The Mechanism of Intra-Industry Technology Spillover Effects of Up-Gradient ODI and Down-Gradient ODI in China

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Abstract. With the fast development of the global division of labour, intra-industry technology spillover has become a significant manifestation of both Foreign Direct Investment (FDI) and its impact on the domestic industrial structure, as well as the key to industrial value chain upgrading. Meanwhile, China’s outbound foreign direct investment (ODI) has developed rapidly since the reform and opening up, with a large number of both up-gradient ODI in developing countries and down-gradient ODI in developed countries. Therefore, it is essential to figure out the relation between ODI and industrial technology change. This paper intends to theoretically clarify the adjustment function of ODI to intra-industry technology change and to construct the mechanism of this process. It provides a theoretical reference for the empirical analysis of the role of direct investment in intra-industry upgrading.

1. Introduction
The Chinese economy has achieved rapid growth due to the comprehensive implementation of reform and opening-up. Back in 1978, China’s gross domestic product (GDP) was about 364.5 billion Yuan, and the per capita GDP was 381 Yuan. They then soared significantly during the years, and in 2015, GDP had reached 68.55 trillion Yuan with per capita GDP of 50,000 Yuan¹. However, the rapid growth is accompanied by high investment and massiv e consumption. Take the manufacturing industry as an example; the contribution rate to its growth is 63.04% for capital, 26.23% for the labor force, but only 10.72% for total factor productivity (Zheng Ruogu, 2009). Therefore, its growth is mainly driven by factor input. This has a serious negative externality, indicating an unreasonable industrial structure, a low-position in the global value chain, and a lack of mutual support among industries, which have hindered the industrial development in China. Thus, transforming and upgrading industrial structure is urgent and important. One solution is to put forward the Belt and Road Initiative (B&R), which helps achieve new and sustainable economic growth by investing in the countries along the Road, as well as making use of their complementary advantages.

Many scholars have investigated into the competitiveness and complementarity between China and the countries along the Road, yet few went deeper into the interaction of competition and cooperation,
which can achieve capacity cooperation, coordinated upgrading, and mutual benefit. For example, when examining the economic cooperation between China and B&R countries, scholars focus mainly on the cooperation of energy and resources (Liu Jiajun, 2013), but fail to develop it at a multi-pattern and multi-aspect level. Thus, further study is of great importance. If China’s ODI in both developing countries and developed countries are of equal significance (Chen Juncong and Huang Fanhua, 2014), it should be divided into two types and studied separately: the up-gradient ODI to developing countries and the down-gradient ODI to developed countries. Due to the limitations, this paper develops solely from the perspective of intra-industry technology spillover effects to set up a theoretical framework for the impact of ODI on intra-industry technological change in China. The specific empirical analysis will be introduced later.

For up-gradient ODI, the existing studies mainly include the Flying Geese Pattern theory from Kaname Akamatsu (1962), the Product Life Cycle theory from Raymond Vernon (1966) and the Marginal Industrial Expansion theory from Kiyoshi Kojima (1978). When applying those theories, it can be deduced that with the on-going international division of labour and the worsening environmental problems, the competitive advantage of traditional factor endowments of developing countries has changed, so has their positioning of core competitiveness. Therefore, the developing countries transfer the low value-added intermediate industries or production departments to the less-developing countries through up-gradient ODI, so that they can shift the focus onto research and development, design, marketing, and other high value-added intermediate industries or departments. This can better promote the domestic industrial upgrading. As for down-gradient ODI, developing countries mainly invest with the purpose of seeking advanced technology, because the investment object is more developed than the home country enterprises. With reference to those theories, this paper embeds the consideration of foreign direct investment cost from Helpman et al (2004), as well as consideration of technology factors from Kohler (2004), in the Feenstra and Hanson (1996) model, to construct the theoretical mechanism of the effect of up-gradient ODI and down-gradient ODI on industry technology change.

2. Model Construction

2.1. Theoretical Framework of Up-gradient ODI and the Determination of the Scope of ODI

Assume that there are only two countries in the world: the more developed country D and the less developed country U; the two factors of production: capital K and labour L, in which labour is divided into high-skilled labour H and low-skilled labour L; an industry Y: an integration of a series of continuous intermediate inputs z. Each unit of intermediate input z needs \( b_L(z) \) unit of low-skilled labour, \( b_H(z) \) unit of high-skilled labour and \( b_K(z) \) unit of capital, so the total factor demand of intermediate input is \( L(z), H(z) \) and \( K(z) \), respectively. Besides, assume that z is ordered as technological intensity increases, that is \( \frac{\partial (b_L(z) / b_H(z))}{\partial z} > 0 \), to index all commodities z to a continuous set of commodities \([0,1]\). What’s more, a supplementary assumption is made to the order of z that it is in accordance with the order in which the capital intensity increases.

Here we assumed the production function of intermediate input z is compound by Leontief and C-D, that is:

\[
x(z) = A \min \left\{ \frac{L(z)}{b_L(z)}, \frac{H(z)}{b_H(z)}, \frac{K(z)}{b_K(z)} \right\}^{1-\theta}, i = D, U
\]  

where \( 0 < \theta < 1 \) and A is a constant.

The two countries have Hicks-neutral technical difference, that is \( A_D > A_U \), indicating that the technical level of the more developed country D is higher than that in the less developed country U. The final product is assembled at no cost according to the production technology:

\[
\ln Y = \int_0^1 a(z) \ln x(z) \, dz, \quad (2)
\]

where \( \int_0^1 a(z) \, dz = 1 \) and \( a(z) \) is the proportion of intermediate inputs in total inputs (2)
A country's low-skilled labour endowment, high-tech labour endowment, and capital endowment are defined as \( L_i \), \( H_i \), and \( K_i \) respectively as the factor price corresponding to \( w_i \), \( q_i \), and \( r_i \). Assume that the technological gap and factor endowment differences between countries D and U are large enough so that factor prices will not be equalized.

Since the more developed country D has more sufficient capital endowment and high-tech labour, while the less developed country U has more low-skilled labour, country D has a lower capital return \( (r_D \leq r_U) \), and a higher wage return rate ratio of high-tech labor to low-skilled labour \( (q_D/w_D > q_U/w_U) \) compared with country U, according to the law of supply and demand. At the same time, suppose that the supply of high-skilled labour and low-skilled labour is in comparison to the relative wage, then \( L_i'(q_i/w_i) \leq 0 \) and \( H_i'(q_i/w_i) \geq 0 \) can be proved, since the increase of relative wage will lead to the decrease of the low-skilled labour supply, as more of them become high-skilled labour by means of learning and technological training.

According to the principle of cost minimization, the cost of producing a unit of commodity \( z \) by country \( i \) can be expressed as:

\[
c_i(w_i, q_i, r_i; z) = B_i[w_i b_L(z) + q_i b_H(z)]^{\theta} [b_K r_i]^{1-\theta}
\]

where \( B_i = \theta^{-\theta} (1-\theta)^{-(1-\theta)} A_i^{-1} \), while \( c_D(w_D, q_D, r_D; z) \) and \( c_U(w_U, q_U, r_U; z) \) are the cost of producing a unit of commodity \( z \) by country D and U respectively.

About the principle of cost minimization, we can deduce the production cost line \( CD \) for country D and \( CU \) for country U, with all commodities \( z \in [0,1] \). Since country D has competitive advantage over high-skilled labor-intensive product, while country U has that over low-skilled labor-intensive product, \( CD \) must be higher than \( CU \) when producing the high-skilled labor-intensive product. It could be applied in the production of a low-skilled labor-intensive product that \( CD \) must be lower than \( CU \), as shown in Figure 1. Since all the intermediate input \( z \in [0,1] \), the proportion of capital in cost for the two countries is both \((1-\theta)\). Therefore, the two lines will have only one point that equates the two costs, as \( z^* \) in Figure 1, which satisfies:

\[
c_D(w_D, q_D, r_D; z^*) = c_U(w_U, q_U, r_U; z^*)
\]

Here we add a method to determine whether the more developed country D has a competitive advantage of saving cost in producing commodity \( z \):

\[
r(w, q, r; z) = \frac{c_D(w_D, q_D, r_D; z)}{c_U(w_U, q_U, r_U; z)} = \frac{A_U}{A_D} \frac{w_D}{w_U} \frac{1 + \frac{q_D b_H(z)}{w_D b_L(z)} \frac{r_D}{r_U}}{1 + \frac{q_U b_H(z)}{w_U b_L(z)}}^{\theta} (1-\theta)
\]

If \( r(w, q, r; z) > 1 \), that is, \( c_D(w_D, q_D, r_D; z) > c_U(w_U, q_U, r_U; z) \) and \( z < z^* \), it means that the less developed country U has the advantage of saving cost when producing commodity \( z \in [0, z^*] \). On the contrary, if \( r(w, q, r; z) < 1 \), that is, \( c_D(w_D, q_D, r_D; z) < c_U(w_U, q_U, r_U; z) \) and \( z > z^* \), it means that the more developed country D has the advantage of saving cost. Yet if \( r(w, q, r; z) = 1 \), that is, \( c_D(w_D, q_D, r_D; z) = c_U(w_U, q_U, r_U; z) \) and \( z = z^* \), there would be no difference in cost for the production of \( z \) in the two countries. Meanwhile, since \( q_D/w_D < q_U/w_U \) and \( \frac{\partial(b_H(z) / b_L(z))}{\partial z} > 0 \), when the price of the two production factors and technology remain constant, \( r(w, q, r; z) \) decreases as \( z \) increases.
Then we consider the cost of ODI referring to the idea of Helpman et al. (2004). Lots of input costs are incurred in the process of ODI, such as contract signing, information exchange, plant construction and so on. When the cost of ODI is lower than that of trade, a country will choose the former. Suppose this input cost is \( \tau(z) > 1 \), which means that when the country U produces one unit of commodity z domestically, the foreign direct investment in country U should produce \( \tau(z) \) unit of z. Thus, the investment cost will lead to a certain loss for cross-broader production. At the same time, given that ODI will have reverse technological spillover effect \( \rho(z) > 1 \), which is generated by the Industrial Combined effect, Forward and Backward Connection Effect, as well as Synergy Effect, the home country can achieve economy of scale and technology advancement. Meanwhile, the country receiving foreign direct investment would benefit from technological spillover effect \( \lambda(z) \), since the FDI inflow is accompanied by the transfer of integration of technology, management experience, and human resources, which ultimately generate technological spillover through Connection Effect. To simplify the analysis, we refer to the methodology of Zheng Ruogu (2011) to assume a Hicks-neutral technological spillover, whose impact on capital and labour is proportional.

Taking the cost of ODI and the reverse technological spillover into consideration, the competitive advantage of cost in producing commodity z is determined by:

\[
\Gamma(w, q, r; z) = r(w, q, r; z) = \frac{A_D(\lambda(z))}{A_D(\tau(z), \rho(z))} \left( \frac{w_D}{w_U} \times \frac{1 + \frac{q_D b_H(z)}{w_D b_L(z)}}{1 + \frac{q_U b_H(z)}{w_U b_L(z)}} \right)^{\theta} \left( \frac{\tau_U}{\tau_D} \right)^{1-\theta} \tag{6}
\]

In this equation, \( A_D \) is the function of \( \tau(z) \) and \( \rho(z) \). Since \( \partial A_D / \partial \tau < 0 \) and \( \partial A_D / \partial \rho > 0 \), the increase of ODI cost has a negative impact on the production technology of country D’s multinationals, while the reverse technological spillover effect can positively promote technology growth for them. On the other hand, \( A_U \) is the function of \( \lambda(z) \), and \( \partial A_U / \partial \lambda > 0 \) means that positive technological spillover can boost technology development in the host state being invested.

Given that the cost of ODI and the reverse technological spillover effect exist, we assume the more developed country D has a higher level of “technology” than the less developed country U, \( A_D(\tau(z), p(z)) > A_U(\lambda(z))^2 \). Therefore, \( A_D(\tau(z), p(z)) \) would have a lower limit, which represents the overall “technology” level of country D. In this way, we can assure that \( \Gamma(w, q, r; z) \) has the same \( z \) monotonicity as that of \( r(w, q, r; z) \).

Thus, we can determine the scope of industries for the ODI of a more developed country based on their competitive advantage, as shown in Figure 4.2. To be specific, if \( \Gamma(w, q, r; z) > 1 \), the less...
developed country U has a competitive advantage in producing commodity \( z \in [0, z^*] \); On the contrary, if \( \Gamma(w, q, r; z) < 1 \), the more developed country D gains a competitive advantage in producing commodity \( z \in [z^*, 1] \). If \( \Gamma(w, q, r; z) = 1 \), there would be no difference between the two countries to produce commodity \( z \).

It can also be proved that, when the more developed country encounters a rapid growth of technology, a reducing ODI cost, and rising trade barriers, the scope of ODI would be enlarged, as shown in Figure 2, a movement from \( z^* \) to \( z' \).

2.2. Theoretical Framework of Down-gradient ODI and the Determination of the Scope of ODI

Similar to the examination of up-gradient ODI, we still assume the only two countries in the world: the more developed country C and the less developed country D, and other assumption being the same as that of up-gradient ODI. Also, suppose the production function of intermediate input \( z \) is compounded by Leontief and C-D, that is:

\[
x(z) = A \left[ \min \left( \frac{L(z)}{b_i(z)}, \frac{H(z)}{b_j(z)} \right) \right]^{\theta}, \quad \text{if } i = \text{D, C}
\]

where \( 0 < \theta < 1 \) and \( A \) is a constant.

The two countries have Hicks-neutral technological differences that \( A_C > A_D \), which means the technology level of the more developed country C is higher than that of the less developed country D. The final product is combined with no cost according to production technology:

\[
\ln Y = \int_0^1 \alpha(z) \ln x(z) \, dz, \quad \text{where } \int_0^1 \alpha(z) \, dz = 1
\]

According to the cost minimization principle and the analysis of up-gradient ODI, it can be deduced that the less developed country U have a competitive advantage when producing commodity \( z \in [0, z^*] \), while the more developed country C gains a competitive advantage when producing \( z \in [z^*, 1] \). Furthermore, when the more developed country encounters a rapid growth of technology, a reducing ODI cost, and rising trade barriers, the scope of ODI would be enlarged.

2.3. The Impact of ODI on Industrial Technological Change

2.3.1. The Analysis of Technological Spillover Effect of Up-gradient ODI

Here we loosen the assumption that the technical level of all intermediate inputs for the more developed country D has a lower limit of AD. Since there is not only reverse technology spillover in ODI but also technology spillover effect on host country being invested. That means \( \rho(z) > 1 \) will lead to the increase of AD and AU of country D and U, which ultimately lower the cost of producing commodity \( z \) for both countries. Thus, as shown in Figure 4-1, the cost line of CDCD and CUCU moves downward, and the intersection of the two cost lines is a marginal scope of ODI, which is also the intersection of 1 and every curve of competitive advantage of cost. This means that ODI is the function of both positive technology spillover and reverse technology spillover. Furthermore, taking into account the expansion of ODI (increasing \( z^* \)), which is to increase an amount of \( dz \) on the original \( z^*_D \) basis, so that the previous equilibrium of E0 is broken and a new equalization of E1 is reached, the equal-cost line can be expressed as:

\[
\Gamma(w, q, r; z_D^* + dz) = r(w, q, r; z_D^*) = \frac{A_U(\lambda(z_D^*))}{A_D(\tau(z_D^*), \rho(z_D^*))} \left( \frac{w_D}{w_U} \right) \times \frac{1 + \frac{q_D b_H(z_D^*)}{w_D b_i(z_D^*)} \theta}{1 + \frac{q_U b_H(z_D^*)}{w_U b_i(z_D^*)} \theta} \left( \frac{r_U}{r_D^*} \right)^{1-\theta}
\]

Due to the technology spillover that \( \partial A_D(\tau, \rho) / \partial \rho > 0 \) and \( \partial A_U(\lambda) / \partial \lambda > 0 \), the cost lines of both two countries continue to move downward and reach a new equilibrium of E2. However, whether it is bigger or smaller depends on the degree of movement. In this way, after many rounds of adjustment, it will finally reach the equilibrium of En, with an outsourcing critical point of \( z_D^*_n \). Thus, it can be deduced...
that if the cost reduction from positive technology spillover generated by investing abroad is greater than the cost reduction from reverse technology spillover to the home country, the scope of ODI will be enlarged. In contrast, if the cost reduction from positive technology spillover generated by investing abroad is less than the cost reduction from reverse technology spillover to the home country, the scope of ODI will shrink.

2.3.2. The Analysis of Technological Spillover Effect of Down-gradient ODI. Similar to the examination of up-gradient ODI, we loosen the assumption that the technical level of all intermediate inputs for the more developed country D has a higher limit of \( \bar{A_D} \). Since \( \rho(z) > 1 \), the \( A_D \) and \( A_C \) for country D and C move upward, so that a new equilibrium is reached. Due to the technology spillover effect that \( \partial A_D(\tau, \rho) / \partial \rho > 0 \), as well as \( \partial A_H(\lambda) / \partial \lambda > 0 \), the cost lines of both two countries continue to move downward and form a new equilibrium. Again, whether the new level is bigger or smaller depends on the level of movement of the two cost lines. In this way, after many rounds of adjustment, it will finally reach the equilibrium of \( E_n \), with an outsourcing critical point of \( z^* \). However, what is different from up-gradient ODI is that down-gradient ODI seeks more for reverse technology spillover and less for the spillover to the host country. What’s worse, the host country may even adopt various barriers to hinder down-gradient ODI. Therefore, we deduce that the reverse technology spillover effect is much larger than the spillover to host country in down-gradient ODI.

3. Conclusion
Based on the above models, the internal mechanism of intra-industry technological change for up-gradient ODI and down-gradient ODI is deduced as follows:
Firstly, the technology spillover effect generated from the expansion of ODI scope is determined by the relative degree of positive technology spillover effect and reverse technology spillover effect.
Secondly, since there is a positive technology spillover effect on the host country and a reverse technology spillover effect on the home country, the technology change generated from the expansion of the ODI scope is determined by the relative degree of the positive technology spillover effect and the reverse technology spillover effect.

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