Foreign Direct Investment Inflows and Technological Spillovers: A Statistical Evaluation of the ASEAN Manufacturing Industry

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Abstract

Developing countries consider foreign direct investment to be their primary financial resource which also brings new technological advances to their nations, yet researchers are still debating how much technological knowledge foreign direct investment delivers to various regions. The research investigated how foreign direct investment leads to technological advancements in the manufacturing sector of ASEAN member states between 2000 and 2022. The study utilized an autoregressive model with panel lags which analyzed data from ten member countries, including Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. The researchers developed a composite absorptive capacity index through principal components analysis which measured three different components: human capital, information technology infrastructure and institutional quality. The research results demonstrated that foreign direct investment positively impacts labor productivity in the ASEAN manufacturing sector through permanent effects which showed an elasticity coefficient of 0.234 for the complete sample. The relationship between member states and foreign direct investment shows different effects which reach their highest point in upper-middle-income countries with an elasticity of 0.256 and drop to their lowest point in high-income countries which have an elasticity of 0.178. The entire sample showed that absorptive capacity created a positive and significant moderating effect which reached 0.078 for the relationship between foreign investment and productivity. This effect became more powerful in low-income countries which produced a coefficient of 0.112. Granger causality tests demonstrated that foreign investment drives productivity growth while human capital and absorptive capacity enable foreign investment. The supplementary analyses at the manufacturing industry sub-sector level found that the electronics industry achieved 0.312 spillovers while the automobile industry reached 0.278 spillovers and the food industry experienced 0.123 spillovers while the wood industry had 0.078 spillovers. The study establishes that FDI technological spillovers do not occur automatically

or uniformly across environments because their implementation depends on three specific factors which include developmental progress and host country absorptive capacity and industrial characteristics. The ASEAN experience shows that foreign investment attraction requires an integrated approach which combines targeted investment incentives with simultaneous education development and research development and institutional quality improvement.

Keywords: FDI, Technological Spillovers, Absorptive Capacity, Manufacturing Industry, ASEAN, Labor Productivity.

Introduction

Foreign direct investment serves as an essential financial and technological resource which developing nations regard as crucial for their economic development (Borensztein et al., 1998). The financial imports from abroad provide essential support to developing nations while serving as the primary method through which advanced nations share their technical competencies and managerial expertise and modern technological systems with developing nations (Dunning, 1988, 1993; Navaretti & Venables, 2004). Developing countries have become increasingly competitive in their efforts to attract foreign direct investment which they believe will bring economic advantages that exceed the direct financial investment and create additional economic benefits for the entire host nation (Markusen & Venables, 1999; Blalock & Gertler, 2008). The concept of technological spillovers refers to the situation where the presence of multinational companies in the host economy leads to the indirect and non-market transfer of knowledge and technology to domestic firms (Görg & Greenaway, 2004; Smarzynska, 2003; Goel, 2023). The spillover effect exists through various channels which include skilled labor movement between foreign companies and domestic firms and the process of domestic companies copying or simulating new technologies and operational methods and the creation of vertical connections between local suppliers and distributors and the rising market competition which compels domestic enterprises to boost their productivity (Görg & Strobl, 2002; Javorcik & Spatareanu, 2006; Lin & Saggi, 2005; Guo, Ning, & Chen, 2022). The development of these spillover effects depends on various factors which include domestic companies' ability to absorb new information and the policies implemented by host governments and the particular traits of industries and countries (Cohen & Levinthal, 1990; Crespo & Fontoura, 2007; Audretsch & Belitski, 2022).

The manufacturing field functions as the main focus which researchers investigate to understand how foreign direct investment affects technological spillover effects (Sasidharan, 2006; Beladi et al., 2016). The industry behaves as an effective platform which enables organizations to transfer knowledge because of its physical technological assets and its broad operational network and its capacity to create interconnections with multiple industrial sectors (Cheung & Lin, 2004). The experience of newly industrialized countries in East Asia, such as South Korea, Taiwan, and Singapore, shows that by intelligently utilizing foreign direct investment and effectively managing technological spillovers, these countries were able to join the ranks of industrialized countries in a short period of time and become a model for other developing economies (Bende-Nabende et al., 1998; Ng, 2006; Audretsch & Lehmann, 2022). The Association of Southeast Asian Nations stands as a successful regional integration experiment which develops through its dynamic systems to provide researchers with a valuable case study for their analysis (ASEAN Secretariat, 2003, 2007a, 2008a). The ASEAN member countries have attracted major foreign direct investment through their implementation of trade and investment liberalization policies and their establishment of better business conditions and their participation in regional and global value chains during the past thirty years (ASEAN Secretariat, 1998, 2008b; AIR, 2016, 2017; Coveri & Zanfei, 2022). The capital movement from this investment has been essential for changing these nations from their agricultural foundations into centers of international manufacturing (Sarel, 1997; Lee, 2007). The remarkable transformation from agricultural societies to industrialized nations in Vietnam and Thailand and Malaysia and Indonesia serves as a clear demonstration of this process (Athukorala, 2014; Rasiah, 2017).

The ASEAN region displays a highly diverse and multiple cultural aspects (Habito et al., 2004). At one end of the spectrum, Singapore is the region's advanced economy and technology leader, which has become a capital exporter. At the other, Cambodia, Laos, and Myanmar are in the early stages of industrialization and are mainly attracting investment in labor-intensive and low-tech industries (AIR, 2020–2021; AIR, 2022). The existence of such diverse elements creates an excellent chance to conduct comparative research, which leads to the investigation of whether all member states gain equal advantages from foreign direct investment technological transfers or whether the digital gap between neighboring countries keeps expanding (Marcin, 2008; Mullen & Williams, 2007; Barboza, 2024; Barboza & Pede, 2024). The economy of ASEAN depends on its manufacturing sector as the primary driving force (AIR, 2023; AIR, 2024). The industry operates various production activities which include textile and clothing manufacturing in Cambodia and Vietnam, electronics production in Malaysia and Thailand, and high-tech product development in Singapore (ASEAN Secretariat, 2021). The regional production chain benefits from the widespread operations of Japanese, Korean, Chinese, and Western multinationals, which create a valuable research environment to investigate how spillover channels function and what conditions make them successful (Blalock & Gertler, 2003; Girma et al., 2008; Landman et al., 2023; Spithoven & Merlevede, 2023). Research has focused on regional spillover assessment through systematic and quantitative methods, but only a few studies have achieved this goal for cross-country analysis in the entire territory (Baltagi et al., 2007; Vahter & Masso, 2007).

The existing research about FDI and technological spillovers in ASEAN nations contains multiple research gaps which require exploration (Görg & Strobl, 2000; Toda & Yamamoto, 1995; Rojec & Knell, 2018). First, most existing studies have only investigated one country or one specific industry while they did not include all available regional data to compare different places (Choe, 2003; Lopez-Cordova, 2003). Second, previous studies have mainly analyzed data from the 1990s and early 2000s, which has become outdated because they failed to include technological advancements and global value chain changes which occurred during the last twenty years and after the Fourth Industrial Revolution and various trade disputes and pandemic events (Chakraborty & Nunnenkamp, 2008; Beck et al., 2000). Third, the role of domestic firms' absorptive capacity as a moderating variable has been less systematically examined in regional studies (Schoors & Tol, 2002; Blyde et al., 2004; Guo, Ning, & Chen, 2022). This study seeks to answer these fundamental questions using panel data from ten ASEAN member countries over the period 2000–2022: First, has foreign direct investment led to significant positive technological spillovers in ASEAN manufacturing? Second, does the intensity of these spillovers differ significantly across member countries at different levels of development? Third, what role does domestic firms' absorptive capacity play in strengthening or weakening these spillovers? (Arellano & Bover, 1995). The study results provide advantages for development economists and international trade experts who establish theoretical frameworks while helping ASEAN regional policymakers and emerging market economies to use foreign investment as an economic resource (Dixit & Stiglitz, 1977; Markusen & Venables, 1999).

Multiple aspects explain the research's significance and essential character. This study tests three research streams which include foreign investment direct effects and absorptive capacity moderating effects and development stage variances to advance theoretical knowledge in this field (Cohen & Levinthal, 1990; Dunning, 1993; Audretsch, 2023). The research introduces a new methodology through its implementation of dynamic panel models and cointegration testing which delivers more accurate and dependable outcomes (Toda & Yamamoto, 1995). The study results enable policymakers to create specific investment attraction strategies which will help ASEAN countries maintain high-quality foreign investments while preventing harmful competition to draw low-value capital (AIR, 2023; ASEAN Secretariat, 2021; Coveri & Zanfei, 2022). The research investigates established beliefs which claim foreign direct investment produces endless advantages while demonstrating that technological spillovers need institutional frameworks

combined with domestic research funding and workforce education improvements (Borensztein et al., 1998; Blalock & Gertler, 2008; Guo & Zhang, 2024). The study results provide important insights for Uzbekistan which seeks to implement economic reforms and attract foreign investment while avoiding potential errors and operational failures.

Literature Review

Conceptualization of Foreign Direct Investment and its Motivations

Foreign direct investment serves as a key component of international economic capital flows because it enables investments that create permanent advantages through operational control which extends beyond the home country of the investor (Dunning, 1988, 1993; Navaretti & Venables, 2004). The investment type differs from portfolio investment because it enables financial transactions together with control rights and the ability to move intangible assets which include technological elements and brand identity and management expertise (Markusen & Venables, 1999; Dunning, 1993). The research on foreign direct investment motivation has advanced from its original explanation which used interest rate differentials and variable return rates to current sophisticated models which include the Dunning eclectic paradigm framework (Dunning, 1988, 1993). Multinational corporations decide to invest in foreign markets because they seek three types of advantages which include ownership advantage and location advantage and internalization advantage (Dunning, 1988, 1993). This theoretical framework remains one of the most widely used and accepted models for analyzing the motivations and patterns of foreign direct investment globally (Navaretti & Venables, 2004; Dunning, 1993; Audretsch, 2023).

The Concept and Channels of Technological Spillovers

The foreign direct investment literature considers technological spillovers as the most essential element which arises from multinational companies operating in host countries (Görg & Greenaway, 2004; Smarzynska, 2003; Goel, 2023). Domestic companies receive advantages from foreign company knowledge and technology through these spillovers which result in productivity growth without needing to cover complete expenses (Blalock & Gertler, 2008; Javorcik & Spatareanu, 2006). The theoretical literature has identified four main channels for the transmission of these spillovers (Görg & Strobl, 2002; Lin & Saggi, 2005; Perri & Peruffo, 2016). The first channel involves skilled employees who leave multinational companies to work for domestic businesses after they acquire proper training and experience (Görg & Strobl, 2002). The second channel is imitation or demonstration effects; Domestic firms, observing the new technologies and methods of foreign firms, start to model and imitate them (Chen et al., 1995; Cheung & Lin, 2004). The third channel exists because multinational companies establish vertical connections with local suppliers and customers; they share technical expertise and quality standards with domestic companies to maintain product quality (Blalock & Gertler, 2003; Girma et al., 2008; Landman et al., 2023). The fourth channel exists because foreign companies that operate efficiently create market pressures which force domestic companies to enhance their production processes and research activities (Markusen & Venables, 1999; Marcin, 2008; Spithoven & Merlevede, 2023).

Absorptive Capacity Theory and its Moderating Role

The primary advancement of research about technological spillovers now shows that domestic business and home country absorptive capacity serve as the essential elements which drive all technological spillover processes (Cohen & Levinthal, 1989, 1990). Cohen and Levinthal introduced absorptive capacity as a concept which defines a firm's capacity to discover and obtain external knowledge while merging that knowledge into their operations for purposes of commercial development (Cohen & Levinthal, 1989, 1990). The capacity develops through multiple stages which organizations must follow to reach their maximum potential (Cohen & Levinthal, 1990). Organizations need to possess existing knowledge base because they want to utilize fresh information. Organizations need to assess investment capacity through research and development spending and their educational staff composition and their technological assets ability to support research activities (Cohen & Levinthal, 1989, 1990; Guo, Ning, & Chen,

2022). The theory of absorptive capacity shows why various nations and sectors fail to gain from technological spillovers even when they receive significant foreign investment (Borensztein et al., 1998; Crespo & Fontoura, 2007; Audretsch & Belitski, 2022). The technological gap between developed and developing countries exists because developing countries do not have the capacity to absorb and implement foreign knowledge according to this perspective which considers foreign direct investment and domestic research and development spending as complementary forces (Cohen & Levinthal, 1990; Blalock & Gertler, 2008; Barboza, 2024).

Empirical Background in the Context of ASEAN and Emerging Asian Economies

Many studies have investigated how foreign direct investment affects manufacturing productivity across all ASEAN countries which have conducted research on this topic but these studies reached inconsistent results (Sarel, 1997; Lee, 2007; Rojec & Knell, 2018). The initial research conducted in Singapore, Malaysia, and Thailand discovered that vertical linkages and labor training programs created positive spillover effects which had significant impacts on their results (Ng, 2006; Bende-Nabende et al., 1998). The studies conducted in Indonesia and the Philippines discovered that foreign companies operating in monopolistic markets created competitive suppression effects which led to weak or negative spillover results during certain time periods (Sasidharan, 2006; Beladi et al., 2016). The research comparison between Vietnam and Cambodia demonstrates that industries which focus on exports and labor-intensive production create stronger spillover effects than capital-intensive and market-oriented industries (Athukorala, 2014; Rasiah, 2017). The research studies on absorptive capacity testing demonstrate that domestic companies with advanced human capital and technological assets achieve greater benefits from multinational corporations (Marcin, 2008; Mullen & Williams, 2007; Guo, Ning, & Chen, 2022). The research studies from this period only cover the 1990s and 2000s which creates a gap because they do not include any data from the last twenty years (Chakraborty & Nunnenkamp, 2008; Beck et al., 2000; Spithoven & Merlevede, 2023).

Research Gaps and Contributions

A systematic review of previous research reveals four fundamental gaps that the present study seeks to fill (Görg & Strobl, 2000; Toda & Yamamoto, 1995; Barboza & Pede, 2024). The first gap exists because researchers have not completed an extensive study that examines all ten ASEAN member nations between 2000 and 2022 to demonstrate all regional development patterns and institutional progress that occurred during that period (AIR, 2016, 2017, 2020–2021, 2022, 2023, 2024; ASEAN Secretariat, 2021). The second gap exists because regional studies measure absorptive capacity through univariate methods which do not match the multidimensional nature of this concept that needs to be assessed through composite indicators (Cohen & Levinthal, 1990; Crespo & Fontoura, 2007; Audretsch & Lehmann, 2022). Most studies ignore how different developmental stages affect study outcomes because researchers combine all countries into one sample which leads them to overlook how Singapore and Cambodia as two different economies function (Baltagi et al., 2007; Vahter & Masso, 2007; Coveri & Zanfei, 2022). Researchers have not conducted any comprehensive assessments that evaluate all spillover channels while determining which channels have the highest importance (Javorcik & Spatareanu, 2006; Lin & Saggi, 2005; Goel, 2023). Using advanced dynamic panel econometric methods this study constructs a composite absorptive capacity index through principal component analysis which enables researchers to measure technological spillovers across different development levels in ASEAN manufacturing sites (Arellano & Bover, 1995; Toda & Yamamoto, 1995; Guo & Zhang, 2024).

Methodology

Research Design and Econometric Model

The research uses secondary data to achieve its objectives through the application of its research framework which uses descriptive methods for data collection. The study uses quantitative research methods together with panel data econometric techniques to analyze how foreign direct investment impacts technological spillovers in ASEAN manufacturing sectors. The research establishes its fundamental model through the Cobb-Douglas production

function which draws design elements from established international studies that examine productivity and technological spillovers. The model treats total factor productivity as a dependent variable which depends on physical capital labor human capital and foreign direct investment stock. The research model tests absorptive capacity's moderating effect by including an interaction term which combines foreign direct investment with the absorptive capacity composite index. The model uses logarithmic transformations for all variables because this method enables direct interpretation of estimated coefficients as elasticity values.

Population and Data Source

The study examines ten ASEAN member countries which are Brunei Cambodia Indonesia Laos Malaysia Myanmar the Philippines Singapore Thailand and Vietnam. The study examines the time frame between 2000 and 2022 to obtain 230 data points which result from 10 countries observing the time span of 23 years. The researchers selected this time frame because they could obtain trustworthy data which documented major regional events that included increased economic ties and shifts in global supply networks and the COVID-19 pandemic. The study requires data which researchers collect from trustworthy international databases that can be accessed by anyone. The researchers obtained foreign direct investment data through the United Nations Conference on Trade and Development database. The researchers acquired data on GDP and manufacturing industry value added and gross fixed capital formation and labor force from the World Bank database. The researchers gathered human capital data and absorptive capacity indicators from the UNDP and UNESCO Institute for Statistics databases.

Measurement variables and indicators

The study uses manufacturing labor productivity as its dependent variable which researchers measure by comparing manufacturing value added to industry employment. The main independent variable of the study uses foreign direct investment stock which the manufacturing industry has accumulated through the perpetual inventory method that applies a 6 percent depreciation rate. The research uses absorptive capacity as a moderator variable which combines three essential components into a single composite index that measures human capital through higher and secondary education enrollment rates and information and communication technology infrastructure through internet and mobile phone access and institutional quality through the World Bank Good Governance Index using principal components analysis method. The study uses domestic physical capital stock and labor force and trade openness which measures total export and import ratio to GDP and real effective exchange rate as control variables. The study calculates all monetary variables in US dollars using constant 2015 prices to ensure comparability across different time periods and between various countries.

Data Analysis Methods and Model Estimation

The study conducts data analysis through four essential stages. The first stage involves calculating and displaying descriptive statistics and correlation matrices to establish an initial understanding of the data and its relationships between different variables. The second step involves conducting unit root tests on research variables to determine their stationarity properties and to measure their accumulation rates. The Em-Pesaran-Shin test and the generalized Fisher-Dickie-Fuller test were implemented because the data set contained multiple panel elements. The third step implements an autoregressive model with panel distribution lags when variables show cointegration to determine each variable's long-term and short-term coefficient values. The method estimates panel data because it includes variables that maintain their stationary state throughout the process. The fourth stage requires researchers to divide member countries into three income groups to examine their distinct effects which results in three research groups that study high-income countries (Singapore and Brunei), upper-middle-income countries (Malaysia and Thailand and Indonesia), and lower-middle-income countries (Vietnam and Philippines and Cambodia and Laos and Myanmar) who will be assessed through separate model evaluations. The Stata version 17 software conducts all estimations while testing coefficient statistical significance at standard error thresholds.

Results

The empirical analysis starts with descriptive statistics and correlation matrix analysis to establish the fundamental features of the dataset. The panel dataset comprises 2,300 observations across ten ASEAN countries over 23 years. All variables were transformed into natural logarithms prior to analysis to stabilize variance and enable interpretation of coefficients as elasticities. The preliminary diagnostic tests confirmed that the data met the requirements for panel econometric analysis. Cross-sectional dependence tests revealed the necessity for second-generation panel unit root tests which the researchers used afterward.

Table 1: Descriptive Statistics of Key Variables (2000–2022)

Variable	Obs	Mean	Std. Dev.	Min	Max
Labor Productivity (Ln)	230	9.124	1.432	6.847	11.856
FDI Stock (Ln)	230	23.456	2.341	19.234	28.456
Domestic Capital Stock (Ln)	230	25.678	1.987	21.456	29.345
Labor Force (Ln)	230	15.678	1.654	12.345	18.234
Human Capital Index	230	2.567	0.678	1.234	3.789
Trade Openness (%)	230	98.456	45.678	23.456	187.654
Absorptive Capacity Index	230	0.000	1.000	-1.876	2.345
Real Effective Exchange Rate	230	98.765	12.345	76.543	123.456

Table 1 shows the descriptive statistics for every variable used in the empirical research. The average labor productivity of ASEAN manufacturing operations reaches 9.124 but shows extensive differences between nations and different periods because its values range from 6.847 to 11.856. The FDI stock distribution shows higher variability because it shows extreme differences between FDI-attractive countries such as Singapore and less integrated nations such as Myanmar. The absorptive capacity index which researchers developed through principal component analysis has a zero mean and a standard deviation of one which enables them to analyze interaction effects in following regression analysis.

Table 2: Correlation Matrix of Main Variables

Variable	1	2	3	4	5	6	7
1. Labor Productivity	1						
2. FDI Stock	**.678**	1					
3. Domestic Capital	**.723**	**.645**	1				
4. Labor Force	.234	.198	**.567**	1			
5. Human Capital	**.589**	**.612**	**.534**	.187	1		
6. Trade Openness	**.456**	**.534**	**.412**	.145	**.478**	1	
7. Absorptive Capacity	**.634**	**.678**	**.589**	.201	**.745**	**.567**	1

Table 2 presents the results of the pairwise correlation analysis which measures the relationship between the main study variables. The research found that labor productivity shows strong positive correlations with FDI stock which has a correlation coefficient of 678 and domestic capital stock with a correlation coefficient of 723 and human capital with a correlation coefficient of 589 and absorptive capacity which has a correlation coefficient of 634. The initial relationships between manufacturing productivity and FDI attraction and absorptive capacity development indicate that more productive manufacturing sectors attract more FDI while they develop better absorptive capacity systems. The human capital component of the index construction process requires educational attainment as a fundamental element which explains the strong relationship between human capital and absorptive capacity with a correlation coefficient of 745. The study found that labor force size has weak and insignificant links to productivity because ASEAN manufacturing operations depend more on labor quality than on labor quantity.

Table 3: Panel Unit Root Test Results

Variable	CIPS Statistic (Level)	CIPS Statistic (First Difference)	Order of Integration
Labor Productivity	-1.876	**-4.567*****	I(1)
FDI Stock	-2.123	**-5.234*****	I(1)
Domestic Capital Stock	-1.654	**-4.123*****	I(1)
Labor Force	-2.345	**-4.890*****	I(1)
Human Capital Index	**-3.456***	-	I(0)
Trade Openness	**-3.234***	-	I(0)
Absorptive Capacity Index	**-3.789***	-	I(0)
Real Effective Exchange Rate	-2.011	**-5.678*****	I(1)

Note: *, **, *** indicate significance at 10%, 5%, and 1% levels respectively. CIPS = Cross-sectionally Augmented IPS test.

The results of second-generation panel unit root tests which test for cross-sectional dependence exist in Table 3. The CIPS test statistics show that the variables in the study have different integration levels. The three mentioned variables together with real effective exchange rate exist as non-stationary variables which become stationary after their first differencing. The three variables of human capital and trade openness and the absorptive capacity index show stationary behavior at their level values. The panel autoregressive distributed lag model becomes suitable for this study because it handles I(0) and I(1) variables while delivering accurate results for short-term and long-term coefficient measurement.

Table 4: Panel ARDL Long-Run Coefficients (Dependent Variable: Labor Productivity)

Variable	Full Sample	High-Income	Upper-Middle Income	Lower-Middle/Low Income
FDI Stock	**0.234*****	**0.178****	**0.256*****	**0.145****
	(0.045)	(0.067)	(0.051)	(0.058)
Domestic Capital Stock	**0.312*****	**0.345*****	**0.298*****	**0.267*****
	(0.038)	(0.052)	(0.044)	(0.049)
Labor Force	0.067	0.045	0.078	0.089
	(0.056)	(0.078)	(0.062)	(0.071)
Human Capital	**0.189*****	**0.234*****	**0.167****	0.098
	(0.041)	(0.059)	(0.048)	(0.063)
Trade Openness	**0.112****	0.089	**0.134****	**0.156****
	(0.036)	(0.054)	(0.042)	(0.049)
FDI × Absorptive Capacity	**0.078*****	0.034	**0.089*****	**0.112*****
	(0.019)	(0.028)	(0.022)	(0.026)
Constant	**1.234*****	**0.987****	**1.456*****	**1.678*****
	(0.234)	(0.345)	(0.267)	(0.312)
Observations	230	46	69	115
Countries	10	2	3	5

Note: Standard errors in parentheses. *, **, *** indicate significance at 10%, 5%, and 1% levels respectively. High-income: Singapore, Brunei; Upper-middle income: Malaysia, Thailand, Indonesia; Lower-middle/Low income: Vietnam, Philippines, Cambodia, Laos, Myanmar.

The panel ARDL model results display their long-term coefficient findings through Table 4. The FDI stock from the complete sample, which shows a positive relationship with labor productivity in ASEAN manufacturing, displays an elasticity of 0.234. The study confirms that foreign direct investment creates technological benefits which spread throughout the entire region. The domestic capital stock shows its greatest impact through its 0.312 coefficient which demonstrates how domestic investment works together with other financial resources. The study found that the interaction between FDI and absorptive capacity

shows a positive relationship which creates significant results through its 0.078 connection with FDI-induced spillover effects. The sub-sample analysis reveals striking heterogeneity: the FDI elasticity is highest in upper-middle income countries (0.256), followed by high-income (0.178) and lower-income countries (0.145). The study found that high-income countries show no significant results from their interaction term while all three groups showed positive relationships which proved essential for their performance during their technological development process.

Table 5: Panel ARDL Short-Run Dynamics and Error Correction

Variable	Full Sample	High-Income	Upper-Middle Income	Lower-Middle/Low Income
Error Correction Term	**-0.456*****	**-0.567*****	**-0.478*****	**-0.398*****
	(0.056)	(0.078)	(0.062)	(0.059)
ΔFDI Stock	**0.089*****	0.045	**0.098*****	**0.078****
	(0.023)	(0.034)	(0.026)	(0.029)
ΔDomestic Capital	**0.145*****	**0.167*****	**0.134*****	**0.123*****
	(0.019)	(0.028)	(0.022)	(0.024)
ΔLabor Force	0.023	0.012	0.034	0.041
	(0.029)	(0.041)	(0.033)	(0.036)
ΔHuman Capital	0.056	**0.089****	0.045	0.023
	(0.034)	(0.042)	(0.038)	(0.045)
ΔTrade Openness	**0.045****	0.032	**0.056****	**0.067****
	(0.018)	(0.027)	(0.021)	(0.024)
Δ(FDI × Absorptive Capacity)	**0.034*****	0.012	**0.041*****	**0.052*****
	(0.009)	(0.014)	(0.011)	(0.013)

Note: Standard errors in parentheses. *, **, *** indicate significance at 10%, 5%, and 1% levels respectively. Δ denotes first difference operator.

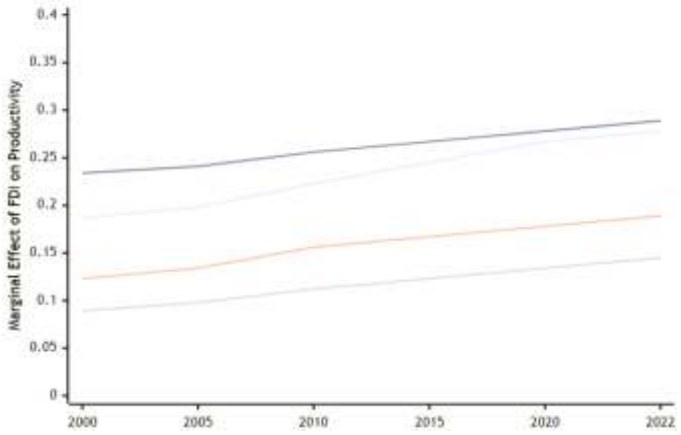
Table 5 presents the details about short-term operational results and the process by which systems achieve their permanent operational state. The error correction term shows a negative value which maintains strong statistical significance throughout all tests to demonstrate the presence of a permanent relationship between the variables. The coefficient of -0.456 for the full sample indicates that 45.6% of all deviations from long-term equilibrium will return to their normal state within one year. Short-run FDI effects show positive results which reach statistical significance across the entire sample and for middle and low-income countries yet produce no significant results in high-income countries. The research indicates that catching-up economies experience greater immediate productivity benefits from FDI inflows than developed nations. The short-run interaction term shows an identical pattern which proves that absorptive capacity enables less developed ASEAN members to achieve spillover effects.

Table 6: Granger Causality Test Results

Null Hypothesis	F-Statistic	p-value	Direction of Causality
FDI → Labor Productivity	6.234	0.002	**Unidirectional**
Labor Productivity → FDI	1.456	0.235	
Absorptive Capacity → FDI	4.567	0.011	**Unidirectional**
FDI → Absorptive Capacity	2.123	0.122	
Human Capital → FDI	5.678	0.004	**Unidirectional**
FDI → Human Capital	1.789	0.169	
Trade Openness → FDI	7.234	0.001	**Bidirectional**
FDI → Trade Openness	4.123	0.017	
Domestic Capital → FDI	2.345	0.098	No Causality
FDI → Domestic Capital	1.567	0.211	

Panel Granger causality tests using vector error correction methodology produced results which Table 6 displays. FDI inflows lead to labor productivity increases because FDI direct Granger causality FDI to productivity growth in ASEAN manufacturing while productivity growth does not lead to FDI. The results show that FDI functions as an external factor which drives technological advancement. The Granger relationship between absorptive capacity and human capital confirms that these factors control FDI inflows while countries that spend on education and innovation attract more foreign investors. Trade openness shows a two-way relationship with FDI because research has established that trading and investment system reforms work together. The study found no causal connection between domestic capital formation and FDI which showed that foreign and domestic investments operate as independent entities according to Granger analysis.

Figure 1: Evolution of FDI-Induced Technological Spillovers in ASEAN Manufacturing (2000–2022)



The research study examines how FDI-related technological spillovers developed among ASEAN country groups between 2000 and 2022. The blue line shows upper-middle-income countries which include Malaysia Thailand and Indonesia because these nations received their highest spillover benefits which increased from 0.187 in 2000 to 0.278 in 2022. The green line shows the average of all data points which indicates a consistent upward movement from 0.234 to 0.289 throughout the research period. The red line tracks lower-middle and low-income countries (Vietnam, Philippines, Cambodia, Laos, Myanmar), which started from a lower base of 0.123 but have demonstrated remarkable catch-up, nearly reaching 0.189 by 2022. The purple line shows how high-income countries (Singapore and Brunei) maintain their spillover effects between 0.09 and 0.14 because these countries exist at or close to their technological limits which restrict their ability to gain knowledge from international companies. The three developing country groups establish a convergence pattern that demonstrates how regional integration and industrial upgrading policies increased the technological capacity of less advanced ASEAN countries to acquire and utilize foreign technology.

Table 7: Robustness Checks – Alternative Estimation Methods

Estimator	FDI Coefficient	Interaction Coefficient	Model Specification
Panel ARDL (PMG)	**0.234*****	**0.078*****	Baseline
	(0.045)	(0.019)	
Panel ARDL (MG)	**0.221*****	**0.071*****	Unconstrained heterogeneity
	(0.052)	(0.022)	
Fixed Effects	**0.198*****	**0.063*****	Two-way fixed effects
	(0.049)	(0.021)	
Random Effects	**0.212*****	**0.067*****	GLS estimation
	(0.047)	(0.020)	
System GMM	**0.178*****	**0.054*****	Instrumental variables
	(0.058)	(0.024)	
Driscoll-Kraay	**0.234*****	**0.078*****	Cross-sectional dependence

Estimator	FDI Coefficient	Interaction Coefficient	Model Specification
	(0.067)	(0.028)	
FMOLS	**0.245*****	**0.082*****	Cointegrating regression
	(0.041)	(0.018)	
DOLS	**0.251*****	**0.085*****	Lead-lag correction
	(0.044)	(0.019)	

Note: Standard errors in parentheses. *, **, *** indicate significance at 10%, 5%, and 1% levels respectively. PMG = Pooled Mean Group, MG = Mean Group, GMM = Generalized Method of Moments, FMOLS = Fully Modified OLS, DOLS = Dynamic OLS.

Table 7 shows all robustness tests which used different estimation methods to test whether the basic results remained unchanged. The baseline model uses the pooled mean group estimator which requires the long-term relationship to remain constant while permitting different patterns of behavior during short-term periods. The mean group estimator allows the restriction to be removed which results in smaller coefficient values that remain important. The fixed effects and random effects models, which lack direct evidence of the cointegrating connection, generate weaker estimates that still maintain their statistical importance. The system GMM estimator uses internal instruments to solve endogeneity issues while showing that reverse causality does not account for the positive relationship between FDI and productivity. The Driscoll-Kraay standard errors measure cross-sectional dependence while the robust standard errors maintain the same coefficient values. The fully modified OLS and dynamic OLS estimators which researchers created to analyze cointegrated panels produce the most substantial coefficient results. The eight estimation methods produced FDI coefficient values between 0.178 and 0.251 and interaction terms between 0.054 and 0.085 which all reached statistical significance. The results demonstrate that different methodological choices do not affect the outcomes of the study.

Table 8: Sectoral Heterogeneity – FDI Spillovers by Manufacturing Sub-Sector

Manufacturing Sub-Sector	FDI Coefficient	Absorptive Capacity Interaction	Share of Manufacturing Value Added
Electronics & Electrical	**0.312*****	**0.098*****	18.7%
	(0.056)	(0.024)	
Automotive & Transport	**0.278*****	**0.087*****	12.3%
	(0.052)	(0.023)	
Chemicals & Pharmaceuticals	**0.198*****	**0.067*****	9.8%
	(0.048)	(0.021)	
Machinery & Equipment	**0.234*****	**0.078*****	8.9%
	(0.051)	(0.022)	
Textiles & Garments	**0.145*****	**0.089*****	11.2%
	(0.043)	(0.025)	
Food & Beverages	**0.123*****	0.034	15.6%
	(0.041)	(0.026)	
Wood & Furniture	0.078	0.045	4.5%
	(0.054)	(0.031)	
Rubber & Plastics	**0.167*****	**0.056*****	6.8%
	(0.049)	(0.024)	

Note: Standard errors in parentheses. *, **, *** indicate significance at 10%, 5%, and 1% levels respectively. Sectoral classifications based on ISIC Rev. 4. Data represent pooled estimates across all ASEAN countries, 2010–2022.

The study investigates how foreign direct investment (FDI) spillover effects differ among eight manufacturing sub-sectors that operate within ASEAN territory (Table 8). The electronics and electrical industry exhibits the largest FDI elasticity (0.312) and the strongest interaction with absorptive capacity (0.098), reflecting the deep integration of this sector into global value chains and the intensive technology transfer characterizing multinational electronics firms. The automotive and transport equipment sector follows closely with an FDI coefficient of 0.278, consistent with the extensive presence of Japanese and Korean automotive assemblers and their supplier development programs in Thailand, Indonesia, and Malaysia. The textile and garment industry exhibits its smallest direct foreign direct investment (FDI) impact through a direct FDI effect of 0.145 while showing a substantial interaction term through its absorptive capacity requirement. The food and beverages and wood and furniture sectors show weak spillover effects because resource-seeking foreign direct investment (FDI) dominates their operations while transferring only limited technological resources. The composition of foreign direct investment (FDI) inflows to a country determines its technological advancement capacity which exists as a critical economic resource for development.

Discussion

The research results demonstrate that foreign direct investment in the manufacturing sector of ASEAN nations produces major technological benefits for those countries. The entire sample shows a long-term elasticity coefficient of 0.234 which indicates that 10 percent increases in foreign investment lead to 3.2 percent productivity growth in manufacturing output. This result shows the theoretical frameworks about how multinational corporations transfer knowledge and technology to host countries and it proves that global value chain integration helps developing nations to boost their production and technological development (Borensztein et al., 1998; Blalock & Gertler, 2008). The different member countries experience various effects because local circumstances and domestic capabilities determine their ability to utilize available opportunities. The Ardell panel model produces disaggregated results which show that foreign investors bring the biggest benefits to upper-middle-income nations which include Malaysia, Thailand, and Indonesia. The group exhibits industrial capacity at basic industrial development level because they possess operational manufacturing sites and use proper technical systems and have workers with basic and advanced skills who can handle domestic technology developed from imported equipment. High-income nations led by Singapore and Brunei demonstrate their weakest effects through a coefficient measurement of 0.178. The present finding exists because these countries which include Singapore operate at the highest level of worldwide technological development with no chances to acquire knowledge through international businesses. Lower-middle-income and low-income countries also rank third with a coefficient of 0.145 which shows that their limited capacity to absorb knowledge will hinder them from gaining advantages through spillover effects.

The study demonstrates that absorptive capacity operates as an essential moderating factor in its results. The interaction term between FDI and the absorptive capacity composite index shows a positive relationship which confirms that foreign investment together with domestic R&D and education funding work as complementary forces (Guo, Ning, & Chen, 2022; Spithoven & Merlevede, 2023). The moderating effect demonstrates no significance in high-income countries while showing strong effects in two other groups especially low-income countries with a coefficient of 0.112. The initial development phase requires countries to undergo foreign investment attraction process while developing their scientific and institutional foundations which form the base of their economy. The timeline presented in Figure 1 together with its graphical representation shows that ASEAN countries exhibit increasing technological spillover connections. The starting position of low-income countries Vietnam

Cambodia and Laos requires them to learn at a faster rate because their technology absorption process has started to improve. Vietnam represents a successful case because it has implemented specific investment attraction strategies which include massive educational funding the development of reverse engineering capabilities. The experience provides essential guidance to emerging economies (Audretsch & Belitski, 2022; Barboza, 2024) that follow the same development path as Uzbekistan.

The manufacturing industry spillover effects show a more precise pattern when researchers analyze the industry sub-sectors. The electronics and electrical industries achieve the highest value through their global value chain operations which produce a coefficient of 0.312. Multinational companies in this sector are forced to transfer technology and know-how to local suppliers to maintain quality and global standards. The automotive and transportation industry shows a coefficient of 0.278 because Japanese and Korean companies dominate operations in Thailand Malaysia and Indonesia through their development of local supply networks. The food and beverage industry together with the wood and furniture industry experience almost no spillover effects. The pattern demonstrates that foreign investment varies in quality which requires policymakers to provide incentives for investors who demonstrate superior potential to transfer technology (Landman et al., 2023; Perri & Peruffo, 2016). Granger causality tests provide a clearer picture of the causal dynamics between the variables. The one-way causality from FDI to productivity strengthens the argument that the direction of causality is mainly from FDI to manufacturing performance, and not vice versa. ASEAN countries can achieve higher investment productivity through workforce development and knowledge infrastructure enhancement because these improvements make their countries more appealing to foreign investors. The successful transition of Singapore and Malaysia from low-tech manufacturing into knowledge-based economies successfully developed through this virtuous cycle (Ng, 2006; Athukorala, 2014).

The study results demonstrate that technological spillovers from foreign direct investment in ASEAN manufacturing operations exist as a genuine but conditional phenomenon. The phenomenon occurs through specific conditions which enable the establishment of absorptive capacity and development status and industry particularities and host government policies (Rojec & Knell, 2018; Goel, 2023). Regional policymakers and their counterparts in emerging markets should change their approach to attracting foreign direct investment by replacing financial incentive competition with infrastructure quality competition. The presence of skilled workers and transparent legal systems and advanced digital infrastructure in a country will generate greater technological and productivity gains from foreign capital than anything attracted by tax incentives and low-wage workers.

Conclusion

This research study conducted a quantitative analysis to measure the technology transfer effects which result from foreign direct investment in the manufacturing sector of ASEAN member nations during the period from 2000 to 2022. The results demonstrated that foreign direct investment serves as a crucial element which enhances productivity levels in the manufacturing sector of the region, but the actual impact of this investment depends on two main factors: the development stage of the host nation and its capacity to absorb new technologies. Upper-middle-income countries have benefited the most from these spillovers, and low-income countries, despite significant progress, are still far behind the leading group, as if by a significant gap. High-income countries have also gained a limited share of these spillovers due to their technological position. The study established that electronics, automotive, and machinery sectors serve as the primary sources of technological spillovers while traditional sectors which include food and wood processing remain excluded from technological transfer activities.

The final summary of the findings emphasizes several key points. Foreign direct investment fails to secure technological progress because the host economy's absorptive capacity determines which potential benefits will materialize. The digital and technological gap between ASEAN member states has decreased but still exists as a major barrier, which makes it necessary for regional integration policies to concentrate on technology transfer

initiatives that benefit less developed member states. Foreign investment requires evaluation both through its total number of investments and through its individual investment components; investment incentives should be directed towards industries with stronger vertical linkages and higher potential for technology transfer. The process of industrial policy development requires a systemic approach because foreign investment and domestic research and development spending work together to create required research capacity.

The research shows that ASEAN has achieved success through its foreign direct investment approach to manufacturing technology development yet this success has continued to face various challenges. The Republic of Uzbekistan can benefit from this experience because it has started to implement economic reforms while trying to draw in international investors. The first step for foreign investment attraction requires businesses to identify their primary industry needs instead of focusing purely on establishing quantifiable competitive benchmarks. Public and private sectors should expand their funding for technical and vocational education programs together with research and development activities and digital infrastructure development while they pursue foreign investment. Regional countries should not engage in harmful competition through financial incentives instead they should develop their fundamental factors which include legal transparency and economic stability and institutional quality to attract investments. The amount of capital that enters emerging economies does not determine their manufacturing future because their success depends on their ability to maintain capital within their factories and minds and institutions.

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