technology must meet the organizational needs of the recipient.

(e) The technology must be economically viable.[8]

Characteristics of the originator of the transfer

The TT success depends to a large extend if not completelt on the transferors willingness, transparency and efficiency. Owever, there are other factors apart from the supply side which affects the effective outcome of TT, such as enabling environment, institutions and finance.

The enabling (or disabling) environment in the country of origin

The environment of in the country of origin can enable or disable TT. Patents can be generated by private sectors which are publicly funded. Hence, even when governemnt transfers or licenses the patent they still follow the rules of privately owned technologies. Technology markets are normally very intense in the country of origin, and bargaining power is lopsided

Technology Denial Regime in the country of origin also sometimes constitute a barrier to technology transfer, especially for multiple-use technologies. Thus supercomputers can be used for climate modelling and global circulation models and also to design missiles.

The conditions of the transfer

The means of TT is selected in such a way that the transfer acts as a motivator to manage and maintain the technology from transferor's perspective.Some common ways of TT are:government assistance programs, direct purchases, trade, licensing, foreign direct investment, joint ventures, cooperative research agreements, co-production agreements, education and training and government direct investment. It is beneficial from the developing country perspective to have the technology along with knowhow at a favorable, concessional and preferential terms.

The characteristics of the recipient

The transferee is to know the local needs and should have the ability to choose the best technology, import, assimilate, adapt and develop apprpriatelly.

The enabling (or disabling) environment in the host country

Some of the disabling factors in the recipient country are actors for TT in thhe disabling human and institutional capacity, adequate science and educational infrastructure. and abovea all lack of long-term commitments

The ultimately valuable post-transfer steps, i.e. assimilation, replication and innovation.

A transferors ability to assimilate new technology helps to renovate and innovate. It is not enough to have only engineering and management skill, rather "active technological behavior' is the essence behind innovation and replication capability.[6]

2.3 Flows of Technology

There are different flows of technology that occur with different purposes of each flow. Technology is transferred via distinct flows of transferable technology between suppliers and importers.[9] The different flows of technology that Bell (1990) proposed are:

i) Flow 1: Capital goods, equipment designs and other artefacts.

ii) Flow 2: Skills and know-how for operation and maintenance.

iii) Flow 3: Knowledge and experience for technological change.

Each of these flows that have been identified by Bell have different implications in TT. Although the first concists of tangible assets and the second flow focuses on intangible assets, both are useful to importing firms or countries because they can deliver new equipment and methodology to increase production capacity within the firm or country. The third flow that also consists of intangible assets is considered to be critical for emerging countries or firms because the it aids a firm or country to be able to innovate new products and techniques and develop and shape its own path without being reliant on other companies or countries.

2.4 Different Transfer Mechanisms

The different pathways of TT can be broadle classified into two types; Conventional TT methods and Unconventional TT methods.

1. Conventional TT: This Is considered the easier method of both, where it focuses on "low levels of cross-border interaction".[10] Usually this type of transfer occurs with the first two type of flows as mentioned above and it is the importation of simple equipment that is generally available and the general skills and techniques that are required for operation and maintenance.

2. Unconventional TT: This method is the complex type of technology transfer. It requires high levels of cross-border interaction and requires considerable effort and investment capability. It usually encompases R&D technological transfers and would generally fall under the 3rd flow identified by Bell above. Figure 2. was developed by Rasmus& Adrian Lema and explains the how recipent's effort and investment capability determines the type of cross border iinteraction in TT.

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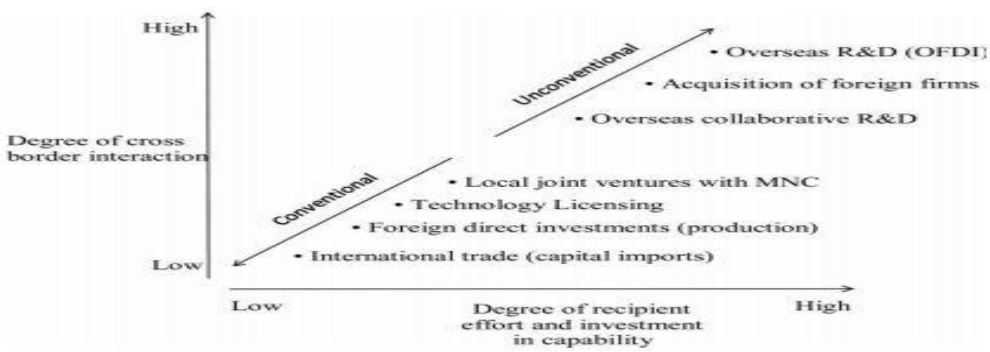


Figure 2. Conventional and Unconventional TT Methods [10]

2.5 TT Approaches by Developing Countries

Indigenous innovation is the ultimate essence of innovation original innovation, integrated innovation, and re-innovation basel on assimilation of imported technology. As illustrated in Fig. 3, China has been seeking two approaches to innovative energy technologies. One is through government-led R&D to make original innovation; another is through the decoding of technologies and adapting and improving technology imported from the developed countries to make secondary innovation.

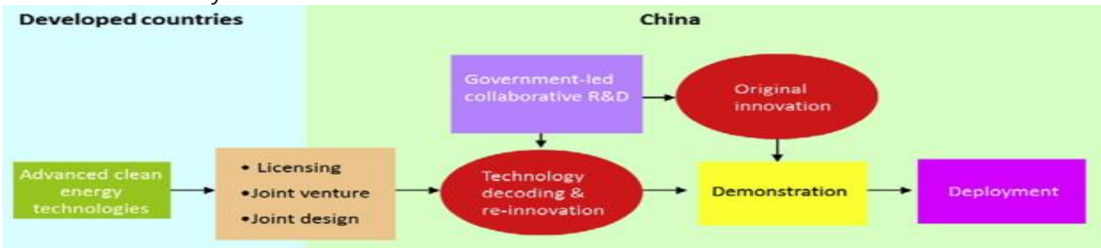


Figure 3: TT Approaches in China

TT is a crucial part of the process of innovation. Some forms of technology transfer are:

Joint venture: Joint venture is contractual arrangement between two (or more) firms in which each provides some advantage that should make the joint operation successful. For example, the foreign participant will make the advanced technology available while the domestic firm provides its knowledge of the local market, the domestic regulatory and business environment, and some other local advantages. Joint venture mechanism can help foreign firms easily access to the Chinese market and freely use their own business model. The transfer of technology through this arrangement nevertheless has certain limitations. For instance, such technology transfer may unwillingly result in a loss of competitiveness and market share in the mid to long term, considering foreign partners might then become competitors within and outside China. Therefore, foreign firms are very reluctant to share ownership of advanced technologies with local partners. Because of this drawback, many joint ventures in China act as manufacturers or post-sale maintenance facilities instead of technology developers.

Licensing: Licensing involves the purchase of production rights, protected by IPRs, and in many cases, the provision of technical assistance and know-how, which are needed to adopt and adapt the technology. The transfer of tacit knowledge and the provision of technical services are central to ensure that the licensor will secure the proper capabilities so as to use the technology in an effective way. However, the tacit knowledge is complex and therefore difficult to define in the contractual arrangement.

Joint design: Through joint design, the phases of absorption, adaptation, and assimilation of subsequent improvements are in a sense embedded in the collaboration process, which is likely to reduce the total life cycle cost required to get the job done.[11]

2.6 Model for Identifying TT

The different options of technology transfer are given by a Technology Transfer Model by Levin, et al. (1987) and Teece (1986).[Identification of Technology transfer options based on technological characteristics]

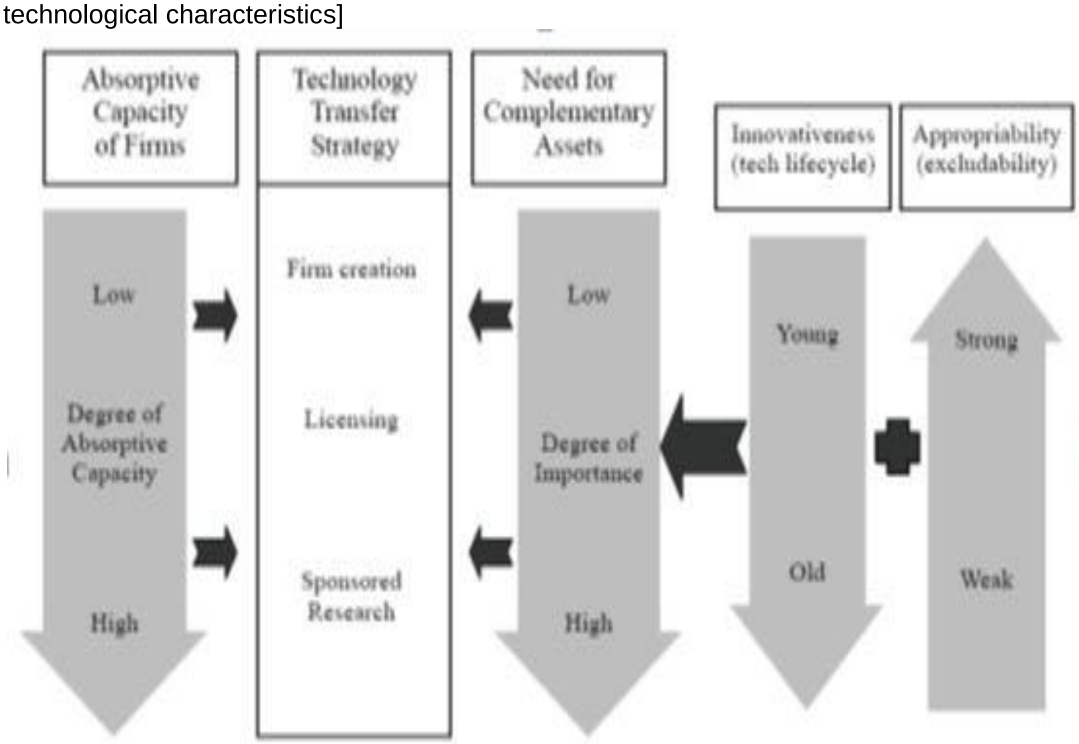


Figure 4. Technology Transfer Strategy Model: Realtionship between absorptive Capacty, Complementary Asset and Technology Transfer Strategy.

The different methods of technology transfer and the strive for innovation have allowed for different capactieis and functions that fall under R&D. The first is the absorptive capacity, which is a function of R&D that resonates from the investment by firms, while patents are the products of that R&D investment.   Hence, the number of patents in a certain field is a substitute metrics for absorptive capacity. Employees' ability and motivation helps them to internalize external knowledge and through absorptive capacity firms' innovative capability can be enhanced. Hence, knowledge is related to absorptive capacity.

If the attractiveness of technology is high then the field of technology is young; Since the high attractiveness of technology means that the technological field is young, attractiveness of technology may be directly matched to the innovativeness technology. Attractiveness of a technological field can be measured by using relative growth rates of patent applications. Patent growth in recent years relative to patent growth in preceding years is a measure of attractiveness because it shows recent developments in patent growth. Technological fields with high relative patent growth rates are considered as the potential fields   that would become more attractive in the future than those fields with low relative patent growth.

Complementary assets are assets that are utilized in manufacturing, marketing, and distribution system in order to package technology. so that it becomes valuable to end users.

Aappropriability is the property of knowledge and the environment in which an invention is protected from imitation' If IPR is effective then new technology will not be bothered by infringement. If the patent protection or appropriability is high it will allow time   to raise money from capital markets. This helps to build or acquire complementary assets needed to successfully commercialize the technology.[12]

Considering the different levels of strength in technology attractiveness and need for complementary assets, the following matrix can be drawn based on the technology framework.

Absorptive Capacity

Licensing	**Collaborative R&D**
New Firm Creation Strategy	**Joint Venture**

Low **Need for Complementary Assets**

Figure 5: Different Technology Transfer Options Based on Absorptive Capacity and Complementary Assets.

3.0 PV Industry

3.1 What is Photvoltaic Cell

PhotoVoltaic Cells (PV Cells) is the "Direct Conversion of light into electricity at the atomic level." The main component that makes this converstion possible are semi-conductors. This process is possible due to a property that is known as photoelectric effect. This causes semiconductors to absorb photons of light and release electrons, which are then captured resulting in an electric current (electricity).[13]

3.2 PV Manufacturing Process

The PV production follows four stages:

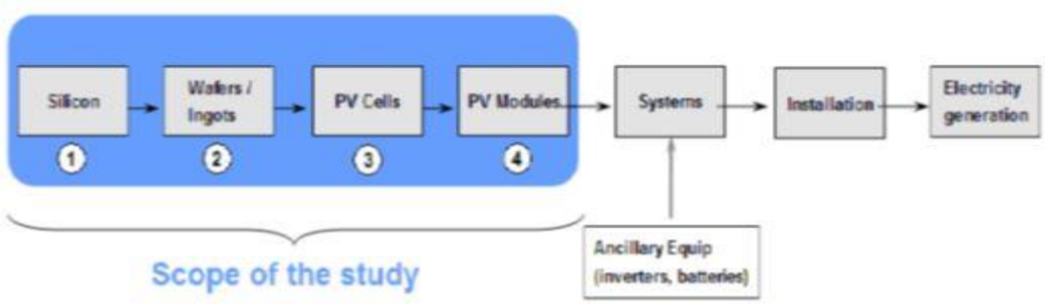
1. Silicon purification
   Silica ($SiO2$) found in quartz sand ified s purified (> 99.999% pure) through heavy and highly energyconsuming chemical processes.

2. Ingot and wafer manufacturing
   Pure silicon is molded into an ingot – a cylinder or a brick of silicon. It can be a single crystal, called monocrystalline silicon or monosilicon, or multiple silicon crystals that are smaller; a material called polycrystalline silicon or polysiliconiv. Then, using a saw, ingots are sliced into thin layers called wafers. Secondary processes like polishing are involved.
3. Cell production
   To form the cell, two differently doped wafers are assembled together to form a so-called p-n junction responsible for the photovoltaic effect, and the top and rear metal contacts are applied. Many treatments or modifications in the process can be applied to increase the efficiency.

4. Module assembling
   Cells are soldered together, the electrical junction being done by hand or automatically, and the cells are encapsulated in glass sheets to form a module which will be cooked in a laminating machine.

3.3 PV Supply Chain

Figure 6. shows the supply chain of PV industry. After the four technical stages of production, PV systems are connected with complementary equipment e.g., battery or inverters. It is an integrated system which can generate power after installation.



Source: Tour, Glachant,Ménière (2010)

Figure 6: PV Supply Chain

The first four stages accounted for 60% of the average global cost of installed PV systems in 2006.[14]

4.0 Methdology

Data is collected on Chinese and Indian Photovoltaic Cell industries. With the aid of the TT framework, the questions intended to be clarified in the objective section are answered for industries in individual county. A cross case analysis is done to compare the size, TT approaches (in take-off and catch-up stage and number of patents to compare the innovation capability. This is a qualitative analysis based on the data available in various literatures or articles.

5.0 Findings and Analysis

5.1 Chinese PV Technology

China produced one third of worldwide solar photovoltaic cell production in 2008. It exports 95% of what it produces. Chinese producers are mostly active in downstream segments of the PV production chain – cell production and module assembling. Western companies continue to lead upstream markets – in silicon purification, ingot and wafer manufacturing – where technological skills are key assets. In order acquire this capability China adopted technology transfer strategy through different ways.[14]

<table>
<tr><td colspan="3">1. How production technology and skill are acquired</td></tr>
<tr><td>AbsorptiveCapacity</td><td>High</td><td>China has more patents in downstream segments. Knowledge enrichment is made possible by Chinese entrepreneurs from the Chinese Diaspora who have managed to build pioneer PV firms, exploiting China's comparative advantage of cheap labour and energy in PV cells and module segments</td></tr>
<tr><td>Need for Complementary Assets</td><td>High</td><td>The purification of metallurgical grade silicon into electronical grade silicon is based on the Siemens process –which is known for decades. The key to purifying silicon at reasonable cost, however, is challenging, which requires precisely controlling the parameters of all the chemical reactions. Major western and Japanese silicon producers have developed advanced know-how in this domain, which they usually keep secret. Hence, China needs complementary assets to package the PV cell technology.</td></tr>
<tr><td>TLC</td><td>Growing</td><td>Private patents represent less than 40% of total Chinese patented innovation against around 85% in industrialized countries.</td></tr>
<tr><td>Appropriability</td><td>Weak</td><td>Lack of implementation of Intellectual Property Rights</td></tr>
<tr><td colspan="3">China has acquired the technologies to produce cells and modules through the purchase of manufacturing equipment – in particular turnkey production lines – on acompetitive international market   Foreign Direct Investments, mainly through the establishment of joint-ventures with western partners, are very significant in recent times.</td></tr>
<tr><td colspan="3">2. How diffusion of technology ocurred?</td></tr>
<tr><td colspan="3">Diffusion of technology occurred through the following means.</td></tr>
<tr><td colspan="3"><u>Diffusion through import of equipment</u>
The explicit part of knowledge diffused through Importing of equipment goods. The tacit knowledge or complementary know-how is induced by training sessions of engineers and technicians operating the production line. The PV manufacturers adapt their production chain to local conditions. Some equipment substituted with a cheaper workforce. Large PV manufacturers develop partnerships with equipment suppliers, sharing know-how and feedback to improve the manufacturing process. Although they may include temporary exclusivity clauses, such partnerships allows suppliers to propagate the know-how to other customers. This expedites spread of knowledge across the industry.
<u>Diffusion through International Trade</u>
Chinese equipment goods supplier cannot produce turnkey production lines but there are significant number of firms who sell specific equipment. Chinese firms manufacturing PV products to buy cheaper production equipment customize their production line to integrate specific Chinese equipment.
<u>Diffusion through labor mobility</u>
For operation of manufacturing process skilled employees are required. Highly skilled professionals from abroad brings capital, professional network and technology/knowledge acquired from foreign companies and universities to China.[14]</td></tr>
</table>

5.2 Indian PV Technology

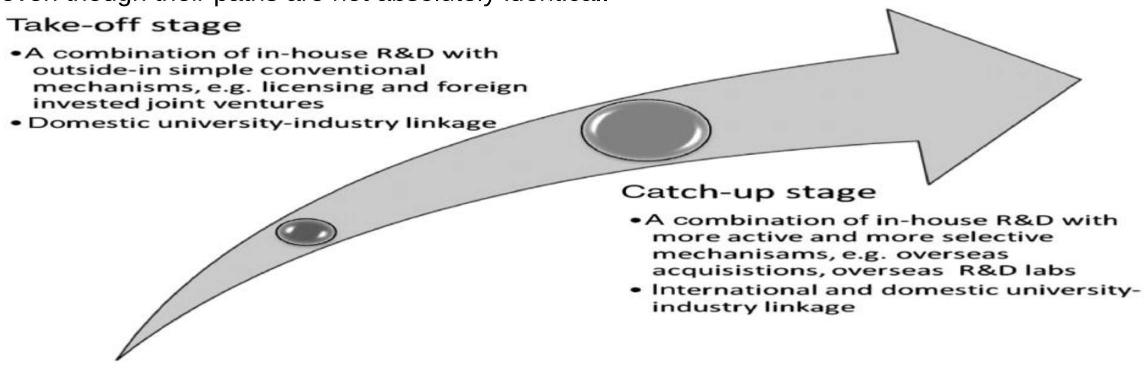
India has had significant capacity in solar cell and module manufacturing, with almost no presence in the upstream sectors, such as polysilicon and wafer.Solar PV Industry: Global and Indian Scenario, 2008,India Semiconductor Association.[14]

1. **How production technology and skill are acquired**		
AbsorptiveCapacity	**High**	Sound manufacturing capability and availability of an abundant talented workforce. India has had a national solar PV programme since the mid 1970s. In the first decades, the sector was mainly public, with state owned enterprises undertaking R&D and manufacturing of solar modules and other public organization purchasing solar systems. By the mid-1980s, own indigenous technology and manufacturing capacity was completed and emerged in to commercial sales . Although not close to world state-of-the art PV module efficiency, India did develop indigenous capabilities in the field of PV.
Need for Complementary Assets	**High**	The solar PV manufacturing base in India comprises primarily of cell and module manufacturing; with the bulk of the value addition needs to be filled up from outside the country**.** India needs investment inThin film technology and Crystalline silicon technology.
TLC	**Growing**	A large number of solar PV production patents for mature mono- and multi-crystalline silicon cells have expired and the technology and have been picked up by many Indian manufacturers. In more advanced technologies where patents remain, it has been easy for Indian companies to acquire the technology through licensing agreements. However, Indian owned PV patents are on the rise and the domestic engineering and technical capabilities have proved important to pick up and refine technologies, and produce at a low cost.
Appropriability	**Weak**	Lack of implementation of Intellectual Property Rights
TT in India has taken place through licensing of patents; collaboration and acquisitions, such as strategic alliances, and joint ventures and other equity relations; and in-house R&D. In addition, collaboration with national research institutions and use of expired patents have been key inputs of Indian PV firms for technology acquisition.		
2. How diffusion of technology ocurred?		
Diffusion of technology occurred through the following means.		
<u>**Diffusion through International Trade**</u> The Indian solar PV case is a blend of conventional and unconventional technology transfer and indigenous technology, particularly a crucial effort in own R&D. Although not necessarily a state-of-the-art industry, capabilities and cost advantages have enabled India to become a solar PV industry manufacturing at a relatively high quality and low cost. Even though linkages to foreign technology are strong in industry, there are not always transfer-transferee relationships and the source of competitiveness is as much the country's own capabilities. Mallett et al. (Mallett*et al.* 2009: 73) find that "Indian firms actively drive the process and so play more a leadership role in the technology transfer process". <u>**Diffusion through labor skill**</u> For operation of manufacturing process skilled employees are required. Highly skilled professionals in this field are available in India.[14]		

6.0 Cross Case Analysis

The analysis concludes the following differences with respect to PV technology in China and India:

Figure 7. provides a general path of development for the solar PV industries of China and India, even though their paths are not absolutely identical.[16]



.**Figure 7. Mixing and sequencing of technology creation and acquisition mechanisms in solar PV industry in China and India.**

	China	India
Type of TT	“Home-based’ outside-in technology transfer and indigenous innovation model;	‘Go-global’ active technology acquisition model.

Table 1 shows the statistics of different TT options adopted by China and India and different stages of technology.

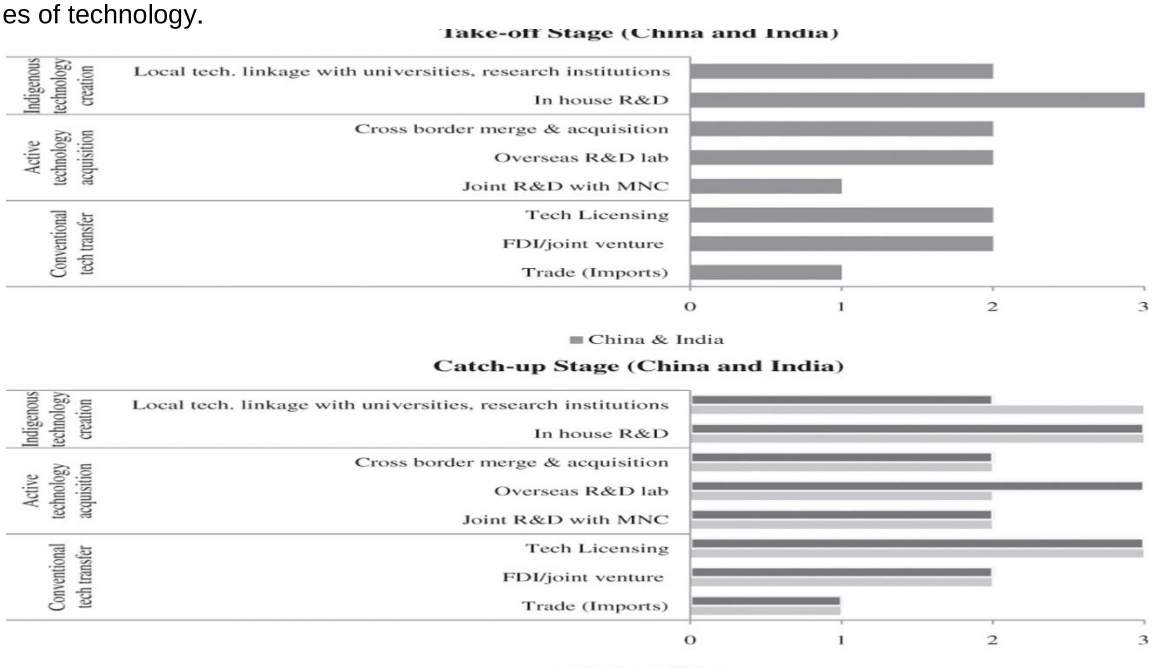


Table 1:Take-off Stage and Caught-up Stage Comparison Between China and India

	China	India
Take-off	Similar approaches	Similar approaches
Caught-up	In Indigenous Technology Creation, China leads India in their Local technology linkage with universities and research institution.	In the Active Technology Acquisition, India leads China in Overseas R&D Labs.

Table 2. Details of leading solar PV companies in China and India.[16]						
	China*			**India**		
	Suntech	**Yingli Solar**	**Trina Solar**	**Moser Baer Solar**	**TATA BP Sola r#**	**HHV Solar**
Year founded	2001	1998	1997	2005	1989	2007
No. of employees	20,231	11,435	12,863	>7000	>600	100–500
Turnover (million)	$ 2901.9	$1893.9	$1857.7	> $500	$250	$35†
Total assets (million)	$ 5217.1	$3664.9	$2132.1	>$1000	N/A	N/A
Sales in MW	1572	1061.6	1057	300‡	67.4	40
Exports (%) of sales	94.7%	94.00%	96.20%	90%	79.20%	81–90%

Notes: *all data for Chinese companies are as of the end of 2010; # turnover, sales, and exports for TATA BP solar are as of 2008–2009 fiscal year; †the 2010 goal set by HHV Solar; ‡production capacity by 2010.

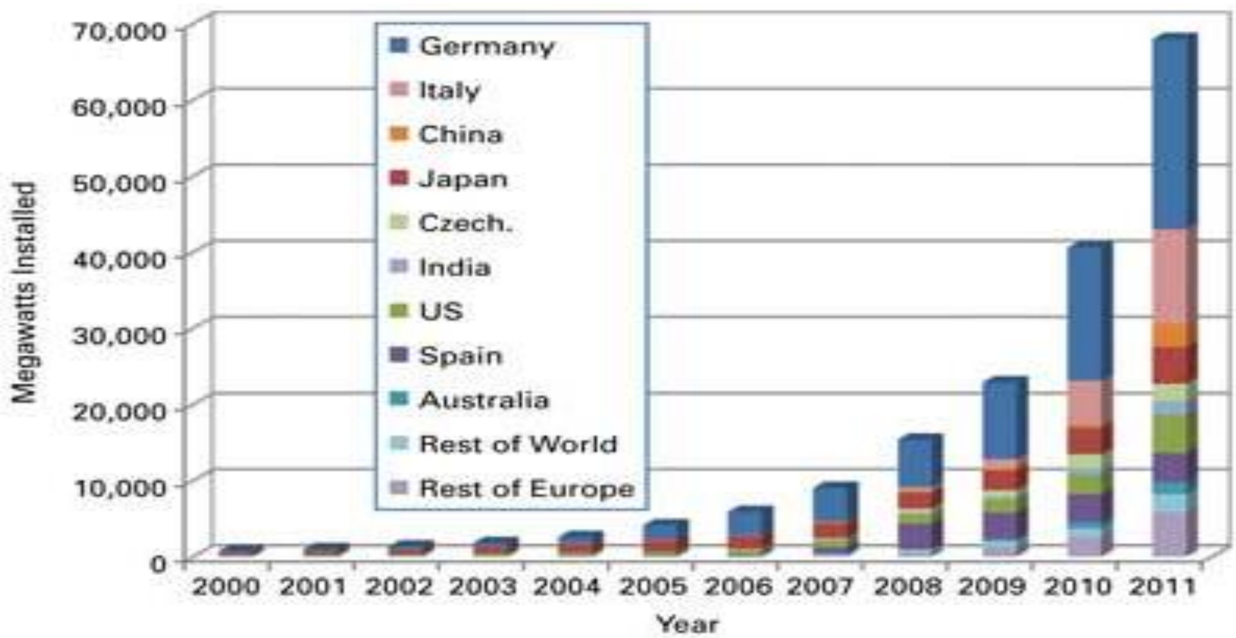
Sources: Company websites, annual reports and various press news.

	China	**India**
SIze	Firms are almost three times larger than in India	Indian firms are smaller
PV Technology	China started loate than India and all the large firms developed within five years time span.	Tata Sola is the oldest PV manufacturing firm but the other firms developed quite late.
Turnover and Sales in MW	Chinese firms are larger in terms of turnover and sales in MW	Indian firms have less turnover and sales in MW
Export % of sales	Most of the firms export above 90% of their sales	Indian firms also export comparable % of sales
Innovation capabilities of the countries	Chinese companies have acquired innovation capability through R&D ‘State Key Laboratory’ that cooperates with key suppliers,local universities and research, strong international technology linkages including R&D cooperation with MIT in the US, Australia National University and Singapore’s national institute for applied solar energy research. These collaborations are backed by in-house R&D, local R&D cooperation and acquisitions backwards in the supply chain. On the other hand, it has research agreements with centres of excellence and technology companies in The Netherlands and has opened a facility in Singapore to do overseas in-house R&D.[14]	Domestic engineering and technical capabilities have enbled India to pick up and refine technologies, and produce at a low cost. India has the innovation capability in PV.
IP Effect	In the PV sector, the developing nations are facing a loose oligopoly with many entrants. Thus, developing countries have been able to enter the industry as demonstrated by firms such as Tata-BP Solar in India and Suntech in China. For biofuel technologies, IP does not appear to be. So IP is not a barrier to TT of PV in China and India. [15]	

7. 0 Conclusion

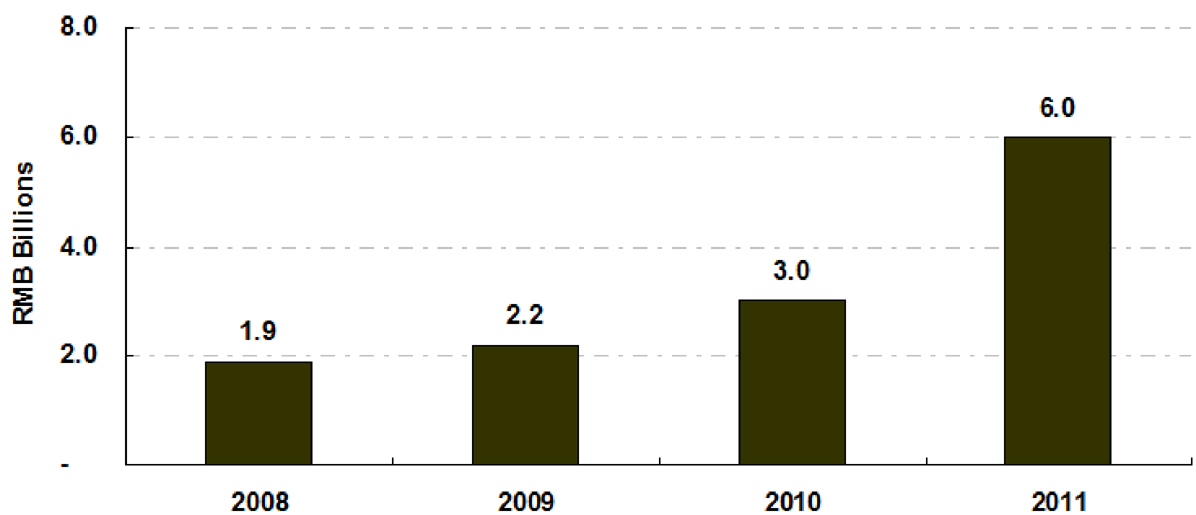
China and India have both succeeded in assimilating technology transferred through different Pathways. However, considering the respective countries adaptive capability, different means of enhancing technological capability are adopted. In both countries, humanware has proved to be an essential requirement for internalization or indeginization, Moreover, both these countries are found to be emphasizing different forms of collaboration involving universities, research centers and suppliers alike. Hence, the case analysis gives an essence how developing countries are catching up in technology with the developed countries like paratroopers through absorptive capability and choosing the right route of TT to complement assets for packaging technology that would bring value to end users.

Appendix I



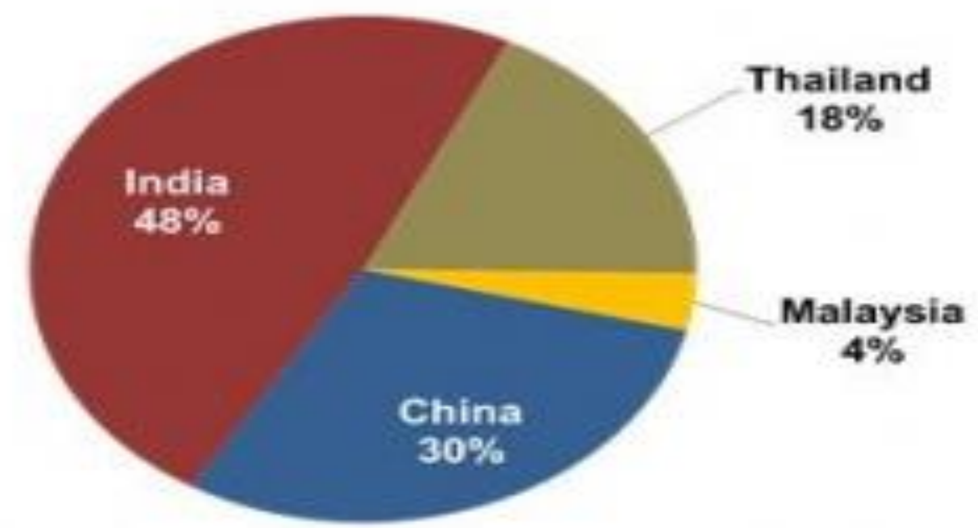
Source: EPIC, 2012

Appendix II



Source: CEPEA, 2012

Appendix III



Note:

1. PV pipeline is based upon signed PPA's, issued tenders & projects currently under construction

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