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FDI and the Evolution of Directed Technological Progress Bias: New Evidence from Korean Outward Investment

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Abstract

Purpose – Southeast Asia has been the focus of Korea's foreign investment. Korea has been helping developing countries in Southeast Asia achieve economic growth and win-win cooperation through capital exports. FDI is an important channel for technology diffusion. However, the impact of FDI on the bias of technological progress in the host country is dependent on the host country's own endowment structure and capital–labor factor substitution elasticity. Therefore, the central issue of this paper is to accurately evaluate the impact of Korea's FDI to the four Southeast Asian countries in various industries on their bias of technological progress.

Design/methodology – The paper uses macroeconomic data for Korea and four East Asian countries to estimate capital–labor factor elasticities of substitution using nonlinear, seemingly uncorrelated regressions (NLSUR). Then, the biased technological change index (BTCI) is calculated for each country. Finally, panel data analysis is used to explore the impact of Korean FDI in various industries in the four Southeast Asian countries on their own directed technological progress, and a robustness test is conducted.

Findings – There is a substitution relationship between capital and labor factors based on their elasticity in Korea, Singapore and the Philippines. There is a complementary relationship between capital and labor factors in Indonesia and Malaysia. According to the BTCI, there is a trend toward labor-biased technological progress in all countries. Korean investments in manufacturing, wholesale and retail trade in the host country trigger capital-biased technological change in the host country; investments in the finance, insurance and information and communication sectors trigger labor-biased technological change. In addition, this paper also confirms that directed technological progress can enable cross-country transmission.

Originality/value – The innovation of this paper lies in three aspects. First, we estimate the BTCI for five countries and explore the trend and situation of directed technological progress in each country from each country's own perspective. Second, we explore the impact of Korean FDI in the host country on the bias to its technological progress at the industry level. Second, we explore the impact of Korean FDI in various industries in the four Southeast Asian countries on the four countries' own directed technological progress from a national perspective. Finally, we propose corresponding countermeasures for technological progress from the perspective of inverse factor endowment. These innovative points not only expand the understanding of technological progress and cross-country technology transfer in East Asia but also provide practical references for policy-makers and business operators.

Keywords: Capital-labor Factors Substitution Elasticity, Directed Technological Progress, FDI, Korea, Southeast Asian

JEL Classifications: C30, F21, O33

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1. Introduction

Economic globalization strengthens the connection and cooperation of national economies, and dynamic economies are bound to benefit neighboring countries or regions by means of trade, technology export, and capital export. This leads to changes in technology, industry, etc., in the host country and benefits passed on to them. (Caves, 1971; Lin and Kwan, 2016). In a technology-neutral analytical framework, host countries benefit more from FDI, such as by gaining technology spillovers (Kohpaiboon, 2006; Lu et al., 2017; Razzaq et al., 2021; Tian, 2007). However, technology is not neutral. Hicks (1963) argues that technological progress can be classified as capital-saving, labor-saving, and neutral. Acemoglu (1998, 2002, 2003a) further defines biased technological progress as the effect of changes in the marginal rate of substitution of production factors on different degrees of technological progress. However, when new technologies are assumed to be nonneutral, there is heterogeneity in the impact of new technologies, transmitted through FDI, on countries with different levels of relative factor abundance. In recent years, emerging economies, transitioning countries and developing countries have relaxed their FDI policies and introduced many policies to attract investors. Host countries can benefit more from FDI than the country sending the investment, with benefits ranging from technology spillovers to human capital accumulation, a better market environment, and deeper regional integration (Papanastassiou, 2009; Schneider and Frey, 1985).

Korea is a country with an export-oriented economy (Su and Zhang, 2022). Since the relaxation of restrictions on FDI in 1990, Korean outward investment has increased significantly (Hill et al., 1996). Korean outward investment has generally focused on selecting labor-intensive industries, creating many jobs in host countries (Bae and Jang, 2013; Mah and Noh, 2012). The reasons for Korean firms to invest overseas include rising local production costs in Korea, demand from overseas markets, scarcity of natural resources, and the development needs of domestic firms. The endowment structure of Southeast Asian countries is mutually compatible with that of Korea and therefore favored by Korean investors. For a long time, Korea has been continuously investing in Southeast Asian countries in search of broader markets, various natural resources, and higher production efficiency (Tan, 2013). As a result, South Korea signed a free trade agreement with ASEAN in 2006. In 2017, South Korea proposed the New South Policy to diversify its foreign economy by increasing investment and trade with ASEAN countries (Ha and Ong, 2020). Due to the different endowment structures of ASEAN countries, four ASEAN countries that are more compatible with Korea's endowment structure are selected as the research samples in this paper to make the study more representative.

Therefore, we explore the impact of FDI inputs in various industries in host countries on their bias in technological progress from the perspective of targeted technological progress. This paper can fill the gap in the literature on regional economic integration and provide empirical support for Korea's next step in capital export. Korean FDI helps Southeast Asian countries achieve economic development and improve Korea's international status in Southeast Asia. In addition, this paper provides policy recommendations for countries that introduce FDI. Based on the above analysis, this paper aims to assess the impact of FDI from Korea to four Southeast Asian countries (Indonesia, Malaysia, the Philippines, and Singapore) on the directed technological progress in the host countries through industry transmission. This paper selects macro and trade data for five countries from 2000-2019, constructs a standardized supply-side systems approach to estimate the capital–labor factor substitution elasticity for each country using NLSUR, and calculates the BTCI. The study finds that the capital–labor factor substitution elasticity for South Korea, Singapore, and the Philippines show a substitution relationship during 2000-2019. The capital–labor factor substitution elasticity for Indonesia and Malaysia shows a complementary relationship. The capital–labor factor substitution elasticity for Indonesia and Malaysia shows a complementary relationship. Based on the calculated BTCI, it is found that although there are differences in the BTCI across countries, there is a trend toward labor-biased technological progress in all countries.

Finally, we conducted robustness tests based on the estimation results of fixed effects combined with SYS-GMM. We find that, first, Korea's FDI investment in wholesale and retail trade and manufacturing is significantly positive for the four Southeast Asian countries. This indicates that Korea's investment in these two industries influences the BTCI in the host country in the direction of capital, which raises the marginal output of capital. Information and communications, financial and insurance activities are significantly negative, suggesting that Korean investment in these two sectors influences the BTCI toward labor in the host country and raises the marginal output of labor. Second, comparing FDI inputs in different industries corroborates that directed technological progress is transmitted across countries using FDI as a channel. It is also found that the directed technological progress of the host country has different effects when investing in different industries. However, in some industries, there is a trend of inverse endowment with itself.

This paper is related to a wide range of topics in the literature, such as studies on the effects of FDI and technology spillover. The technology spillover effects of FDI to host countries have also been extensively discussed in existing studies, revealing that host country governments bring in foreign investment by developing a series of macro and micro policies to attract foreign investors. (Anyanwu, 2012; Herrera-Echeverri et al., 2021; Schneider and Frey, 1985; Teeramungcalanon et al., 2020). FDI can influence the innovation capacity and efficiency of host countries by providing newer technologies through technology spillovers (Coe and Helpman, 1995; Ito et al., 2012; Liu and Buck, 2007; Pietrucha et al., 2018). FDI is an important component of globalization, which improves international trade in products and services trade, expanding the scope of a country's economy and thus improving labor skills and labor income in host countries (Clark et al., 2011; Driffield and Taylor, 2000; Jauhari and Mohammed, 2021; Yunus et al., 2015). In the aforementioned studies, scholars have studied the relationship between FDI and technology spillovers within the framework of the study of neutral technological progress. The difference between this paper and the above studies is that this paper introduces directed technological progress. The relationship between FDI and technology spillover has been studied within the framework of nonneutral technology spillover, i.e., it has been put into the framework of directed technological progress.

FDI also positively affects the technological progress of different industries in the host country. Nadiri (1992) argues that the increase in the capital stock of multinational companies increases new investments in plant and equipment in the host country and positively affects the total factor productivity of manufacturing in the host country. Patibandla (2014) argues that FDI promotes technological progress in the supply chain of wholesale and retail trade in the host country, expanding output and contributing to economic and employment growth. Therefore, this paper argues that FDI promotes capital efficiency in the host country through its inputs in wholesale and retail trade. Latif et al. (2018)

argued that after the relaxation of ICT sector conditions for FDI in BRICS countries, FDI brought advanced ICTs to the host countries, e.g., fiber optics, internet, big data, wireless telephone services and the internet of things (IoT). Capik and Drahokoupil (2011) argue that FDI can create employment and skilled labor in business services, increase labor output, and transform the host region into a knowledge-based economy. Osabutey et al. (2014) argue that in the construction industry, FDI is used to transfer human capital through construction. The enhancement of human capital can effectively absorb and adapt to new technologies. In summary, scholars have analyzed the impact of FDI on various industries from both theoretical and empirical perspectives. They believe that the host country's wholesale and retail trade, manufacturing and information and communication industries will obtain improvements in capital efficiency and the capital output due to FDI. In contrast, labor efficiency and labor output are increased in business services and construction. Although these strands of the literature have studied the improvement of capital or labor efficiency and the increase of their output, they do not specifically answer the question of what kind of bias FDI has on the directed technological progress of the host country. Therefore, this paper will answer this question through an in-depth study.

This paper conducts an empirical study of FDI and directed technological progress. While a technology-neutral framework suggests that FDI can introduce new technologies, increase productivity and promote economic growth, technology is not neutral. Li et al. (2016) use a game-theoretic approach to study the impact of developed countries on directed technological progress and economic growth in developing countries through FDI.

They argue that host countries must improve their human capital to effectively absorb advanced technologies. Wang et al. (2017) use a standardized supply-side approach to calculate a BTCI for manufacturing in China and the U.S. and find that U.S. FDI has a capital-biased effect on directed technological progress in China. Jincheng LI et al. (2021) used a standardized supply-side systems approach to calculate the BTCI and used threshold regression analysis to investigate how FDI transmits directed technological progress across countries. Other scholars have also studied the relationship between FDI and directed technological progress from various perspectives, including technology outsourcing, intellectual property rights, endowment structure, trade, and migration flows (Acemoglu et al., 2015; Afonso and Magalhaes, 2021; Leite et al., 2019; Rauf et al., 2023).

This paper draws on empirical studies by scholars on FDI and directed technological progress. However, this paper takes a different research direction from the aforementioned studies. This paper aims to shift the focus of the study to examine how South Korea affects directed technological progress in four Southeast Asian countries, which has not been fully explored in previous studies. Most of the previous studies by scholars have studied FDI and directed technological progress between North and South countries or between two countries, concluding that the relationship between FDI and directed technological progress is influential between two countries. This paper, on the other hand, examines the impact of FDI on the directed technological progress in the host country by analyzing Korean investments in different industries. This approach, while examining the cross-country transmission of directed technological progress, also allows for a more comprehensive understanding of how FDI influences the directed technological progress in host countries by analyzing investment in each industry. This study provides empirical support for Korea's investment in Southeast Asian countries and enhances Korea's international position in the Southeast Asian region. In addition, this study can provide valuable insights to complement existing research on the impact of Korean FDI on directed technological progress in Southeast Asian countries.

This paper is divided into five chapters. The first chapter is the introduction. Chapter 2 presents the theoretical framework of directed technological progress, capital–labor factor substitution elasticity, and directed technological change. Chapter 3 outlines the empirical strategy, including the model construction of capital–labor factor substitution elasticity, FDI transmission, and technological progress. Chapter 4 gives the empirical results, including the estimation of capital–labor factor substitution elasticity, BTCI and regression analysis. Finally, Chapter 5 concludes the paper and discusses policy implications.

2. Theoretical Framework

2.1. Directed Technological Progress

The theory of directed technological progress was developed and refined by Acemoglu (2002, 2003a, 2003b, 2007), based on Hicks (1963). Acemoglu (2003a) further defines directed technical progress as the effect of changes in the marginal elasticity of the substitution of production factors on technical progress. Acemoglu (2002) argues that price effects and market size effects influence the direction of technical progress.

First, Acemoglu (2002) gives a micromotivation for the mechanism of directed induction of technological progress. In his model, the technological progress bias is determined by the type of machines produced and supplied by technology monopolists. The proportion of supply of different factor-enhancing machines by "technology monopolists" is determined by the relative profitability of developing two different types of machines. Directed technological progress is driven by the profits of the "technology monopolists" rather than by factor prices, thus avoiding the situation in which directed technological progress and factor substitution effects are indistinguishable.

Second, Acemoglu (2002) suggests that "technology monopolies" face two opposite effects when developing and providing intermediate goods of different technology types: the price effect and the market size effect. The elasticity of substitution of elements affects the price effect and the market size effect. When the elasticity of substitution is very low, the price of scarce factors is higher, and the strength of the price effect will exceed the market size effect. The market size effect in the mechanism induced by directed technological progress is also proposed by an innovation.

Finally, Acemoglu (2007) suggests that a directed technology model can lead to several conclusions about the bias of technological progress at equilibrium. (1) Equilibrium technology always favors the factor that becomes more abundant. (2) If the elasticity of substitution among factors is large enough, the directed technological progress will outweigh the substitution effect, leading to an increase in the relative price of the affected factors. (3) Technological progress triggered by changes in factor supply is always biased in the direction of factors of production becoming more abundant, ultimately increasing their marginal output. (4) If the overall set of production possibilities is nonconvex, then there will be a strong absolute equilibrium bias: increasing the supply of a factor induces a larger change in technical progress, which increases the marginal productivity of this factor that is becoming abundant. Thus, the endogenous technology demand curve for such a factor is upward sloping.

Thus, the price effect and the market-scale effect influence directed technological progress by affecting the profitability of technological innovation and technological progress. Under the price effect, producers are more willing to develop technologies that favor scarce factors, while under the market-scale effect, producers are more willing to develop technologies that favor abundant factors. When production factors are substitutes for each other, the market scale effect plays a dominant role. When production factors are in a complementary relationship, the price effect dominates. In general, the country's bias in technological progress matches its factor endowment. The bias is in favor of capital when capital dominates and in favor of labor when labor dominates. Combining the above methods for determining the bias of technological progress, it is clear that directed technological progress needs to be derived from changes in relative marginal output. Therefore, to study directed technological progress, it is first necessary to assess the size of capital–labor factor substitution elasticity.

2.2. Capital-labor Factor Substitution Elasticity and Directed Technological Progress

According to the range of values of the capital–labor factor substitution elasticity $\sigma \in (0, +\infty)$, the production function has four cases: $\sigma = \infty$, complete substitution, and purely linear output. $\Sigma = 1$, when the Cobb–Douglas production function is valid; $\sigma = 0$ (no substitution), when the Leontief production function is valid. If $\sigma > 1$ or $\sigma < 1$, then there is capital–labor factor substitution elasticity or complementarity. At this point, it is necessary to use the CES production function for the study. Thus, when the model is set to model the Cobb–Douglas or Leontief production functions, technological progress does not affect the marginal output ratio of capital labor. In this paper, we refer to the study of van de Klundert and David (1965) and assume that the production function is the CES production function, as follows.

$$Y_t=[\left(E_t^L \cdot L_t\right)^{\frac{\sigma-1}{\sigma}}+\left(E_t^K \cdot K_t\right)^{\frac{\sigma-1}{\sigma}})]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

Y_t is the output, K_t and L_t are the inputs of capital and labor factors, respectively, and σ ($\sigma \in (0, +\infty)$) is the capital–labor factor substitution elasticity. E_t^K and E_t^L represent capital efficiency and labor efficiency, respectively. They are called capital-augmented and labor-augmented technological progress.

Inspired by Hicks (1932) and Acemoglu (2002, 2003a), the paper argues that the bias of technological progress needs to be judged in terms of the change in relative marginal output. It is related not only to the growth rate of factor-growth technological progress but also to the size of the capital–labor factor substitution elasticity.

Based on the CES production function of Equation (1), we can derive the marginal output of capital and labor inputs from the perspective of including both capital and labor as.

$$\frac{\partial Y}{\partial L}=\left(\frac{Y_t}{L_t}\right)^{\frac{1}{\sigma}}(E_t^L)^{\frac{\sigma-1}{\sigma}} \tag{2}$$

$$\frac{\partial Y}{\partial K}=\left(\frac{Y_t}{K_t}\right)^{\frac{1}{\sigma}}(E_t^K)^{\frac{\sigma-1}{\sigma}} \tag{3}$$

Acemoglu (2003a) argues that directed technological progress occurs as a result of changes in the elasticity of the substitution of the factors of production. In this paper, we use Equations

(2) and (3) to calculate the capital–labor factor substitution elasticity to obtain the marginal rate of technological substitution (MRTS) [1].

$$MRTS=\frac{\partial Y/\partial K}{\partial Y/\partial L}=(\frac{K_t}{L_t})^{-\frac{1}{\sigma}}\left(\frac{E_t^K}{E_t^L}\right)^{\frac{\sigma-1}{\sigma}} \tag{4}$$

It can be seen that output is influenced by the capital–labor ratio (K_t/L_t) and the efficiency of capital–labor technical progress (E_t^K/E_t^L). To explore labor and capital efficiency and directed technical progress, these core concepts should be defined first. For example, labor efficiency is the idea that the same output can be achieved with fewer labor inputs. Acemoglu (2002) argues that an increase in labor efficiency through direct technological progress leads to an increase in marginal labor and capital goods. The elasticity of capital–labor substitution determines which factor benefits more from an increase in labor efficiency. If the elasticity is greater than one, the increase in labor efficiency raises the marginal output of labor, and if the elasticity is less than one, it raises the marginal output of capital. Thus, technological progress can change the relative marginal output of factors.

Thus, the following is the Biased Technical Change Index (BTCI). The BTCI is a measure of the change in the relative marginal output of factors caused by technological progress, provided that the capital–labor ratio remains constant. According to the above equations, the determinants of directed technical progress are combined.

Biased Technical Change Index (BTCI)

$$BTCI_{i,t}=\frac{\sigma-1}{\sigma}[\log E_t^L-\log E_t^K] \tag{5}$$

The role of the BTCI is to study the impact of changes in this part of technological progress on the MRTS as a whole. It is assumed that the directed technical progress index is positive. In this case, technological progress increases the relative marginal output of the capital–labor factor, and technological progress exhibits a capital–labor factor substitution elasticity. Conversely, if it is negative, technological progress behaves as labor biased.

If the capital–labor factor substitution elasticity (σ) in BTCI is greater than 1, which is a substitution relationship, $\sigma-1/\sigma$ is positive multiplied by $\log E_{i,t}^L-\log E_{i,t}^K$with a constant sign, representing an increase in the efficiency of labor (capital) and an increase in the marginal output of the labor (capital) factor. If it is less than 1 and is complementary, $\sigma-1/\sigma$ is negative multiplied by $\log E_{i,t}^L-\log E_{i,t}^K$ with the opposite sign, representing an increase in the efficiency of labor (capital) but contributing more to the marginal output of the other factor.

Combined with the CES production function of Equation (5), BTCI contains labor efficiency E_t^L, capital efficiency E_t^K and capital–labor factor substitution elasticity (σ), thus requiring an analysis of the above parameters.

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[1] Marginal rate of technical substitution (MRTS) refers to the rate at which a factor of production (such as labor) can be substituted for another factor of production (such as capital) while holding output constant. It is also known as the marginal rate of substitution of one input for another.

3. Empirical Strategy

3.1. Model Construction of Capital-Labor Factor Substitution Elasticity

Joan (1933) and De La Grandville (1989) argue that the two factors of technological progress are capital and labor and that technological progress is affected by capital and labor inputs in a nonneutral way.

To study the capital–labor factor substitution elasticity, it is necessary to estimate the CES production function. Most of the estimation methods for capital–labor factor substitution elasticity are linearized and include the extrapolation method, the optimal conditions method, the horizontal expansion method, and the normalized supply-side system method. However, the extrapolation method cannot estimate the value of the capital–labor factor substitution elasticity. Both the optimal conditions method and the horizontal expansion method use single equation for estimation. Both need to include either a perfectly competitive market or a constant rate of technological progress to ensure the feasibility of the estimation. The set of equations contains the CES production function, the first-order conditional equations for firm profit maximizing capital and labor demand, and the super logarithmic cost function. However, the inclusion of multiple preconditions and assumptions can lead to problems of biased estimation. Thus, the estimation of any single equation is subject to systematic bias (Acemoglu, 2002; Antras, 2004; Bentolila and Saint-Paul, 2003; Kalt, 1978; Klump et al., 2007; Panik, 1976; Sato, 1970; Wilkinson, 1968).

The third approach is the standardized supply-side system approach proposed by Klump et al. (2007, 2012). The standardized supply-side system approach consists of two parts: the standardized CES production function and the factor demand function under optimal first-order conditions. The standardized supply-side system consists of three equations consisting of a standardized CES production function and demand functions for capital and labor. The capital–labor factor substitution elasticity and directed technical progress parameters in these three equations interact with each other, thus solving the problem of discriminability of structural parameters and robust estimation of the capital–labor factor substitution elasticity and directed technical progress parameters.

The problem with the inference method, the optimal conditions method, and the horizontal expansion method is the inability to estimate specific elasticity values and systematic biases in the estimation. In this paper, the advantage of the standardized supply-side system approach is that the capital–labor factor substitution elasticity and the directed rate of technological progress parameters in the three sets of equations are mutual. This makes the estimation results more robust than the above methods (Dai and Xu, 2010; Irmen and Klump, 2009; Mallick, 2007; Palivos and Karagiannis, 2010; Sato and Morita, 2009).

Based on León-Ledesma et al. (2010), the paper adopts the Chen and Lian (2013) approach. The model is as follows:

$$\log(r_t)=\log\left(\frac{\bar{\pi}}{1+\mu}\frac{\xi\bar{Y}}{\bar{K}}\right)+\frac{1}{\sigma}\log\left(\frac{\frac{Y_t}{\xi\bar{Y}}}{\frac{K_t}{\bar{K}}}\right)+\frac{\sigma-1}{\sigma}\gamma_K(t-\bar{t}) \tag{6}$$

$$\log(w_t)=\log\left(\frac{1-\bar{\pi}}{1+\mu}\frac{\xi\bar{Y}}{\bar{L}}\right)+\frac{1}{\sigma}\log\left(\frac{Y_t/\xi\bar{Y}}{L_t/\bar{L}}\right)+\frac{\sigma-1}{\sigma}\gamma_L(t-\bar{t}) \tag{7}$$

$$\log(\frac{Y_t}{\bar{Y}}) = \log\xi + \frac{\sigma}{\sigma-1}\log[\bar{\pi}(\frac{e^{\gamma_K(t-\bar{t})}K_t}{\bar{K}})^{\frac{\sigma-1}{\sigma}} + (1-\bar{\pi})(\frac{e^{\gamma_L(t-\bar{t})}L_t}{\bar{L}})^{\frac{\sigma-1}{\sigma}}] \quad (8)$$

π is the capital income share, and γ_K and γ_L are the growth rates of the capital growth rate of technological progress and the labor growth rate of technological progress, respectively. In this paper, the above three nonlinear joint cubic equations are estimated.

For the nonlinear joint cubic system model composed of the above equation, this paper draws on Klump et al. (2007) and León-Ledesma et al. (2010) using nonlinear, seemingly uncorrelated regression (NLSUR). In addition, White estimators are used to calculate the standard errors of the parameters to overcome the effect of heteroskedasticity on statistical inference.

3.2. FDI Transmission and Technological Progress

After completing the estimation of the capital–labor factor substitution elasticity (σ) and the calculation of the BTCI, the effect of FDI cross-country transfer on the deviation of technological progress and the issue of technological progress and cross-country transfer are both examined with the following regression equation.

$$BTCI_{i,t} = \alpha_0 + \beta_2 \Sigma LNFDI_{i,t} + \beta_3 Z_{i,t} + \mu_i + v_t + \varepsilon_{i,t} \quad (9)$$

In the equation, α is the intercept term, β is the regression coefficient, i and t denote country and time, μ_i is the individual effect, v_t is the time effect, and $\varepsilon_{i,t}$ is the random disturbance term. $BTCI_{i,t}$ is the biased technical change index of the four Southeast Asian countries, $\Sigma LNFDI_{i,t}$ which is the log-transformed FDI from Korea to the four East Asian countries in various industries. It includes wholesale and retail trade, manufacturing, information and communications, financial and insurance activities, construction, business facilities management and business support services, and rental and leasing activities. $Z_{i,t}$ is the control variable. According to technological progress bias theory, labor force level and factor structure affect technological progress bias, so human capital (HC) and the log-transformed number of patent applications (LNPA) are chosen as control variables. The capital–labor ratio (KL) is also added considering the effect of the host country's own endowment structure on the technology bias index, and the squared term of the capital–labor ratio (KL^2) is also added to observe the nonlinear effect of factor endowment structure on the technology bias index. Finally, considering that imports may also have an impact on technological progress, the log-transformed measures of imports of goods from Korea for the four Southeast Asian countries are also included as control variables.

3.3. Variables and Data Selection

This paper focuses on the relationship between FDI and directed technological progress. South Korea and four Southeast Asian countries, including Indonesia, Malaysia, the Philippines, and Singapore, are selected for the study.

Malaysia is located in the heart of Southeast Asia and is a bridge between ASEAN on the sea and ASEAN on the road with certain geographical advantages. Malaysia also has a good foreign investment introduction policy and can register companies that are 100% foreign owned, thereby attracting much FDI. Indonesia, the fourth most populous country in the world, has a large, cheap, well-educated labor force. Likewise, the Philippines has a large, cheap, English-speaking workforce, and both countries have rich labor markets. Singapore is a developed country with abundant technological resources and a high-end labor force. Therefore, the selection of these countries allows a better analysis of the impact of the directed technological progress achieved with Korean FDI on different types of countries. The sample interval is 2000-2019. Sources are Penn World Table 10.0, ASEAN Statistical Yearbook, World Bank, and Export-Import Bank of Korea.

On the basis of the above theoretical derivation and combined with previous studies in the literature, scholars mostly use output (Y), capital factor input (K), labor factor input (L), labor cost (w) and capital cost (r) as indicators to construct a standardized supply-side systematic approach to estimate capital–labor factor substitution elasticity (Chen and Lian, 2012; Dai and Xu, 2010; Klump et al., 2007; León-Ledesma et al., 2015).

Therefore, the following variables are selected in this paper.

Output (Y): Real GDP from Penn World Table 10.0 is used as a proxy variable for output. Both nominal GDP and real GDP represent the total value of all goods produced by a country in a year. Compared to nominal GDP, real GDP removes the influence of price factors and better reflects the changes in a country's economic growth.

Capital factor input (K): Replaces capital factor input by the ratio of gross fixed capital formation to GDP in the World Bank database multiplied by real GDP.

Labor factor input (L): replace labor factor input with the number of employed people, data from Penn World Table 10.0.

Labor cost (w): Compensation for labor as a share of GDP multiplied by real GDP, data from Penn World Table 10.0.

Cost of capital (r): Capital rent is used as a proxy variable for the cost of capital. Capital rent is the cost of using capital in a nonperfectly competitive market. It is calculated according to the method of Jorgenson and Yun (1991).

$$R_i=f_t\times(i_t+d_t)-\nabla f_t \tag{10}$$

In this article, the cost of capital is calculated using the metrics provided by Penn World Table 10.0. where ft is the price of capital services, not the price of assets. If it is the real internal rate of return. dt is the average depreciation rate of the capital stock.

Log-transformed FDI by industry (ΣLNFDI): In this paper, we need to analyze the industries which receive FDI. Based on the data from the Export-Import Bank of Korea, this paper selects the industries in which Korea invests the most in the four Southeast Asian countries for analysis. The main sectors include wholesale and retail trade (LNW), manufacturing (LNM), information and communication (LNI), financial and insurance activities (LNF), construction (LNC), business facility management and business support services, and leasing activities (LNB). FDI data are obtained from the Export-Import Bank of Korea.

Human Capital(HC): Human capital is the source of a country's long-term economic development and national research and development (R&D) capabilities. A country's technological progress can depend on other countries as well as on its own domestic R&D. In this case, the level of human capital also affects directed technological progress (Acemoglu, 2003b). Fu (2008) found that the ability to absorb and diffuse technology depends on human capital. The level of human capital determines the breadth and depth of technology absorption and application. In general, regions with high human capital are more conducive to absorbing and applying new technologies. In this paper, human capital based on the average years of education in Penn World Table 10.0 is used as a variable.

Log-transformed resident patent applications (LNPA): Wang et al. (2017), Coe and Helpman (1995) argue that the stock of technology in the host country also affects technological progress, so this paper uses log-transformed World Bank patent applications as this variable.

Capital-labor ratio (KL): Scholars have argued that the direction of a country's technological progress also has a relationship with its own endowment structure (Acemoglu, 2002; David and Van de Klundert, 1965; Sato and Morita, 2009). In this paper, to analyze this relationship more specifically, the squared term of the capital–labor ratio (KL^2) is added to observe the nonlinear effect of factor endowment structure on the directed technological progress. The capital–labor ratio is accounted for using data from Capital Factor Input (K) and Labor Factor Input (L).

Imports (LNIM): International trade plays an important role in technological progress (Das, 2002; Grossman and Helpman, 1991; Managi and Kumar, 2009). Therefore, in this paper, the import value of four East Asian countries from Korea is selected as a control variable. The data are obtained from the Bank of Korea.

Table 1. Descriptive Statistics

Variable	Variable definition	Obs	Mean	Std. Dev.	Min	Max
Y	Outputs	100	10149.488	7485.251	1947.328	31104.695
K	Capital Inputs	100	3027.303	2661.526	572.686	10465.058
L	Labor input	100	3.642	3.783	0.208	13.117
W	Labor cost	100	22809.337	16661.036	4628.952	56888.808
R	Capital cost	100	10.484	3.427	4.581	19.344
LNM	Manufacturing	80	11.001	1.443	7.190	14.120
LNF	Financial and insurance activities	80	10.564	1.35	7.637	13.000
LNW	Wholesale and retail trade	80	9.178	2.031	5.074	13.038
LNI	Information and communications	80	9.269	1.007	7.166	10.774
LNC	Construction	80	8.535	1.598	3.775	10.941
LNB	Business facilities management and business support services, rental and leasing activities	80	7.602	1.508	3.589	10.856
HC	Human Capital	80	2.736	0.432	2.186	4.352
LNPA	Patent Applications	80	6.266	0.794	4.905	8.037
KL	Capital-labor ratio	80	140.11	137.087	20.203	455.682
LNIM	Import	80	2.405	0.026	2.355	2.449

Source: Penn World Table version 10.0, ASEAN Statistical Yearbook, World Bank, Export-Import Bank of Korea.

4. Empirical Results

4.1. Estimation of Capital-Labor Factor Substitution Elasticity

First, to calculate the BTCI, we need to estimate the capital–labor factor substitution elasticity using the NLSUR method. For nonlinear models, the choice of initial values is crucial. In this paper, we refer to the studies of León-Ledesma et al. (2010), Mallick (2012) and McAdam and Willman (2008).

The initial value of the capital–labor factor substitution elasticity (σ) is set to σ (0) ∈ [0.031:0.05:2.181], i.e., the initial value of σ is taken sequentially as an equal series with an initial value of 0.031, a termination value of 2.181, and a tolerance of 0.05. According to Klump et al. (2007), the variables (Y, K, L) are taken as geometric means, and the capital income share parameter (π) of the base value is taken as the arithmetic mean. In addition, to ensure that global convergence can be achieved, the paper draws on León-Ledesma et al. (2010) and sets $\zeta(0) = 1$, $\mu(0) = 0.1$, $\gamma_K(0)= 0.0001$, and $\gamma_N(0)= 0.002$.

The following table contains μ, ξ, σ, γ_K, γ_N, and Log-Det. All estimates of the capital–labor factor substitution elasticity (σ) are significant at the 1% level, and the estimates are presented in Table 2.

First, the scale factor ξ fluctuates around 1, and the Log-Det value satisfies the statistical test.

Table 2. Estimation Results of Capital-Labor Factor Substitution Elasticity

country	μ	ξ	σ	γ_K	γ_N	Log-Det
Korea	3.362***	0.996***	1.079***	0.061	-0.035*	-13.441
	(0.021)	(0.005)	(0.094)	(0.038)	(0.020)	
Indonesia	2.409***	1.011***	0.784***	-0.139**	0.035	-9.697
	(0.026)	(0.018)	(0. 049)	(0.049)	(0.022)	
Malaysia	3.609***	1.001***	0.980***	-0.033	0.007	-11.548
	(0.048)	(0.013)	(0.059)	(0.610)	(0.589)	
Philippines	2.683***	0.992***	1.307***	0.036***	-0.029***	-12.361
	(0.053)	(0.011)	(0.080)	(0.012)	(0.007)	
Singapore	4.176***	0.978***	1.037***	0.203	-0.182	-8.748
	(0.081)	(0.019)	(0.110)	(0.305)	(0.240)	

Notes: 1. *p<0.1, **p<0.05, ***p<0.001.
2. Within parentheses is the standard error of the parameters calculated with the White estimator.
3. Capital-labor factor substitution elasticity (σ)>1 is capital–labor substitution, and <1 is capital–labor complementarity.

Second, it is clear from the sample that the capital–labor factor substitution elasticity (σ) is significant at the 1% level for all countries, and the results for Korea are similar to those estimated by Mallick (2012), where the value fluctuations are within a reasonable range. The results for the four Southeast Asian countries differ in that the capital–labor factor substitution elasticity (σ) decreases and is less than one for Indonesia and Malaysia compared to Mallick (2012). The capital–labor factor substitution elasticity (σ) decreases for the Philippines and Singapore. This difference is caused by the different time periods of the sample.

Mallick (2012) uses data from 1950-2000, a period of high growth and capital inflows in Malaysia and Indonesia, so the σ estimate is greater than 1. Singapore is a developed country, so it is reasonable that the capital–labor factor substitution elasticity is greater than 1.

Third, according to the capital–labor factor substitution elasticity (σ), the capital–labor factor substitution elasticities for Korea, the Philippines, and Singapore are greater than 1, and there is a substitution relationship. Indonesia and Malaysia have a complementary relationship indicated by a σ less than 1.

South Korea and Singapore are developed countries in cutting-edge manufacturing, such as semiconductors, shipping, and pharmaceuticals, and are world leaders in technology. Korea and Singapore also have highly developed financial sectors to support their capital. Thus, the capital factor has formed a strong substitution relationship with the labor factor in economic development. This indicates that the improvement and increase in economic growth patterns, technology levels and openness to the outside world in both countries are conducive to economic efficiency. Efficiency increases the capital–labor factor substitution elasticity so that the capital–labor factor indicates that they can be substituted.

The Philippines has a large, inexpensive, well-educated, English-speaking workforce. The literacy rate of the population is 94.6%, one of the highest rates in Asia. In addition, labor costs in the Philippines are significantly lower than those in developed countries, thus attracting many Western companies to move their operations to the Philippines. The Philippines is a fast-growing country in Asia. In 2017, India's economy grew by 6.7%, ranking third in East Asia behind China and Vietnam. All of these developments contribute to economic efficiency and significantly increase the capital–labor factor substitution elasticity, which results in the substitutability of the capital–labor factor.

The situation of other countries with capital–labor factor substitution elasticity less than 1 is relatively more complicated. These countries are mainly developing countries, and compared with Korea and Singapore, they have gaps in the degree of openness, marketization, capital deepening, and technological progress, which increase the difficulty of substituting between capital and labor. Capital deepening does not incentivize these countries to substitute capital for labor, so capital–labor factors form a complementary relationship.

4.2. Biased Technical Change Index

Further examination of the directed technological progress of countries follows. Table 3 below shows the BTCI calculated using the capital–labor factor substitution elasticity estimated in Section 4.1 combined with Equation (5).

A positive BTCI represents capital-biased technological progress, which implies that technological progress helps increase the marginal output of capital. Conversely, a negative BTCI represents labor-biased technological progress, which implies that technological progress helps increase the marginal output of labor. As shown in Table 3, it is clear that from 2000-2019, technological progress in Korea, Indonesia, and Malaysia is capital biased, while technological progress in the Philippines and Singapore is labor biased.

Based on the BTCI, the paper analyzes the development of each country over 19 years, and the BTCI of Korea fluctuates around 0 until 2012 and then gradually shifts toward labor-biased technological progress. Therefore, this paper argues that the drift toward labor-biased technological progress in Korea after 2012 is due to the economic crisis that affected Korea in 2008. To maintain long-term stable economic growth, the Korean government introduced a series of corresponding policies, including the establishment of an innovative country, securing employment, and increasing investment in education. The implementation of these policies has helped Korea bias the direction of technological progress toward improving the marginal output of labor and has contributed to the shift in the trend of Korea's BTCI toward labor-biased technological progress.

According to the BTCI, both Indonesia and Malaysia have a capital-biased technology bias, but after 2009, there was a large turnaround, with the BTCI gradually decreasing and directed technological progress gradually moving toward a labor-bias. This paper suggests that this is because the directed technological progress in Indonesia and Malaysia was influenced by technological imitation before the economic crisis in 2008. This implies that developing countries such as Indonesia and Malaysia can directly apply capital-biased technologies developed in developed countries at a lower cost, which leads to more capital-biased technological progress (Acemoglu and Zilibotti, 2001; Gancia and Zilibotti, 2009).

However, to maintain stable economic growth after the 2008 economic crisis, both Indonesia and Malaysia developed their talent and education development policies accordingly and chose a route more in line with their own endowments. This led to a shift in the trend of technological progress toward labor. Thus, the gradual shift in the BTCI toward labor-biased technological progress in Indonesia and Malaysia can be attributed to the development of talent and education strategies adopted after the economic crisis, as well as to the choice of technologies that are more suitable for their national development.

Table 3. Biased Technical Change Index

Year	Korea	Indonesia	Malaysia	Philippines	Singapore
2000	0.291	1.214	0.077	-0.161	0.174
2001	0.228	1.161	0.104	-0.303	0.255
2002	0.170	1.158	0.065	-0.386	0.199
2003	0.141	1.128	0.074	-0.376	0.222
2004	0.102	1.168	0.049	-0.265	0.049
2005	0.091	1.128	0.125	-0.269	0.067
2006	0.086	1.126	0.075	-0.182	0.061
2007	0.059	1.132	0.086	-0.176	0.061
2008	0.043	1.172	0.110	-0.284	-0.045
2009	0.066	1.218	0.193	-0.208	0.017
2010	-0.004	1.184	0.088	-0.256	-0.095
2011	0.002	1.108	0.086	-0.226	-0.146
2012	0.001	1.095	0.099	-0.174	-0.191
2013	-0.029	1.052	0.113	-0.230	-0.194
2014	-0.028	1.032	0.078	-0.264	-0.156
2015	-0.025	1.013	0.074	-0.306	-0.110
2016	-0.050	0.985	0.043	-0.382	-0.144
2017	-0.078	0.941	-0.004	-0.431	-0.184
2018	-0.094	0.909	-0.008	-0.459	-0.223
2019	-0.085	0.937	0.004	-0.477	-0.217

The Philippines has been on a labor-biased technological progress slope, which is consistent with the previous description.

Similar to Korea, Singapore also experienced a shift from capital-biased technological progress to labor-biased technological progress around 2008. This was partly due to the impact of the 2008 economic crisis and partly due to Singapore's emphasis on talent development and recruitment in the last decade. Singapore has adopted a talent-centric development model that has attracted a skilled workforce, leading to widespread labor-biased technological advancement in the country. By focusing on talent development, education and talent acquisition, Singapore has succeeded in attracting a highly qualified workforce and enabling it to play a more important role in technological advancement. This shift was in response to the impact of the economic crisis but also to improve Singapore's long-term stable economic growth as well as its international competitiveness.

Thus, it can be concluded that countries have chosen a more appropriate route for their development by developing appropriate talent development and education policies in the face of the economic crisis and have led to a shift in technological progress toward a labor force bias. The experience of these countries shows that a focus on talent and workforce development is essential to achieve sustained economic growth and innovation.

4.3. Analysis of Regression Results

This section uses the BTCI calculated in Section 4.2 as the dependent variable to examine the directional cross-country trans mission of technological progress from Korea to the four Southeast Asian countries using a fixed effects model. The results are shown in Table 4.

According to the regression results, Korea's FDI has a significant effect on the host country's BTCI in several industries, including wholesale and retail trade, manufacturing, information and communication, and financial and insurance activities. Specifically, Korean FDI in wholesale and retail trade and manufacturing in Southeast Asian countries exhibits a positive effect on the host country's BTCI, which leads to capital-biased technical change and thus increases the marginal output of capital. In contrast, FDI in information and communication, finance and insurance activities has a negative impact on the BTCI of the host country, leading to labor-biased technical change and an increase in the marginal output of labor. In addition, based on the regression results and in context, it is found that Korea's underinvestment in construction, business facility management, business support services, and leasing activities has no significant effect on the BTCI of the host country.

From the human capital perspective, all estimates obtained are above the 1% significance level, and all are negative, indicating that human capital investment in the host country may lead to labor-biased technological change. Human capital investment also contributes to a higher marginal output of labor factors, which is consistent with the above results.

Based on the regression results of KL and KL^2, a nonlinear relationship is found between KL and the BTCI. The bias of the KL depends on directed technological progress. At the beginning, when a country is at a lower stage of development, labor is relatively abundant, and capital is relatively small. In such a situation, the country prefers to adopt labor-intensive industries to increase productivity and develop the economy. The term labor-intensive industries usually refers to production methods that depend on human and labor power. Labor-biased technological advances can efficiently utilize human resources, increase employment, and reduce labor costs. Thus, in the early stages of development, the country prefers to develop labor-biased technology because of the relative lack of capital. However, with economic development and technological progress, capital accumulation gradually increases. Capital-intensive technological progress can increase production efficiency, reduce costs, and achieve higher levels of output through the introduction of more advanced machinery and equipment. Thus, when a country accumulates sufficient capital and has the appropriate technology and infrastructure, it tends to shift to capital-biased technological progress, which relies more on capital and mechanized production methods.

The regression results indicate that the LNPA are not significant, suggesting that patent applications have a limited impact on the BTCI at the current stage of economic development in the host country. The main influencing factor of directed technological progress is foreign direct investment. Similarly, the regression results for imports are also insignificant, which further supports the idea that the impact on directed technological progress in the host country is mainly delivered through Korean FDI.

Table 4. Fixed-effects Regression Results

	FE_LNW	FE_LNM	FE_LNI	FE_LNC	FE_LNB	FE_LNF	FE_ALL
LNW	0.026***						0.026***
	(3.08)						(3.12)
LNM		0.016**					0.012*
		(2.28)					(1.91)
LNI			-0.019**				-0.024**
			(-2.07)				(-2.59)
LNC				0.006			0.002
				(0.98)			(0.33)
LNB					-0.004		-0.007
					(-0.66)		(-1.13)
LNF						-0.018**	-0.020***
						(-2.56)	(-2.99)
HC	-0.159***	-0.159***	-0.132***	-0.148***	-0.139***	-0.105***	-0.124***
	(-4.95)	(-4.74)	(-4.01)	(-4.29)	(-4.16)	(-3.03)	(-3.73)
LNDR	-0.006	-0.012	-0.001	-0.011	-0.014	0.004	0.005
	(-0.25)	(-0.49)	(-0.04)	(-0.42)	(-0.52)	(0.16)	(0.21)
KL	-0.381***	-0.342***	-0.379***	-0.368***	-0.321**	-0.229*	-0.236*
	(-3.27)	(-2.87)	(-3.14)	(-2.96)	(-2.47)	(-1.80)	(-1.97)
KL^2	0.036**	0.028*	0.032*	0.032*	0.026	0.013	0.013
	(2.29)	(1.72)	(1.95)	(1.90)	(1.46)	(0.75)	(0.82)
LNIM	-1.451	-0.678	0.437	-0.286	-0.044	-0.708	-1.436
	(-1.58)	(-0.78)	(0.49)	(-0.33)	(-0.05)	(-0.82)	(-1.57)
Constant	4.330**	2.548	0.113	1.716	1.174	2.642	4.374**
	(2.09)	(1.30)	(0.06)	(0.87)	(0.59)	(1.36)	(2.13)
adj. R-sq	0.659	0.640	0.636	0.619	0.616	0.646	0.724
F	26.998	24.914	24.481	22.859	22.609	25.577	20.110
r2	0.698	0.681	0.677	0.662	0.660	0.687	0.773
Hausman test				Prob > chi2 = 0.000			
N	80	80	80	80	80	80	80

Notes: 1. *p<0.1, **p<0.05, ***p<0.001.
2. A positive regression coefficient indicates a capital-biased technological progress index, a negative regression coefficient indicates a labor-biased technological progress index.

After comparing FDI in different industries, there are two important findings. First, directed technological progress is transmitted across countries through FDI. Second, the impact of FDI in different industries on directed technological progress in host countries is different. Combined with previous literature, this study argues that Korean FDI in wholesale and retail trade improves supply chain technology and related suppliers' technology, increases capital efficiency, and raises the marginal output of capital. Meanwhile, in the manufacturing sector, FDI brings advanced manufacturing technologies that reduce the use of labor and increase the efficiency of capital operations, leading to the orientation of technological progress in favor of capital. Conversely, there is a greater demand for highly skilled personnel in the information and communication and financial and insurance activities sectors. However, comparing previous BTCI results across countries, changes in directed technological progress due to investment in different industries are not consistent with directed technological progress in the home country. This highlights the need for host countries to adapt foreign investment to their own development situation and their own endowments for mutual benefit.

4.4. Robustness tests

The baseline regression results show that industry FDI has an impact on the technological progress of the host country. However, technological progress in the host country leads to new demand for FDI in Korea, which in turn leads to reverse causality. To address the endogeneity problem this raises, we use SYS-GMM for robustness checks. It has been shown in the literature that SYS-GMM estimation can mitigate the endogeneity problem to some extent (Berry, 2015; Jiatao Li et al., 2021; Roodman, 2009; Ullah et al., 2018). Combining the approach of He and Yang (2012), the results are as follows:

Table 5. GMM Regression Results

	GMM_LNW	GMM _LNM	GMM _LNI	GMM _LNC	GMM _LNB	GMM _LNF
LNW	0.015^{***} (2.84)					
LNM		0.023^{***} (4.13)				
LNI			-0.027^{***} (-3.51)			
LNC				0.006 (1.37)		
LNB					-0.002 (-0.51)	
LNF						-0.009^{*} (-1.79)
Control	√	√	√	√	√	√
AR1_p	0.057	0.056	0.089	0.081	0.077	0.066
AR2_p	0.144	0.306	0.412	0.117	0.121	0.120
Sargan_p	0.629	0.901	0.684	0.965	0.964	0.548

Notes: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.001$.

The SYS-GMM results showed that the significance levels and signs of the core explanatory variables were basically consistent with the fixed-effects regression result. The SYS-GMM regression results passed the autocorrelation test, indicating that the perturbation term $\varepsilon_{i,t}$ has a first-order autocorrelation and that there is no second-order autocorrelation problem. The results of the Sargan test of overidentifying restriction showed that the instruments used in our model are relevant and valid. Overall, the results of the specification tests suggest that System GMM estimates are reliable.

5. Conclusion

This paper adopts the definitions of capital–labor factor substitution elasticity and directed technological progress proposed by Acemoglu (2002, 2003a) and Hicks (1963). The CES production function and the standardized supply-side system approach are used to estimate the capital–labor factor substitution elasticity. After calculating the BTCI for Korea and the four Southeast Asian countries, a fixed-effects model was used with the BTCI as the dependent variable and the FDI from Korea to the four Southeast Asian countries in different industries as the independent variable. The impact of Korean FDI in different industries on directed technological progress in four East Asian countries was investigated, and robustness tests were conducted using SYS-GMM.

First, this paper calculates the capital–labor factor elasticity and finds that there is a substitution relationship with capital–labor factor substitution elasticity greater than one for Korea, the Philippines, and Singapore. In contrast, Indonesia and Malaysia have capital–labor factor substitution elasticities less than 1 and exhibit a complementary relationship. Korea and Singapore are developed countries that lead the world in technological progress in cutting-edge manufacturing fields such as semiconductors, shipping, and pharmaceuticals. In addition, they have a highly developed financial sector that enhances the substitution of capital and labor in the production process. Countries with capital–labor factor substitution elasticity less than 1 face additional challenges. Most of these countries are developing countries with gaps in marketization, openness, capital deepening and technological progress compared to Korea and Singapore, further complicating the capital–labor substitution relationship. Thus, in these countries, capital deepening alone does not stimulate labor–capital substitution, leading to a situation of capital–labor factor complementarity.

Second, this paper calculates the BTCI for each country. As shown by the development of each country over 19 years, the BTCI of Korea fluctuates around 0 until 2012 and gradually shifts toward labor-biased technological progress after 2012. Indonesia and Malaysia both have a capital-biased technology bias index, and the Philippines has experienced labor-biased technological progress. Similar to Korea, Singapore experienced a shift from capital-biased technological progress to labor-biased technological progress in approximately 2008. However, from the overall trend of each country, there is a shift in the directed technological progress from capital to labor, and it can be seen that all these countries are making great efforts to develop human resources, and technological progress is shifting to the direction of labor. This indicates that human capital has become increasingly important to countries as they enter the 21st century and that all countries see human capital as a driver of national development.

Finally, by estimating the results of fixed effects, we find that (1) Korea's FDI inputs in wholesale and retail trade and manufacturing are significantly positive for the four Southeast Asian countries. This indicates that Korea's investment in these two industries influences the BTCI in the host country in the direction of capital, which raises the marginal output of capital. Information and communications and financial and insurance activities are significantly negative, which indicates that Korean investment in these two sectors influences the BTCI in the host country in the direction of labor and raises the marginal output of labor. (2) By comparing FDI inputs in different industries, it is confirmed that technological progress bias is transmitted across countries using FDI as a channel. It is also found that the technological progress bias of the host country has different effects when investing in different industries. However, in some industries, there is a trend of inverse endowment with itself.

Therefore, on the one hand, Korea's technology spillover through FDI can help improve the host country's independent R&D level. The late-developing countries in Southeast Asia, with a large gap between their own technology level and that of Korea, can learn advanced foreign technology through international technology spillovers, shorten the time for technological progress, and achieve technological leapfrogging. For countries with limited resources and lagging technology, this is the least costly and most efficient way to achieve technological catch-up. On the other hand, from the perspective of technology spillover absorbing countries, when Southeast Asian countries acquire advanced technologies from Korea, the level of independent R&D is a key factor in determining the international technology spillover effect. The advanced technology from Korea's foreign direct investment can truly become the driving force of Korea's technological progress only if it is digested and absorbed by Southeast Asian countries. The host country must continuously increase its R&D investment to realize the digestion and absorption of imported advanced technologies.

Therefore, FDI countries must combine their endowments and begin to mutually benefit the host country. (1) The host country needs to improve human capital, train personnel using the equipment in the enterprise in a timely manner and improve the efficiency of equipment use to adapt to and undertake the transfer of advanced technology. (2) While introducing advanced technology or equipment, the host country should combine its own endowment with the introduction of corresponding technology. A mismatch may cause structural imbalance and hinder economic development. Host countries need to optimize FDI flows, combine their own endowments, introduce more foreign investment to disadvantaged industries, achieve industrial agglomeration capital concentration, form industrial clusters, and drive their economic growth. (3) The technology gap between domestic enterprises and multinational corporations should also be considered. When the technology gap between domestic enterprises and multinational corporations is within a reasonable range, the demonstration effect of multinational corporations can be better utilized by domestic enterprises to improve the efficiency of absorbing new technology and promote technological upgrading.

In future research, on the one hand, we will further increase the sample of observations and conduct more detailed analysis. On the other hand, we will introduce the De La Grandville Hypothesis to conduct a more in-depth and detailed study of the relationship between economic growth and capital–labor factor substitution elasticity.

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