Received: 4 November 2022 | Accepted: 1 April 2023

DOI: 10.1111/ecot.12369

ECONOMICS OF TRANSITION AND INSTITUTIONAL CHANGE

WILEY

ORIGINAL ARTICLE

Foreign direct investment and relative capacity: Theory and evidence

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Abstract

This paper builds a bilateral FDI-output model to study intermediary roles played by the relative differences in human capital and technology in triggering the gross-output-enhancing effect of inward foreign direct investment (FDI). Our model develops several testable hypotheses to assess how these intermediary factors—the differences between leader and follower countries' capabilities—determine the technology transfer and shorten the gross output gap between the frontier and follower countries. In our empirical work, we employ country-level panel data that contain 67 countries from 1977 to 2013 and find that the differences in human capital and technology, which take into account the gap in capacity between the leader and follower countries, are the determinants that trigger the gross-output-enhancing effect of FDI. Our results are robust to the non-linear effects, cyclical fluctuations, endogeneity of FDI per se, and the variation of the host countries' institutions and inflation.

KEYWORDS
foreign direct investment, gross output gap, human capital, technology

JEL CLASSIFICATION
F23, O30, O40

1 | INTRODUCTION

Many countries offer policies, such as generous tax and financial incentives, to attract (henceforth, FDI), resulting in a surge of FDI inflows into both developing and developed countries over the last decade (Li & Tanna, 2019; Li et al., 2022; UNCTAD, 2020). Although there is a general consensus that FDI provides technology transfers and new production processes that can result in higher productivity for domestic firms and promote aggregate growth (Baltabaev, 2014; Biørn & Han, 2017; HerzerLi et al., 2022 & Donaubauer, 2018; Mei, 2021; Walz, 1997; Wang, 1990), controversy remains over the degree to which the impact of FDI on output growth is conditional on the host country's absorptive capacity (Borensztein et al., 1998; Durham, 2004). However, as Findlay (1978) emphasised, the rate of technology externality from FDI is an increasing function of the technology gap between the backward and advanced regions. A naturally important but fundamentally overlooked question is whether the host country's capacity relative to the world frontier country triggers the potential catch-up effects, and thus, indirectly changes the FDI-gross-output-enhancing effect.

Most existing works have focused on the relations between FDI, financial market, total factor productivity (henceforth, TFP), institutional environment, and absorptive capability. Studies focussing on the development of domestic financial markets in mediating the flow of imported capital to enhance growth find that FDI per se plays an ambiguous role in growth regressions and its effect is contingent on the absorptive capacity and financial market of the host countries (Alfaro et al., 2004; Durham, 2004; Lee et al., 2022). In contrast, Woo (2009) finds that the effect of FDI on TFP growth does not necessarily depend on the recipient country's capability.[1] By applying measures of multinationals' expenditures on royalties and licences, Xu (2000), however, finds that the benefits from FDI on technology diffusion and productivity gains depend on a threshold level of human capital in the host country. By using cross-country data and accounting for the roles of human capital and institutions, Li and Tanna (2019) also find a robust FDI-induced productivity growth pattern. On the other hand, Borensztein et al. (1998) find no impact of FDI on growth rates; instead, they show that the benefits from FDI are restricted by the absorptive capability of the country receiving FDI. While other studies also explicitly examine factors, such as openness to trade (Balasubramanyam et al., 1996; Gönel & Aksoy, 2016; Rehman & Islam, 2022) and social capability (Kim et al., 2013), the empirical evidence remains oddly inconclusive.

Although the aforementioned studies examine a variety of technology transmission channels and concentrate on the growth effects of FDI using flow and one-way inward FDI data, the issues played by the relative differences in human capital and technology—in particular the differences between a leading economy to a follower country—in determining the relative gross-output-enhancing effects from FDI using stock and bilateral data are largely ignored.[2] Here, modelling the relative output enhancing effect from the FDI as a process of technology transfer, the relative FDI stock increases the potential access to new knowledge and so increases relative output (or closes the "gap"), but the benefits of absorbing new knowledge on relative output may depend on the relative differences in human capital and technology between the countries. From a theoretical standpoint, technology transfer from a leading economy to a host country is by no means always guaranteed; it requires time and absorptive

[1]By considering the potential within-region and within-period variations, Campos and Kinoshita (2002), Makki and Somwaru (2004), and Iamsiraroj (2016) also confirm the positive impact of FDI on GDP.

[2]FDI stock data are considered more reliable and volatile than flow data. To capture the knowledge stock in an economy, it is reasonable to examine the relationship between output and FDI stock rather than FDI flow. Assuming a linear relationship between FDI and output gross, stock data with no negative values are more appropriate. Please refer to De Sousa and Lochard (2011) for more information.

capacity to adapt and absorb, and the "direct" effects from the FDI may vary through the differences of technology and human capital between the frontier and follower countries. To clarify better, the relative gross-output-enhancing effects of FDI could be distorted by a learning-by-watching effect—the host country may be able to raise the quality of human capital and improve managerial skills by learning and interacting with the leader through FDI (Bengoa & Sanchez-Robles, 2003). The host country's abilities will be improved whilst absorbing new knowledge to close the technology gap with the leader,[3] and this improvement may ultimately reduce the benefits from FDI. In other words, there may be an "indirect" effect from the improvement of ability that may diminish the gross-output-enhancing effect of FDI ultimately.[4] It follows that the effects of FDI on relative output may be subject to the capacity of varying relative differences when the host countries receive FDI.

Figure 1 provides a visual aid; it shows data on the inward FDI stock and country ability differences between the United States and the rest of the world. The data reveals that there is a positive correlation between the relative FDI stock and relative differences in human capital and technology. Moreover, Figure 2 displays data on average relative output and interaction terms between relative capacity and FDI over the leader and follower countries through the period 1977–2013. As can be easily seen, the bilateral relationship shows a negative pattern between the output changes and the interaction effects of FDI and relative capacity. While these stylised facts, which motivate this paper, suggest that the potential correlation among the relative capacity differences could play a fundamental role in determining the effect of FDI over time, these simple correlation plots overlook all cross-countries differences and time-invariant and potential unobserved factors, and so they do not provide precise transmission mechanisms relating to how the relative differences in human capital and technology determine the direct and indirect gross-output-enhancing effects from FDI. This issue requires both theoretical and empirical analyses to differentiate whether and how the relative capacity across countries is important for determining the role of FDI in relative output differences. Thus, this is the aim that we take up in this paper.

Since the literature has not accounted for the potential role played by differences in countries' abilities to link the importance of FDI to relative output differences, this paper explicitly exploits this precise mechanism using human capital and technology as intermediaries. To establish the direct and indirect mechanisms involving human capital and technology, first, we develop a FDI-output model that extends the leader–follower endogenous growth framework, initially developed by Romer (1990), extended by Helpman (1993), Barro and Sala-i Martin (1997), and emphasized in Jones and Vollrath (2013), to properly accommodate the intermediary roles played by the differences in human capital and technology in determining direct and indirect gross-output-enhancing effects from FDI.[5] Our FDI-output model demonstrates that the differences in human capital and technology are the potential factors that trigger the transfer of knowledge and benefits from FDI in the host country. Then, we empirically examine our model predictions by employing a cross-country panel of bilat-

[3]Walz (1997) suggests that the benefits of FDI are accompanied by interregional spillovers of knowledge from developed to less-developed countries. In a model where technology is assumed to be transferred via international capital movements from the developed North to the developing South, Wang (1990) shows that the income gap would be reduced with an increase in the growth rate of human capital. Other well-known early studies, including Benhabib and Spiegel (1994) and Benhabib and Spiegel (2005), also document the potential relationship between human capital and the growth rate in the host country.

[4]Whalley and Zhao (2010) showed that, for example, China had increased the quality of its human capital since receiving significant inward FDI from 1997 to 2007, although the growth rate has since slowed. For more details, please refer to Section 2 on the theoretical model.

[5]We extend the leader–follower endogenous growth model because it allows us to formalise the role of inward FDI in the process of technology transfer. See Borensztein et al. (1998), Xu (2000), Lensink and Morrissey (2006), and Ford et al. (2008) for more details.

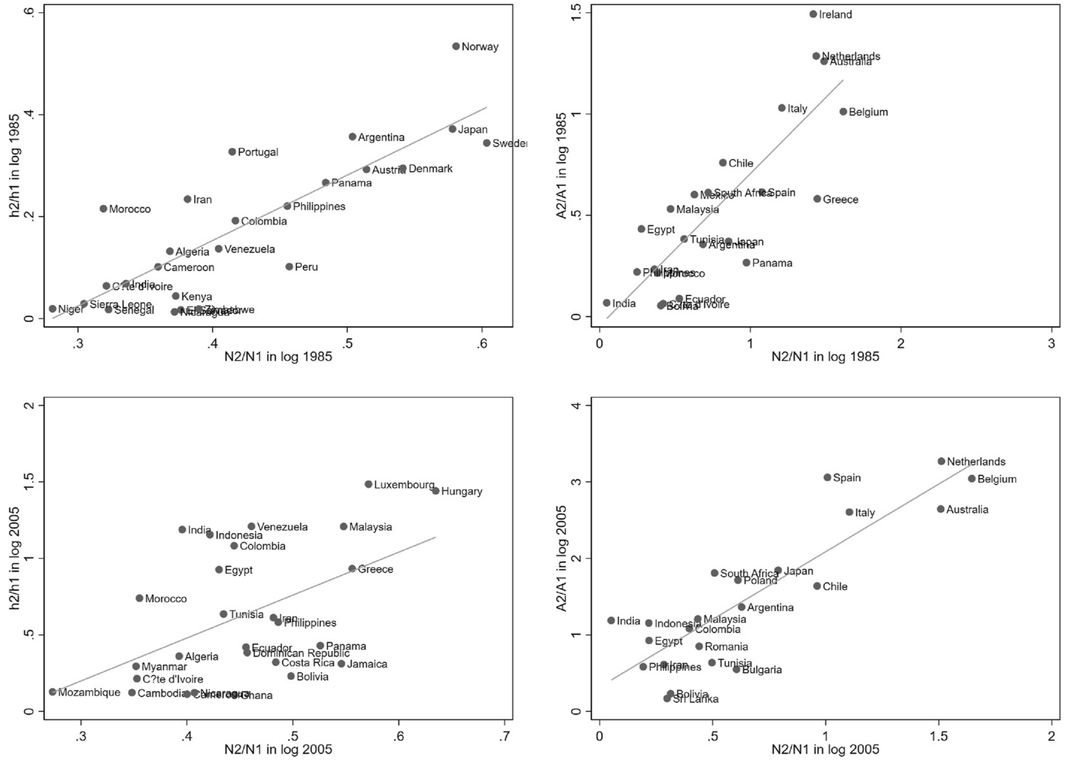

FIGURE 1 Log Inward foreign direct investment (FDI) versus Log Difference in Ability 1985 and 2005. FDI is measured as N_2/N_1 (Equation 12), where N_1 refers to the capital stock in the United States and N_2 refers to the inward FDI in other countries. The differences in abilities are measured as differences in human capital (Equation 13) and total factor productivity (Equation 14) between the United States (leader) and other countries (follower) 1985 and 2005. Outliers are trimmed. See Section 3 for more details.

eral data from 1977 to 2013 with a linear econometric specification.[6] By examining how FDI conducts knowledge and technology transfers to shorten the gross output gap with the leader country through the differences in human capital and technology, our work reconciles the role of FDI in conducting technology transfers and aggregate productivity improvement.

Our work differs from the existing studies, such as Li and Liu (2005), Woo (2009), Baltabaev (2014), Herzer and Donaubauer (2018), Li and Tanna (2019), Luo et al. (2021), Aziz (2022), and Ciftci and Durusu-Ciftci (2022). Li and Liu (2005) study the importance of the distance to the technological frontier as a factor in benefitting from FDI using a sample of 84 countries, while Woo (2009) analyses the absorptive capacities through FDI based on a panel of over 90 countries. Baltabaev (2014) focuses on the direct positive effect of FDI through the distances to the technological frontier on countries' TFP growth. However, these studies focus only on the effects of FDI on TFP growth, and the findings differ substantially, implying the likelihood of omitted variable bias.[7] Most importantly, these stud-

[6]We also examine the role of the nonlinear impact of relative abilities to FDI on the relative gross output in our context, but we do not find the non-linearity to be significant. This gives us confidence to use the linear model with FDI and relative abilities interactions. Please see our result section for more details.

[7]Girma and Görg (2007) also study the role of efficiency gaps relative to the leader in determining the benefits from FDI although their work is an establishment-level empirical analysis focussing on the changes in TFP other than GDP across economies.

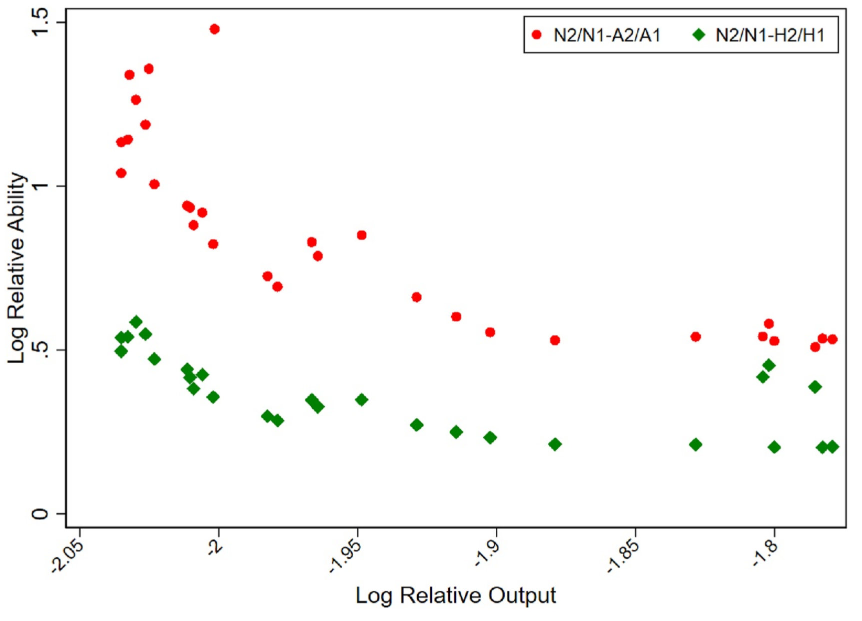

FIGURE 2 Average Relative Output versus Interaction between foreign direct investment (FDI) and Relative Capacity. FDI is measured as N_2/N_1 (Equation 12), where N_1 refers to the capital stock in the United States and N_2 refers to the inward FDI in other countries. The relative capacity is measured as differences in human capital (Equation 13 in green) and total factor productivity (Equation 14 in red) between the United States (leader) and other countries (follower). The relative output is measured as differences in output between the United States (leader) and other countries (follower) based on Equation 11. All values are the mean average (in logs) for the period 1977–2013.

ies relate to the growth effects of FDI rather than the effects of FDI on relative output differences. Furthermore, they employ FDI inflows with one-way FDI flows data but not FDI stock with bilateral data.

Different from the aforementioned literature, Luo et al. (2021) study both the inward and outward FDI using a mediating effect model to estimate the impact of international capital flows on economic growth. While they emphasise that both inward and outward FDI significantly contribute to economic growth, their results are not worldwide comparable and do not focus on the heterogeneous effect of inward FDI through human capital and technology across countries. Li and Tanna (2019), Herzer and Donaubauer (2018), and Aziz (2022) stand relevant to ours. The authors provide evidence on the relationship between inward FDI and TFP growth using cross-country data for 51 and 49 developing countries, and 11 Arab countries over the period 1984–2010, 1981–2011, and 1988–2012. They all find that the effect of FDI on TFP growth is dependent upon the quality of human capital, institutions financial development, and trade openness in the host country. However, they focus on the level of human capital rather than the difference in the level of human capital. More importantly, they look at the relationship between FDI and TFP rather than the impact of FDI in conducting technology transfer and shortening the gap in the gross output to the leading country through the intermediary roles played by the differences in human capital and technology.

While one of the most recent studies carried out by Ciftci and Durusu-Ciftci (2022) is also informative, they focus on the causal relationships between economic freedom, FDI, and economic growth based on countries with the highest amount of FDI inflow 1995–2019 only. To the best of our knowledge, no cross-country study has taken into account the intermediary roles played by human capital and technology to properly accommodate the role of FDI in the host country. Our work explores these relationships, and therefore, fills out the gap in the literature.

Our findings can be summarised as follows. We show that the gross-output-enhancing effect from inward FDI exists when the model properly accommodates both indirect and direct effects originating from the differences in human capital and technology between the leader and follower countries. Specifically, our leader–follower model shows that while the impact of inward FDI is predicted to be directly associated with the change in the gross output gap between the leader and follower countries, there is a predicted and indirect effect coming from the difference in ability between the leader and follower countries. These are important model predictions as they allow us to better understand the mechanisms behind the inconclusive empirical findings persisted in the literature. Empirically, our cross-country panel of bilateral data analysis shows that the differences in human capital and technology between the countries are confirmed to be statistically significant in shortening the gross output gap between the follower and leader nations. Having a bridge that properly accommodates the intermediary roles played by human capital and technology, we show that there is a consistent, statistically significant, and positive gross-output-enhancing effect from FDI. We perform a set of robustness checks at the end of the analysis and find that the results are robust to a potential concern of non-linearity, different income levels, potential cyclical behaviour, potential endogeneity of FDI per se, and the variation of the host countries' institutions and inflation.

The remainder of this paper is organised as follows: Section 2 presents the theoretical model and outlined hypotheses; Section 3 provides information on the data, the measurements for key variables, and the empirical strategy. The results are discussed in Section 4, and Section 5 presents the conclusions.

2 | THEORETICAL FRAMEWORK

We consider a case in which firms participate in innovation and imitation activities in leader and follower countries based on Romer (1990), Barro and Sala-i Martin (1997), Helpman (1993), and Jones and Vollrath (2013). In our extended model, frontier countries in the North produce designs for new types of intermediate goods for which they can transfer certain technologies abroad through FDI by building facilities, licensing, and then adapting technology in the South. The leader and follower countries, denoted by $i = 1, 2$, produce the final output under perfect competition using the following technology:

$$Y_i = A_i H_i^{1-\alpha} \sum_{j=1}^{N_i} \left(X_{ij}\right)^{\alpha} \tag{1}$$

where $0 < \alpha < 1$ and X_{ij} is the quantity employed of the jth type of nondurable capital good, and N_i is the number of types of capital goods available in the country. Following Jones and Vollrath (2013), we assume that the total human capital of the country is given by $H_i = e^{(\varphi \mu_i)} L$, where φ is a measure of the quality of human capital and μ_i is the number of years each worker in the labour force spends in education, and L measures the size of the labour force. The parameter A_i is an overall measure of technological efficiency, which varies across countries. Individuals in the economy are endowed with h units of human capital.[8] Firms in the final good sector will choose H_i, X_{ij} to maximise profit:

[8]For simplicity, we abstract from a household's decision of accumulating human capital.

$$\max_{H_1, X_{ij}} \quad Y_i - w_i H_i - \sum_{j=1}^{N_i} P_{ij} X_{ij}$$

where P_{ij} is the price of intermediate j in the leader nation. The first-order condition associated with each capital good is given as follows:

$$A_i \alpha H_i^{1-\alpha} X_{ij}^{\alpha-1} = P_{ij} \tag{2}$$

which implies that the quantity of the intermediates' j input demanded, X_{ij}, is a function of the price P_{ij}

$$X_{ij} = \left(\frac{\alpha A_i}{P_{ij}}\right)^{\frac{i}{1-\alpha}} H_i \tag{3}$$

Equation (3) is the demand for j-type capital goods innovated in country 1 or adapted in country 2.

2.1 | Adaptation in the follower country: A bilateral FDI-output model

To introduce FDI, we assume that there are two activities that the leader country can undertake: adapting or not adapting their intermediate to the follower economy. If both countries respect legislation regarding international intellectual property, the intermediate producer can exert monopoly rights across both countries. Country 1 adapts the products for use in country 2 at d_2 unit costs of adaptation, and the rate of return to this adaptation activities exceeds the rate of innovation (r_1) at the costs η_1 in country 1.[9]

To analyse the role of FDI in the process of technology transfer through adaptation, the cost of adaptation is assumed to depend on the differences between the countries:

$$d_2 = \left(\frac{N_2}{N_1}\right)^{\sigma} \left(\frac{A_1}{A_2}\right)^{\delta} \left(\frac{H_1}{H_2}\right)^{\beta}, A_2 \le A_1 \textit{ and } H_2 \le H_1 \tag{4}$$

where A_1/A_2 and H_1/H_2 refer to the differences in technology and human capital between country 1 and 2. When adaptation activities take place in the follower country, there will occur a pre-start-up training cost (Teece et al., 1977). As remarked by Teece, the cost d_2 is lower if the follower has more skilled labour so that they have less difficulty in absorbing new technology in the industry. The cost d_2 is also lower if the follower country has the capability to solve unusual technical problems (Oshima, 1973). This implies $\delta > 0$ and $\beta > 0$. For σ, the cost d_2 is lower when little copying occurs but rises with the size of the pool of uncopied ideas (Barro & Sala-i Martin, 2004). This implies that d_2 rises as technologies are transferred from the easiest to the most complicated (i.e., $\sigma > 0$). Following the above, the power of the variables σ, δ, and β is set to be positive, implying that the differences in the human capital and technology between the two countries have significant impacts on technology transfer activities.

The leader country now holds the intellectual property rights over the use of intermediates across countries. Let us denote V_{1d} and V_{1nd} as the value of adopting products and not adopting products, respectively, by the leader country to other countries. If not adopting the intermediate, the value of

[9]To save space, detailed models for innovation in country 1 and imitation in country 2 are provided in Appendix A.

V_{1nd} is given by $\frac{\pi_1}{\eta_1}$.[10] The value of V_{1d} is given by the sum of the profit π_1 and π_2 divided by the sum of the cost in η_1 and d_2 if the leader decides to adopt the intermediate in the follower economy. This can be expressed as follows:

$$V_{1d} = \frac{\pi_1 + \pi_2}{\eta_1 + d_2} \tag{5}$$

where $d_2 = \left(\frac{N_2}{N_1}\right)^{\sigma}\left(\frac{A_1}{A_2}\right)^{\delta}\left(\frac{H_1}{H_2}\right)^{\beta}$. In equilibrium, V_{1nd} and V_{1d} will be the same, which implies

$$\frac{\pi_1 + \pi_2}{\eta_1 + d_2} = \frac{\pi_1}{\eta_1} \tag{6}$$

therefore, the ratio of N_2 and N_1 in the steady state is given as follows: $\left(\left(\frac{N_2}{N_1}\right)^{*}(H_1, H_2, A_1, A_2, \eta_1)\right)$:

$$\left(\frac{N_2}{N_1}\right)^{*} = \left[\eta_1\left(\frac{A_2}{A_1}\right)^{\frac{1+\delta-\alpha\delta}{1-\alpha}}\left(\frac{H_2}{H_1}\right)^{1+\beta}\right]^{\frac{1}{\sigma}} \tag{7}$$

Equation (7) implies that the number of known varieties of intermediates adapted N_2/N_1 is affected by the cost of innovation η_1, the difference in level of human capital H_2/H_1, and the difference in level of technology A_2/A_1. Equation (7) also highlights that a higher innovation cost would increase the number of intermediates produced in the follower country, implying that the leader would adapt more of their intermediates in the follower country. Note that as N_2/N_1 represents the role of inward FDI, this equation highlights the endogenous issue of FDI per se; that is, the effect of FDI is affected and triggered by the differences in the human capital and technology between the countries. We will assess this implication in the robustness check section. Now, the common growth rate in country 1 can be expressed as follows:

$$\tilde{\gamma} = \frac{1}{\theta}\left(\frac{\pi_1 + \pi_2}{\eta_1 + \eta_1\left(\frac{A_2}{A_1}\right)^{\frac{1}{1-\alpha}}\frac{H_2}{H_1}} - \rho\right) \tag{8}$$

Equation (8) shows that in equilibrium, the gross output per capita in country 1 (the leader) is affected by the cost of innovation and the profit gained from innovation activities. The differences in technology and human capital A_2/A_1 and h_2/h_1 also act as two determinants that shorten the gap in gross output per capita between the leader and follower countries. Note that the rate of return in Equation (8) corresponds to a steady state in which N_1, Y_1, C_1, N_2, Y_2 and C_2 all grow at a constant rate $\tilde{\gamma}$.[11] Note that while Eqation (8) shows that the gross output of country 2 will be enhanced once FDI arrives in the country, there will be a reduction in this gross-output-enhancing effect when the differences in human capital and technology (A_2/A_1 and h_2/h_1) between the two countries decrease (i.e., the follower improves their levels of human capital and technology).[12] We assess this implication in the following

[10]See Equations (A5–A7) in Appendix A for more details.

[11]See Appendix A for more details.

[12]For example, the college enrolment in China increased nearly fivefold after receiving large inward FDI between 1997 and 2007, yet the growth rate slowed down when the level of human capital increased (Whalley & Zhao, 2010).

analysis and express the gap of gross output per capita between the two countries (i.e., log difference) as follows:

$$\left(\frac{y_2}{y_1}\right)^* = \left(\frac{A_2}{A_1}\right)^{\frac{1}{1-\alpha}} \frac{h_2}{h_1} \left(\frac{N_2}{N_1}\right)^* \tag{9}$$

It is clear that the gap in relative gross output per capita of the follower to the leader depends on the differences of A_2/A_1, $(N_2/N_1)^*$, and h_2/h_1. It is straightforward, therefore, to claim the following hypotheses.

2.1.1 | The gross-output-enhancing effects of N_2/N_1

The expression of Equation (9) shows that N_2/N_1 can shorten the gross output gap between the leader and follower countries; the more capital goods are adopted (N_2) in the follower country, the more advanced knowledge and technology (i.e., N_1) are transferred from the leader, and all of which shortens the gap in gross output between the leader and follower countries. This leads to the first examinable prediction.

Hypothesis 1. The estimated coefficient of N_2/N_1 is positively associated with y_2/y_1

2.1.2 | The indirect effects from h_2/h_1 & A_2/A_1 through foreign direct investment on y_2/y_1

The expression in Equation (7) shows that the number of intermediates available in both the leader and follower countries is affected by the differences in human capital and technology between them. As unadopted know-hows from the available knowledge stock are more difficult to absorb and implement compared to those that are already adopted, as highlighted by Barro and Sala-i Martin (2004),[13] the relative differences in h_2/h_1 and A_2/A_1 may potentially and indirectly affect the gross-output-enhancing effect of N_2/N_1, reflecting the intermediary roles of relative capacities in diminishing the benefits from FDI on the relative gross output. This leads to the second examinable prediction.

Hypothesis 2. The relative differences in h_2/h_1 and A_2/A_1 affect the changes in N_2/N_1, which indirectly diminish the effects of N_2/N_1 on y_2/y_1

2.1.3 | The direct gross-output-enhancing effects from h_2/h_1 and A_2/A_1

Additionally, existing studies, such as Borensztein et al. (1998), Hermes and Lensink (2003), and Durham (2004), among others, emphasise the concept that the level of human capital in the FDI recipient country is critical to generate positive growth effects. Our theoretical predictions shown in Equation (9), however, outline that it should be the relative differences of human capital and tech-

[13]Barro and Sala-i Martin (2004) emphasise that the cost of adaptation is lower than that of innovation when little copying has occurred. However, the cost of adaptation rises when the pool of uncopied ideas contracts.

nology that positively affect the relative gross output between the leader and follower countries. This leads to the third examinable prediction.

Hypothesis 3. The relative differences in h_2/h_1 and A_2/A_1 shorten the gap between the leader and follower countries and thus positively affect the relative gross output y_2/y_1

3 | DATA AND EMPIRICAL FRAMEWORK

3.1 | Data

We use a balanced panel of data for the estimation of our FDI-output model. We construct a dataset that contains data from 67 countries between 1977 and 2013. The selection of countries and time periods with a starting date at 1977 and an ending date of 2013 is entirely based on cross-country data availability.[14] Our key variables rely on publicly accessible datasets provided by (1) the World Bank National Account, (2) United National Conference on Trade and Development, (3) International Monetary Fund (IMF) Investment and Capital Stock, and (4) Barro and Lee (2015) for the period 1977–2013. The final sample is restricted to observations with non-missing values for key variables, resulting in a total balanced panel of 1964 observations. Using panel data with annual frequency rather than employing cross-sectional data allows us to better filter out those unobserved time-invariant factors, providing more precise and realistic results.

3.2 | Baseline model

To examine the hypotheses, we begin with a linear version of the equation derived from Equation (9) by taking logs and estimating the effects of FDI based on 67 countries from 1977 to 2013 as follows:

$$lny_{i,t} = \beta_0 + \beta_1 lnFK_{i,t} + \beta_2 lnh^{v}_{i,t} + \beta_3 lnA^{v}_{i,t} + \gamma' INTERACTION' + \tau' Z' + \delta_i + \rho_t + \varepsilon_{i,t} \quad (10)$$

where $lny_{i,t}$ refers to the gap in gross output per capita from each country to the United States. The $lnFK_{i,t}$ refers to the number of intermediates available in the leader and adapted by the follower (Hypothesis 1). The term *INTERACTION′* is a set of vectors that contains $lnFK_{i,t} \times lnA^{v}_{i,t}$ and $lnFK_{i,t} \times lnh^{v}_{i,t}$, respectively. The interactions are designed to capture the indirect effects of the differences in technology and human capital through $N2/N1$ (Hypothesis 2). The $lnh^{v}_{i,t}$ is the difference of human capital referred to $lnh^{s}_{i,t}$ and $lnh^{st}_{i,t}$, respectively. The $lnA^{v}_{i,t}$ is the difference of technology refereed to $lnA^{s}_{i,t}$ and $lnA^{st}_{i,t}$, respectively. Both $lnh^{v}_{i,t}$ and $lnA^{v}_{i,t}$ are designed to test Hypothesis 3. The term Z' is a set of vector that contains other control variables.[15] As advocated in Barro and Sala-i Martin (1997),

[14]For instance, the education attainment data from Barro and Lee (2015), the September 2021 update extend up to 2015, but most countries in our dataset have missing values during the period 2014–2015. Additionally, data on the U.S. capital stock and the capital stock from the International Monetary Fund (IMF) Investment and Capital Stock Dataset (2015) provide information on investment and capital stock up to 2013 only. See the next subsection for more information with data links attached.

[15]This set of control variables includes the domestic investment rate, the growth rate of the population, government expenditures (share of GDP), exchange rates, and trade openness. Table B1 in Appendix B provides the summary statistics and data sources for these variables.

Xu (2000), and Delgado et al. (2014), among others, different countries have different steady states, so we allow time- and country-specific effects in the specification to control for the steady-state differences across countries and time.[16] Thus, in Equation (10), the terms δ_i and ρ_t are the country- and time-fixed effects that we set up to control for unobserved heterogeneity across countries and time when using a fixed-effects estimator in order to remove any unobserved heterogeneities.

3.3 | Measuring $y2/y1$, $N2/N1$, $h2/h1$ and $A2/A1$

Four key variables are required to be constructed prior to the econometric analysis. First, the gross output gap between the leader and the follower, which is the dependent variable throughout the analysis, is measured as gross output per capita (in constant 2010 US dollars) in the United States and other countries as follows:

$$y = \frac{y_2}{y_1} = \frac{GDPpc_2}{GDPpc_1} \tag{11}$$

where the *GDPpc* is the gross output per capita, and the subscripts 2 and 1 refer to the follower and leader nations, respectively. Note that we focus on the gap in gross output per capita to capture the technology transfer from a leader to a follower country rather than the Gross Domestic Product (GDP) growth rate of a single country in order to be consistent with our theoretical model.[17] Gross output per capita is measured by the gross domestic product divided by the midyear population, where GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy. We collect these data from the World Bank National Accounts dataset.

Second, the proxy, N_2/N_1, reflects the number of intermediates that are either innovated in the leader country N_1 or adapted by the follower country N_2. To exercise this concept, we construct N_2/N_1 as the inward FDI stock in each follower country divided by the capital stock in the United States. We believe that the FDI stock in each follower country appropriately represents as N_2, and that the capital stock in the United States appropriately represents as N_1.[18] For simplicity, we use the notation *FK* to denote the N_2/N_1. The variable *FK* is constructed as follows:

$$FK = \frac{N_2}{N_1} = \frac{FDI_2}{K_1} \tag{12}$$

where FDI_2 refers to the FDI stock[19] in the follower countries, while K_1 refers to the capital stock (i.e., the number of intermediates available) in the United States. Following Herzer and Donaubauer (2018), among others, we collected the FDI stock variable from the UNCTAD STAT measured in US dollars at current prices in millions.[20] Next, the data on the U.S. capital stock and the capital stock across coun-

[16] Also see Olofsdotter (1998), Borensztein et al. (1998), Campos and Kinoshita (2002), Durham (2004), and Alfaro et al. (2004) for a relevant comparison.

[17] Benhabib and Spiegel (1994), Azman-Saini et al. (2010), Grijalva (2011), and Alaali et al. (2015), for instance, consider only the GDP growth rate of a given country.

[18] Ford et al. (2008), Cipollina et al. (2012), and Wacker (2016), for instance, use stock data to measure FDI in a growth nexus. See Wacker (2016) for a comprehensive concept of FDI stock measurement.

[19] Egger (2001) and Mariam and Cecilio (2004) pointed out that the flow data on FDI may lead to misinterpretations due to the absence of a solid theoretical underpinning. Hence, we make use of FDI stocks other than flows.

[20] The FDI stock measures the total level of direct investment at a given point in time and is the value of foreign investors' equity in net loans to enterprises operating in the reporting economy.

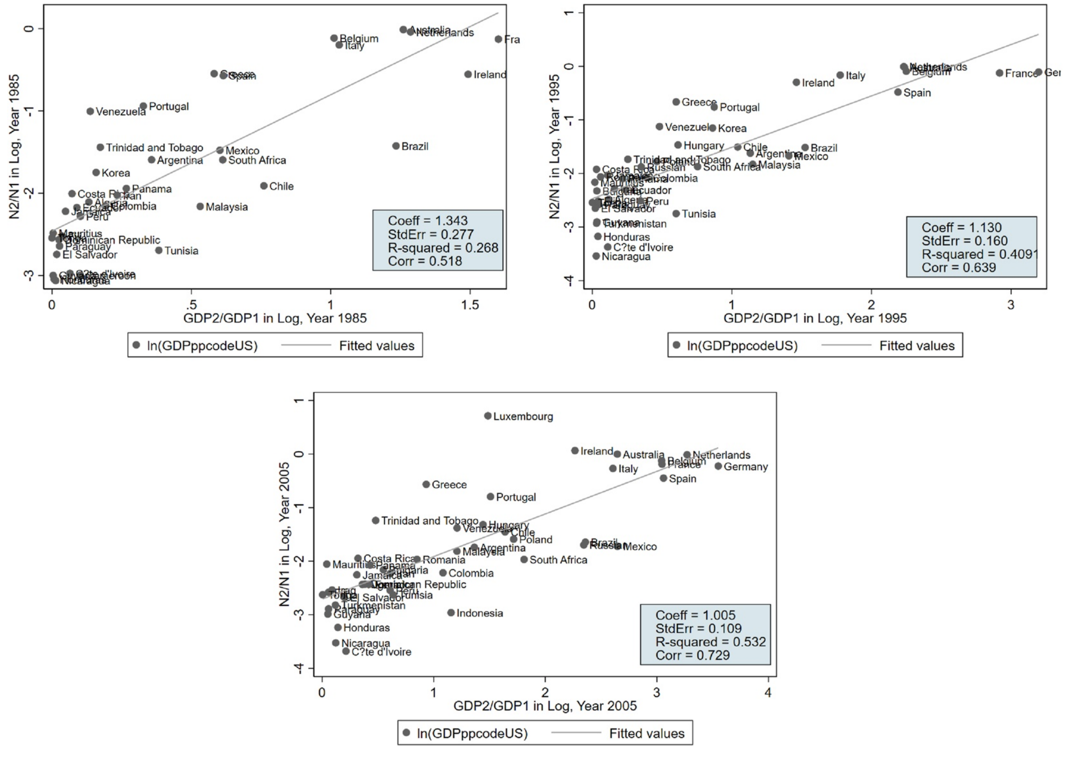

FIGURE 3 The relationship between *lny* (vertical axis) and *lnFK* 1985, 1995, and 2005. *Source*: Authors' calculation.

tries and time are from the IMF Investment and Capital Stock Dataset (2015), which provide comprehensive data on public investment and capital stock (i.e. general government), private investment and capital stock, as well as investment and capital stock arising from public-private partnerships, across IMF member countries through periods 1960–2013.[21] Figure 3 shows *lnFK* across countries plotted against *lny* in the years 1985 and 2005.

Third, to construct the difference of human capital h_2/h_1, we follow Hall and Jones (1999) and Jones and Vollrath (2013):

$$schooling^{v} = e^{\varphi \mu^{v}}$$

where $\mu^{v} = \mu^{s}$, μ^{st} and $\varphi = 0.10$. The parameter μ^{v} refers to the average educational attainment of the labour force in years, where the superscript *s* is the average total educational attainment and *st* is the tertiary education attainment. The parameter φ is assumed to be equal to 10%, which is based on a large body of literature in labour economics demonstrating that an additional year of schooling increases wages earned by about 10% (Jones & Vollrath, 2013, Ch3). Data on educational attainment

[21]The accompanying Document "Estimating Public, Private, and PPP Capital Stocks" http://www.imf.org/external/np/fad/publicinvestment/data/info.pdf to the IMF Board Paper "Making Public Investment More Efficient" (http://www.imf.org/external/pp/longres.aspx?id=4959) describes in great detail the series' definitions, the investment series' data sources, as well as the methodology in constructing the stock series. The methodology follows the standard perpetual inventory equation and largely builds on Kamps (2006) and Gupta et al. (2014).

are drawn from Barro and Lee (2015).[22] Having the *schooling*^{v} constructed, we then compute the difference of human capital as follows:

$$h^v = \frac{h_2^v}{h_1^v} = \frac{Schooling_2^v}{Schooling_1^v}, v = s, st \tag{13}$$

As specified in Equation (4), the higher the level of human capital in the leader country, the lower the cost of adaptation and the higher the gross output per capita in the follower country. This measure in logarithm lies within the range 0.271–0.693 for h^s and 0.624–0.695 for h^{st}. A high ratio in the measure indicates a high level of human capital in the follower country, which enables firms in the United States to transfer knowledge into the recipient economy efficiently. Figure 4 shows that *lny* and the difference in human capital are clearly positive and an upward trend is displayed through the scatter plots.

Last, the difference of technology A_2/A_1 is constructed by using TFP. We derive the TFP formulation from Equation (1) for the leader and follower countries:

$$\begin{aligned} A_1^v &= TFP_1^v = \frac{GDPpc_1}{k_1^\alpha h_1^{v1-\alpha}} \\ A_2^v &= TFP_2^v = \frac{GDPpc_2}{k_2^\alpha h_2^{v1-\alpha}} \end{aligned} \tag{14}$$

where the coefficient α, which is the human capital share, is set at one-third; k is the capital stock per capita. The difference of technology is then measured by taking the level of TFP in the country divided by the level of TFP in the United States (in log), which is:

$$\begin{aligned} A^s &= \frac{A_2^s}{A_1^s} = \frac{TFP_2^s}{TFP_1^s} \\ A^{st} &= \frac{A_2^{st}}{A_1^{st}} = \frac{TFP_2^{st}}{TFP_1^{st}} \end{aligned} \tag{15}$$

where TFP_2^s and TFP_1^s refer to the TFP calculated by using the average total schooling in the follower 2 and leader 1 countries, respectively, while TFP_2^{st} and TFP_1^{st} refer to the TFP calculated using the tertiary education attainment. The data show that the mean values of TFP are 0.844 and 0.738 (denoted as *lnA*^{s} in Table B1 in Appendix B) calculated by using the average total schooling and tertiary education attainment, respectively. The statistics are close to Xu (2000), where the TFP was calculated using the host country TFP divided by U.S. TFP, and the mean was reported around 0.720 with a standard deviation of 0.110. As discussed in the preceding section, the higher the level of TFP in the follower country, the higher the volume of FDI stock and the higher the gross output per capita in the follower country. The relationship between *lnA*^{v} and *lny* is displayed in Figure 5 with an upward trend in the years 1985, 1995, and 2005.

[22]While early studies typically used enrolment ratios or literacy rates to measure the level of human capital, these data do not adequately capture the aggregate stock of human capital available contemporaneously as an input to production (Barro & Lee, 2013). Therefore, we only use data on educational attainment.

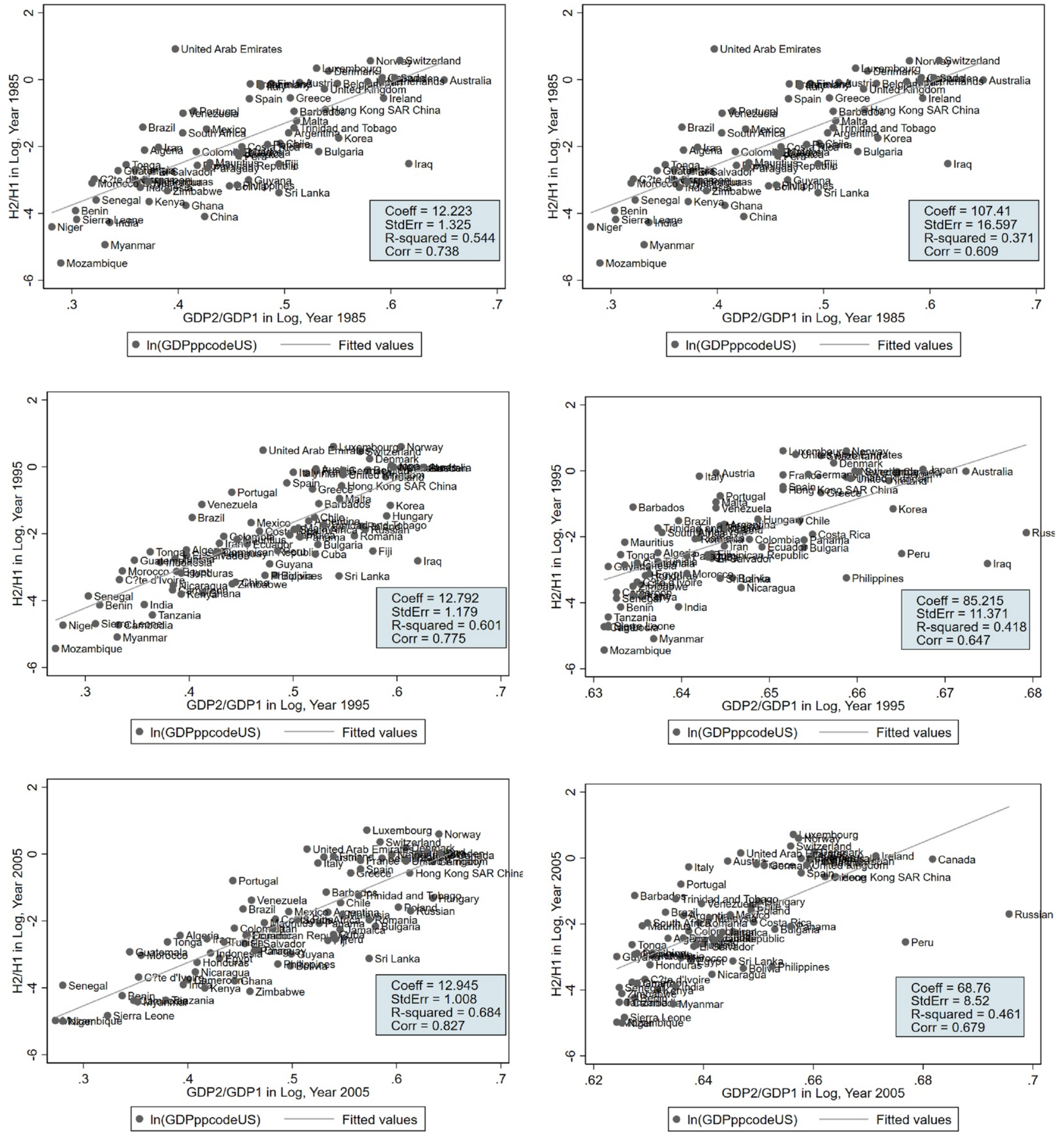

FIGURE 4 The relationship between *lny* (vertical axis) and lnh^v 1985, 1995, and 2005. *Source*: Authors' calculation.

4 | RESULTS

4.1 | The gross-output-enhancing effects

The results for all regressions are reported in Table 1. Columns (1) and (2) show that the results vary across specifications regarding the statistical significance levels. Although the elasticity of *lny* with respect to *lnFK* remains positive, the estimated coefficients become less significant from a 10% significance level in column (1) to insignificant in column (2). From the mean, an increase of 10% in *lnFK* is associated with a minimum 0.082% and a maximum 0.094% gap reduction in the gross output in the follower country to the leading nation. The differences in human capital and technology are confirmed

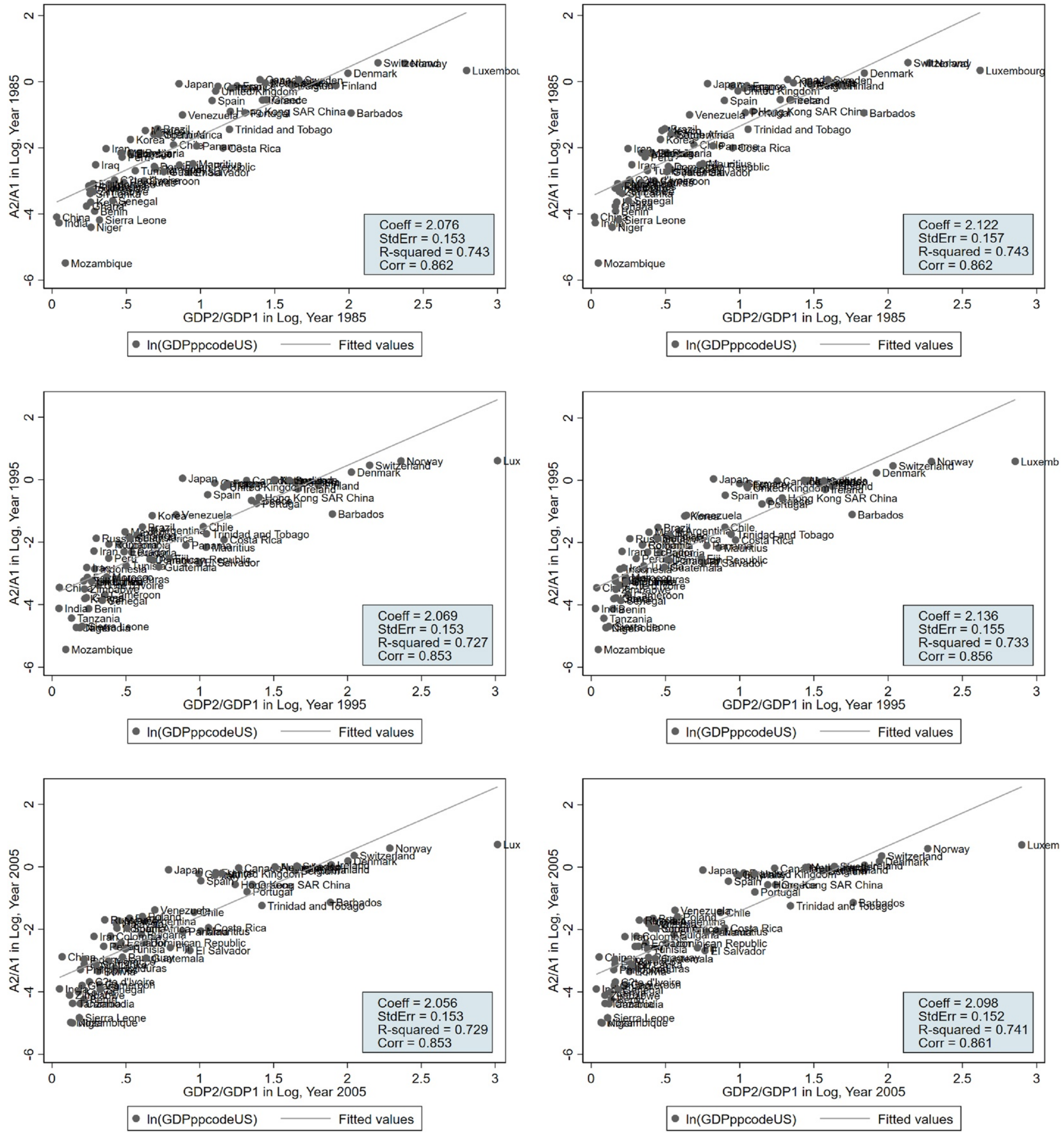

FIGURE 5 The relationship between *lny* (vertical axis) and lnA^v 1985, 1995, and 2005. *Source*: Authors' calculation.

as statistically significant with unambiguously positive signs in both specifications except column (2). As we stated in Hypothesis 2, it can be argued that the differences in technology and human capital potentially and indirectly distort the gross-output-enhancing effect of FDI. To investigate this issue, we allow the interactions between *lnFK* and the differences in human capital and technology to vary across the specifications.

The results are provided in columns (3)–(6); here, the coefficients on the interaction terms are confirmed as statistically significant. First, Columns (3) and (4) correspond to the differential effect of receiving FDI on the gross output gap for the change in the difference of technology between the countries. To be specific, the elasticity of *lny* with respect to *lnFK*, which enters interactively with the difference of technology between the countries, is negative and statistically significant at the 5%

TABLE 1 The gross-output-enhancing Effects from *lnFK*, lnA^v, and lnh^v.

	Log gap in gross output per capita to the United States									
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
lnFK	0.082*	0.094	0.216**	0.237***	0.466**	2.368**	0.228**	0.260***	0.537**	2.318*
	(0.043)	(0.057)	(0.084)	(0.087)	(0.204)	(1.141)	(0.089)	(0.094)	(0.264)	(1.354)
lnA^s	1.941***		2.082***		1.990***		2.106***		2.002***	
	(0.218)		(0.212)		(0.216)		(0.221)		(0.217)	
lnA^{st}		1.959***		2.164***		1.918***		2.230***		1.917***
		(0.250)		(0.271)		(0.254)		(0.287)		(0.255)
lnh^s	1.804***		1.372***		2.183***		1.397***		2.334***	
	(0.436)		(0.502)		(0.445)		(0.492)		(0.503)	
lnh^{st}		0.434		2.420		7.058**		2.272		6.973*
		(3.564)		(2.735)		(3.451)		(2.710)		(3.526)
lnFK × lnA^s			−0.133**				−0.179*			
			(0.055)				(0.092)			
lnFK × lnA^{st}				−0.159***				−0.247**		
				(0.057)				(0.102)		
lnFK × lnh^s					−0.658**				−0.836*	
					(0.299)				(0.462)	
lnFK × lnh^{st}						−3.500**				−3.413
						(1.698)				(2.069)
lnFK × lnA^{2s}							0.006			
							(0.007)			
lnFK × lnA^{2st}								0.012		
								(0.008)		
lnFK × lnh^{2s}									0.022	
									(0.026)	

TABLE 1 (Continued)

	Log gap in gross output per capita to the United States									
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
$\ln FK \times lnh^{2st}$										−0.003
										(0.028)
Marginal effects	-	-	0.083***	0.077***	−0.191*	−1.131**	0.054	0.025	−0.276	−1.098
	-	-	(0.037)	(0.041)	(0.100)	(0.558)	(0.035)	(0.035)	(0.181)	(0.698)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.641	0.570	0.694	0.644	0.672	0.604	0.696	0.651	0.673	0.604
Observations	1964	1964	1964	1964	1964	1964	1964	1964	1964	1964

Note: There are quadratic terms of $lnFK \times lnA^{2v}$ and $lnFK \times lnh^{2v}$ reported in the last 4 rows above the marginal effects. Robust standard errors are provided in parentheses. Robust standard errors for the marginal effects (at the mean) are calculated using the delta method.

*, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

significance level. The estimation of $lnA^s \times lnFK$ and the $lnA^{st} \times lnFK$ suggests that the effect of the change in $lnFK$ on the gross output gap in the follower to the leader depends negatively on the change in the difference of technology. This finding implies that the gross-output-enhancing effect from FDI would be crowded out by the gross-output-enhancing effect from the changes in the difference of technology by 0.125%,[23] which supports the intuition that the gross-output-enhancing effect is lower when the follower country shortens the gap in technology to the frontier country. The result in column (4) then indicates that the effect of FDI on shortening the gap in the gross output to the frontier country decreases by 0.137%[24] at the 1% significance level when there is 1% improvement in technology in the follower country. Regarding the differential effect of FDI on the difference of gross output between the leader and follower for a change in the difference of human capital, our results show that there is a negative and statistically significant estimate shown in columns (5) and (6), respectively. The negative coefficient of $lnh^s \times lnFK$ thus indicates that the gross-output-enhancing effect of $lnFK$ would be again deducted by the increase in human capital in the follower countries. This result holds when $lnh^{st} \times lnFK$ is allowed in the specification.

To get a sense of how the strength of the intermediary roles played by the differences in human capital and technology in determining indirect gross-output-enhancing effects from FDI (i.e., Hypothesis 2 based on the use of the interaction effects) varies when the constitutive terms vary (or become larger in magnitude), we take the marginal effects of the $lnFK$ (0.216) on lny for different relative levels of technology ($lnFK \times lnA^s$ and estimated coefficient -0.133 at the mean) and find that indeed the interaction effect of $lnFK \times lnA^s$ lowers the FDI gross-output-enhancing effect from 0.216 to 0.083 (at the mean) at the 1% significance level (using the delta method).[25] Additionally, we plot the interrelationship between the size of the FDI gross-output-enhancing direct effect and the measure of relative human capital and technology from the minimum to the maximum levels and illustrate this using Figure 6. The first plot of Figure 6 Panel A is based on the estimates using lnA^s shown in Column (3) of Table 1. To show how the estimated FDI gross-output-enhancing direct effect negatively evolves with lnA^s, through the distribution of the lnA^s across our sample, the plot provides results from zero to the 25th, median, 75th, 90th, 95, and 99th levels of lnA^s. While the estimated FDI gross-output-enhancing effect remains statistically and significantly positive at the 25th and median levels of lnA^s, the FDI gross-output-enhancing effect indeed diminishes from 0.216 to 0.181 (all at the 1% significance level) when lnA^s is larger in magnitude. The FDI gross-output-enhancing effect approaches zero when lnA^s is at the 75th percentile. After that, we find that the FDI gross-output-enhancing effect turns to be negative from -0.237 (90th percentile) to -0.488 (99th percentile). We find consistent patterns through the other three plots. These results indicate that while the direct effect of current FDI on the gross output is positive, the overall FDI effect is determined by host countries' ability differences.

Another concern arises from the potential non-linearities among the relative abilities to FDI on the relative gross output. While empirical studies in the literature employ only the interaction analysis in regressions to document the potential threshold effects of FDI conditional on human capital (Borensztein et al., 1998; Li & Tanna, 2019), financial institutions (Alfaro et al., 2004), corruption and institutions (Okada & Samreth, 2014; Li & Tanna, 2019), and absorptive capacity (Figini & Görg, 2011; Kaulihowa & Adjasi, 2018; Kottaridi & Stengos, 2010) on GDP per capita, TFP growth, and income inequality, our theoretical model shows potential variations among the relative level of technology and human capital that affect the relative gross output effects of FDI indirectly and hence

[23]The sample mean of $lnA^s \times lnFK$ is 0.943; hence, the differential effect of $lnA^s \times lnFK$ on lny is $0.943 \times 0.133 = 0.125$.

[24]The mean of $lnA^{st} \times lnFK$ is 0.866, and its estimated coefficient is -0.159. Together, it gives us a reduction in the gross-output-enhancing effect from FDI by $0.866 \times -0.159 \approx -0.137$.

[25]We thank both the referees and the editor for suggesting this excellent point.

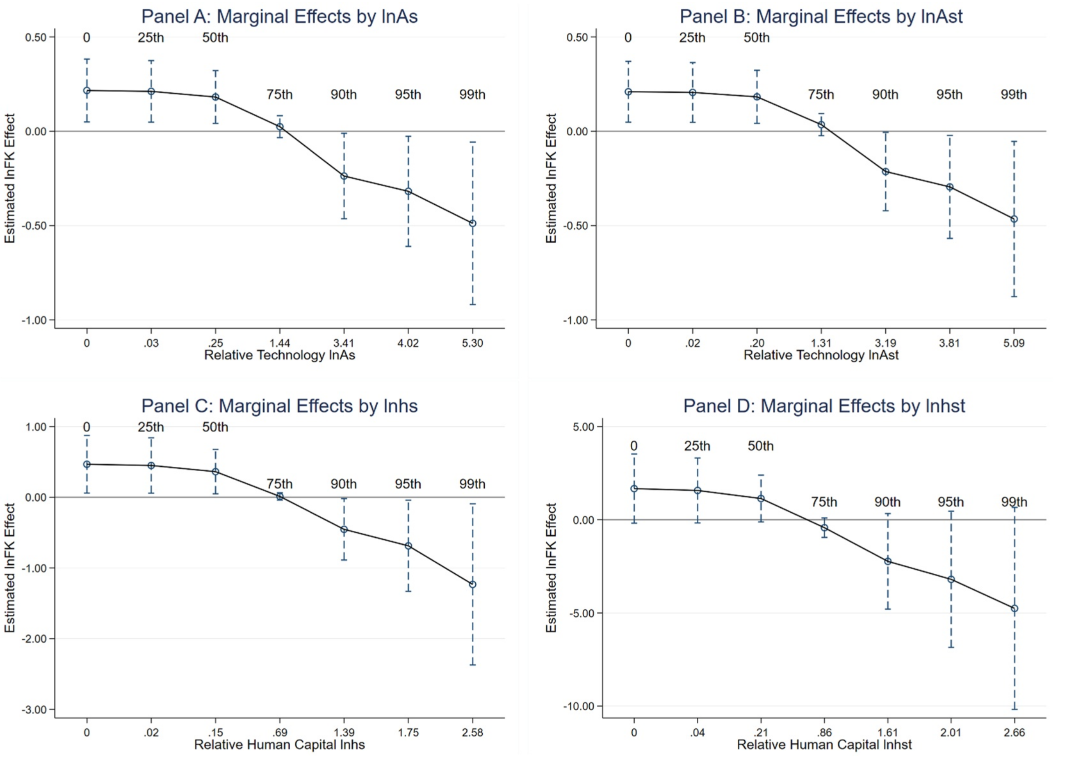

FIGURE 6 Marginal Effects of *lnFK* through Different lnA^v and lnh^v on *lny*. We estimate the conditional marginal effects of *lnFK* through different relative levels of technology (lnA^v, Panels (a and b) and human capital (lnh^v, Panels (c and d) on the log differences in gross output per capita (*lny*). Robust standard errors for the marginal effects are calculated using the delta method.

it is more reasonable and intuitive to consider the non-linearity of the relative abilities to FDI on the relative gross output. Therefore, here, we consider the potential variations among the relative differences of technology and human capital that may affect the relative gross output effects of FDI non-linearly. To capture this potential nonlinearity, we follow Cooray et al. (2017) by adding quadratic terms of the relative technology and human capital interacted with FDI and report the marginal effects based on these non-linear effects. As can be seen, the results presented in columns 7–10 in Table 1 confirm that there is no significant non-linear effect of relative abilities to FDI on relative gross output in our context.[26]

The baseline results suggest that our model fits well with the cross-country data, preliminarily supporting the hypothesis that FDI (Hypothesis 1) as well as human capital and technology (Hypothesis 3) are complementary with respect to enhancing the process of technology transfer increasing the rate of return in the follower countries. In addition, the positive gross-output-enhancing effect from FDI on shortening the gap in gross output to the leader (i.e., Hypothesis 2) is confirmed to be distorted by the changes in the differences in human capital and technology, which restrict further the follower to benefit further from FDI. On the one hand, the existing studies highlight the threshold values for which the effects of FDI can occur. Focussing on developing countries, Borensztein et al. (1998) find that only countries with secondary school attainment above 0.52 (46 out of 69 developing countries)

[26]We thank the referee and the editor for this excellent suggestion.

can benefit from FDI. Using cross-country manufacturing data, Xu (2000) also discovers that only countries with a threshold level of human capital above 2.3 can benefit from FDI. Others suggest that the growth effect of FDI is contingent on the interaction between human capital (Ford et al., 2008 [27]; Li & Tanna, 2019), the quality of institutions (Aziz, 2022), access to foreign financing (Cohen, 1994), the interaction between secondary school enrolment and machinery imports (Romer, 1993), and the interaction between the distance to the technology frontier (measured as labour productivity of the U.S. divided by that of in other countries) and FDI (Baltabaev, 2014). Furthermore, by using data of Western Asia countries 1980–2011, Suliman et al. (2018) find that FDI positively boosts growth only when the simultaneous relationship between growth rate and FDI is controlled for. Although our findings are contrary to some previous studies, we focus on a different intuition by using measures suggested by our theoretical model to emphasise how the gross-output-enhancing effect from FDI is affected by the intermediary roles of human capital and technology. Our results are thus not necessary to be compared with others and should be interpreted in an appropriate way to capture the gross-output-enhancing effect from FDI.[28] Overall, our results suggest that while there is a positive and significant gross-output-enhancing effect from FDI to the follower country, the intermediary roles of the differences in human capital and technology should also be carefully considered.

4.2 | Robustness check

4.2.1 | Cross-country differences and cyclical fluctuations

We now subject our findings to the unobservable country-specific characteristics, as our data contains 67 countries with different income levels. This implies that the results shown in Table 1 with the negative effects from the interaction terms might differ across countries, and countries with a low-income level might experience more reduction in benefiting from FDI when they are improving the level of technology and human capital. To examine this heterogeneity, we split our sample according to World Bank Country and Lending Groups classification shown in Table C1 in Appendix B. Table 2 shows the regression results.

The results for developing (Columns 1–4) countries are close to our previous findings. To be specific, when focussing on the developing countries, the estimated coefficients of the elasticity of lny with respect to FDI remain as significant at the 1% significance level with estimated coefficients of 0.346 in column (1), 0.388 in column (2), 0.745 in column (3), and 3.057 in column (4). The interaction terms are also confirmed as statistically significant at the 1% and 5% significance levels throughout. The results from regressions based on the developed countries are provided in columns (5), (6), (7), and (8), which show that the developed countries generally do not benefit from FDI but benefit from technology and human capital. Estimates of the interaction terms in Table 2 show that the effect of FDI on shortening the gap in gross output to the frontier country decreases with increasing lnA^v

[27]Note that the study of Ford et al. (2008) measures FDI as the average share of non-bank employment of US affiliates of foreign firms in the total employment, which is not the standard measure applied in the FDI-growth literature. Hence, it is unsurprising that they found a different sign of the estimated coefficient of FDI and its interaction term in their study.

[28]Nevertheless, our findings are similar to a number of existing studies including Alfaro et al. (2004) and Durham (2004). The authors find the interaction between FDI and schooling to be negative but statistically insignificant. However, the two studies may suffer from measurement error, as they measure human capital by employing either the male education rate (Durham, 2004) or the average years of secondary schooling (Alfaro et al., 2004). In doing so, they ignore an important implication that the wage is related to the number of years of schooling and the estimates found in their studies might be biased. See Bils and Klenow (2000) and Jones and Vollrath (2013) for more details.

TABLE 2 Different income levels.

	Log gap in gross output per capita to the United States							
	Developing countries				Developed countries			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lnFK	0.346***	0.388***	0.745***	3.057**	−0.017	−0.015	−0.010	0.051
	(0.098)	(0.100)	(0.272)	(1.440)	(0.036)	(0.035)	(0.099)	(0.362)
	(0.087)	(0.087)	(0.273)	(1.412)	(0.030)	(0.029)	(0.095)	(0.289)
lnA^s	2.575***		2.432***		1.144***		1.112***	
	(0.308)		(0.342)		(0.077)		(0.080)	
lnA^{st}		2.879***		2.476***		1.110***		1.062***
		(0.465)		(0.487)		(0.088)		(0.093)
lnh^s	1.225*		1.654**		1.173***		1.259***	
	(0.620)		(0.628)		(0.269)		(0.328)	
lnh^{st}		3.769		7.831*		3.626**		4.148*
		(3.515)		(4.006)		(1.310)		(2.334)
lnFK × lnA^s	−0.449***				−0.015			
	(0.161)				(0.018)			
lnFK × lnA^{st}		−0.626***				−0.017		
		(0.192)				(0.018)		
lnFK × lnh^s			−1.085**				−0.042	
			(0.433)				(0.143)	
lnFK × lnh^{st}				−4.461**				−0.128
				(2.142)				(0.540)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.764	0.730	0.740	0.687	0.787	0.798	0.785	0.795
Observations	1321	1321	1321	1321	643	643	643	643

Note: Robust standard errors are provided in parentheses.

*, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

and lnh^v. This reduction is stronger for developing countries with an estimated coefficient of −0.449 at the 1% significance level in column (1) compared with the insignificant estimated coefficient of −0.015 for developed countries in column (5). This result again highlights that the gross-output-enhancing effect from FDI will decrease by roughly 0.1%,[29] whereas developed countries only face a 0.039% (2.603 × 0.015, statistically insignificant) decrease in this regard. This finding suggests that the gross-output-enhancing effect from FDI for those developing countries will be smaller when there is an increase in the differences of technology and human capital. As shown in the table from columns (5) to (6), however, the results suggest that the effects of FDI do not exist in developed countries nor are the effects from the interaction terms significant.

[29]The mean of $lnA^s \times lnFK$ based on the developing countries is 0.227; hence, the reduction of the benefit of FDI induced by the increase of lnA^s is $0.227 \times 0.449 = 0.101$.

We next subject our findings to cyclical fluctuations in the gap of gross output per capita between the leader and the follower. As the sample contains a long time period, cyclical behaviour may exist in a single year and might potentially bias the results. To alleviate the threat, we follow Baltabaev (2014) and Ford et al. (2008) to construct a 5-year (1980, 1985, 1990, 1995, 2000, 2005) and 10-year (1980, 1990, 2000) average intervals, respectively. The sample is again split into developed and developing countries and the results are reported in Table 3. Columns (1)–(8) report the results when using a 5-year average, whereas columns (9)–(16) provide the results when a 10-year average is employed. For the sample of developing countries, of note is that the elasticity of *lny* with respect to *lnFK* remains as positive and significant at the 1% and 5% significance levels throughout the columns. Hence, the gross-output-enhancing effect from FDI is robust to the potential cyclical effects with estimates being close to the previous findings. For developed countries, the results again confirm the insignificant effect of FDI. For the indirect effects of lnA^v and lnh^v through FDI on shortening the gap in gross output to the frontier country (i.e., Hypothesis 2), the estimated coefficients are confirmed as negative and remain statistically significant for developing countries, yet statistically insignificant for developed countries. For the direct effects of lnA^v and lnh^v (Hypothesis 3), we find that both lnA^v and lnh^v are identified as positive and significant throughout regardless of whether the observations are based on developing or developed countries, confirming the robustness of the findings thus far.

4.2.2 | Endogeneity problems?

Differences in unobserved characteristics across countries could bias the estimates of gross-output-enhancing effects of FDI, and there has been a long debate on this issue. To provide a brief account of what is at stake, consider that the omitted or unobserved variables that potentially attract FDI to flow into the country would induce the correlation between FDI and the error term. To mitigate this concern, one could use a lagged FDI variable (Borensztein et al., 1998; Egger & Pfaffermayr, 2001), the investment promotion agency (Baltabaev, 2014), or the perceptions of corruption (Lensink & Morrissey, 2006). As the variable of corruption is only available for a point in time, it is not helpful to overcome the issue. Also, because of the restriction of data access for the investment promotion agency, we do not use this variable. Borensztein et al. (1998) and Egger and Pfaffermayr (2001) suggest that the lagged values of FDI can be rational instruments for FDI itself. However, since the lagged value of FDI might still partially be a determinant of the dependent variable, it might not be robust at predicting the variable of concern. For this reason, we do not follow these two prominent studies.

Instead, as our theoretical model provides prediction for the pre determinants of N_2/N_1 in Equation (7), we therefore follow our model prediction to adopt the lagged values of lnA^v and lnh^v as two internal instruments to mitigate the endogeneity issue. To see this, consider that the ability gap between leader and follower countries can take into account the degree by which technology and knowledge spill over; the follower country whose level of technology is closer to the technological frontier is more likely to adopt new technologies faster than countries with relatively wider technological gaps. The lagged values of lnA^v and lnh^v therefore stand as rational instruments to mitigate the concern there. Furthermore, as similar to Moshirian (1997) and Alfaro et al. (2004), we employ insurance and financial services, measured as a percentage of commercial service imports and service imports as the two external instruments to FDI. In the study of Moshirian (1997), the author suggests that the greater the demand in the U.S. insurance market, the greater the number of potential investors willing to invest in the U.S. insurance market. Thus, Moshirian (1997) finds a positive correlation between FDI in insurance and then hypothesises that the size of the U.S. insurance market, which reflects the demand

TABLE 3 Cyclical fluctuations: 5-Year and 10-year averages.

	Log gap in gross output per capita to the United States															
	Developing countries: 5 years average				Developed countries: 5 years average				Developing countries: 10 years average				Developed countries: 10 years average			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
lnFK	0.357***	0.399***	0.892***	1.735***	−0.005	−0.003	0.007	0.150	0.387***	0.429***	0.978***	1.489***	0.018	0.019	0.012	0.172
	(0.101)	(0.103)	(0.250)	(0.415)	(0.037)	(0.036)	(0.081)	(0.099)	(0.103)	(0.108)	(0.245)	(0.435)	(0.041)	(0.042)	(0.084)	(0.102)
lnA^s	2.768***		2.572***		1.173***		1.137***		3.011***		2.735***		1.274***		1.187***	
	(0.341)		(0.351)		(0.111)		(0.113)		(0.347)		(0.339)		(0.148)		(0.147)	
lnA^{st}		3.100***		2.619***		1.131***		1.072***		3.355***		2.741***		1.189***		1.081***
		(0.518)		(0.458)		(0.108)		(0.108)		(0.544)		(0.454)		(0.133)		(0.121)
lnh^s	0.920		1.469***		1.156***		1.259***		0.617		1.317**		1.140***		1.250***	
	(0.573)		(0.517)		(0.237)		(0.310)		(0.653)		(0.540)		(0.265)		(0.356)	
lnh^{st}		1.747		3.822		3.399**		4.141***		0.773		2.264		4.602**		5.341**
		(2.904)		(2.958)		(1.276)		(1.227)		(2.896)		(3.477)		(2.065)		(1.910)
lnFK × lnA^s	−0.487***				−0.014				−0.550***				−0.025			
	(0.164)				(0.018)				(0.167)				(0.020)			
lnFK × lnA^{st}		−0.664***				−0.014				−0.729***				−0.023		
		(0.198)				(0.016)				(0.206)				(0.018)		
lnFK × lnh^s			−1.376***				−0.048				−1.540***				−0.040	
			(0.388)				(0.113)				(0.377)				(0.117)	
lnFK × lnh^{st}				−2.456***				−0.261*				−2.088***				−0.279**
				(0.566)				(0.133)				(0.619)				(0.131)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.777	0.749	0.762	0.715	0.850	0.847	0.847	0.849	0.801	0.767	0.787	0.725	0.870	0.869	0.863	0.865
Observations	309	309	309	309	149	149	149	149	180	180	180	180	86	86	86	86

Note: Robust standard errors are provided in parentheses.

*, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

for insurance services, is an important factor in attracting foreign investors. Alfaro et al. (2004) also suggests that a well-functioning stock market is associated with the sources of finance for foreign firms, playing a crucial role in attracting foreign firms operating in the host country. Since the size of the insurance and financial market could potentially determine whether foreign investors would invest in the host country, we use the two variables as external instruments.

We begin with the two-stage least squares with an instrumental variable fixed-effect estimator.[30] The instrument should satisfy the validity requirement; it should be correlated with FDI (i.e., relevance condition) but uncorrelated with the error term of Equation (10) (i.e., exogeneity condition). The relevance condition can be examined by the estimated results of the first stage in the two-stage least squares analysis, but the exogeneity condition is unfortunately not examinable. Nevertheless, since the predicted value of *lnFK* rules out the potential predetermination of FDI, it is believed to be uncorrelated with other potential biases, which implies the satisfaction of the exogeneity condition. For the relevance condition, the first-stage regression results are provided in Appendix B, where the relevance condition of the instruments is satisfied by the estimated coefficients of the instruments being statistically significant. In addition, we reject the null hypothesis of the weak instrument at the 5% significance level, given that the reported Wald F-statistics in the first-stage regressions are large throughout the specifications.[31]

The results are provided in Table 4. In columns (1)–(4), the lagged lnA^v and lnh^v are used as the two internal IVs, whereas in columns (5)–(8), the insurance and finance variables are employed as the two external IVs. Columns (9)–(12) combine the four IVs. First, we find that the estimated coefficients of *lnFK* remain as positive and statistically significant at the 1% significance level in columns (1) and (4) with the rational statistics in Sargan-Hansen (over-identification) and Lagrange multiplier (LM) (under-identification) tests. This result means that a 1% increase in *lnFK* will generate either a 0.393 or 12.042% increase on $GDPpc_2/GDPpc_1$. The variables lnA^v and lnh^v and the interactions remain as statistically significant. Furthermore, we find that the estimated coefficients of *lnFK* remain positive and statistically significant at the 1% significance level in columns (5) and (6), and these estimates are again with the rational statistics in Sargan and LM tests. The effects of FDI, though, increase slightly compared to the results in column (1). The indirect effects of lnA^v and lnh^v through FDI are still confirmed to be negative and statistically significant at the 1% significance level throughout the columns. While the direct effects of lnA^v remain as statistically significant and stable, the effects of lnh^v on $GDPpc_2/GDPpc_1$ reported in columns (5) and (6) vary across specifications. Also, columns (7) and (8) show that there is an issue of weak instruments in the two specifications; thus, we do not focus on the results presented under these two regressions.

Lastly, we try to employ both internal and external IVs into the regression analysis as the final attempt to mitigate the endogeneity of FDI. The results are provided in columns (9)–(12). Columns (9) and (10) show the robustness of the effects of FDI; the estimated coefficient on *lnFK* is 0.435 in column (9) and the estimated coefficient on $lnFK \times lnA^s$ is −0.277, identified as statistically significant at the 1% significance level. It suggests that while a 1% increase in *FK* will increase the $GDPpc_2/GDPpc_1$ by 0.435%, an improvement in the level of technology in the follower country crowds out the benefits from *FK*. We find a similar result in column (10). Columns (11) and (12) again suggest potential issues in the validity of the instruments and under-identification test.

[30]The computation package developed by Schaffer (2015) in STATA implements instrumental variables (IV) estimation of the fixed-effects panel data models with possibly endogenous regressors. The package supports all the estimation with heteroskedastic, cluster and autocorrelation robust covariance matrix, as well as over-identification, orthogonality tests, first-stage, weak and under-identification tests. See Schaffer (2015) for more details.

[31]We test for weak identification based on reported Wald F-statistic $(N - L)/L1$, where L is the number of instruments and $L1$ is the number of excluded instruments.

ECONOMICS OF TRANSITION AND INSTITUTIONAL CHANGE

TABLE 4 System-GMM and 2SLS fixed-effects with external and internal IVs.

	Log gap in gross output per capita to the United States															
	2SLSFE internal IVs				2SLSFE external IVs				2SLSFE internal and external				System-GMM			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
lnFK	0.393***	−0.953	0.098	12.042***	0.423***	0.401***	5.284	−10.524**	0.435***	0.390***	−0.142	−1.120	0.254**	0.249***	0.208	−0.026
	(0.075)	(0.755)	(0.105)	(4.302)	(0.103)	(0.095)	(4.276)	(4.858)	(0.112)	(0.095)	(0.173)	(1.187)	(0.102)	(0.092)	(0.131)	(0.391)
lnA^s	2.162***		2.034***		1.829***		2.185***		1.828***		1.797***		1.819**		1.192	
	(0.053)		(0.055)		(0.085)		(0.435)		(0.086)		(0.092)		(0.701)		(0.717)	
lnA^{st}		1.702***		1.677***		1.812***		1.811***		1.809***		1.756***		1.443**		0.481
		(0.337)		(0.130)		(0.102)		(0.145)		(0.101)		(0.095)		(0.637)		(0.463)
lnh^s	0.286		1.325***		−0.614		7.456		−0.655		1.065***		1.259		1.670	
	(0.316)		(0.128)		(0.512)		(5.233)		(0.537)		(0.254)		(1.427)		(1.029)	
lnh^{st}		−1.338		24.024***		2.713***		−24.029*		2.837***		0.670		−0.053		−3.031
		(4.672)		(6.799)		(0.897)		(12.818)		(0.882)		(3.008)		(1.927)		(2.335)
lnFK × lnA^s	−0.253***				−0.270***				−0.277***				−0.174**			
	(0.045)				(0.066)				(0.070)				(0.066)			
lnFK × lnA^{st}		0.612				−0.294***				−0.285***				−0.177**		
		(0.507)				(0.067)				(0.067)				(0.070)		
lnFK × lnh^s			−0.103				−8.830				0.279				−0.333*	
			(0.171)				(7.186)				(0.284)				(0.176)	
lnFK × lnh^{st}				−18.259***				16.054**				1.737				0.014
				(6.541)				(7.413)				(1.806)				(0.605)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internal IVs	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
External IVs	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No

(Continues)

TABLE 4 (Continued)

	Log gap in gross output per capita to the United States															
	2SLSFE internal IVs				**2SLSFE external IVs**				**2SLSFE internal and external**				**System-GMM**			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**
LM statistic	28.620	4.888	90.399	11.955	16.754	17.077	0.265	7.332	16.992	17.233	25.060	24.349	-	-	-	-
Wald-F	22.930	1.483	133.955	3.813	16.939	18.185	0.3880	3.621	9.488	8.705	13.416	6.240	-	-	-	-
Hansen J-test	0.267	0.785	0.000	0.621	0.581	0.351	0.446	0.0781	0.421	0.172	0.000	0.000	0.752	0.634	0.775	0.637
Arellano-Bond AR (2)	-	-	-	-	-	-	-	-	-	-	-	-	0.012	0.226	0.967	0.167
$GDPpc_{2,t-1}/GDPpc_{1,t-1}$	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Observations	1954	1954	1954	1954	1019	1019	1019	1019	1016	1016	1016	1016	1882	1882	1882	1882

Note: The IVs in columns 1–4 for FDI are the 1-year lagged of lnA^v and lnh^v. Columns 5–8 the IVs for FDI are the finance variables. Columns 9–12 the IVs for FDI are the lagged lnA^v, lnh^v, and the finance variables applied with altogether. Robust standard errors are in parentheses. Wald-F statistic tests the issue of weak instruments. Sargan test reports the chi-squared statistics that examine whether or not the instruments are correlated with the error term. In columns (13)–(16), lny, $lnFK$, and the interaction terms between $lnFK$, lnA^v, and lnh^v are considered endogenous and are instrumented with their own lags. The Arellano-Bond AR (2) tests whether the first-difference regression exhibits no second-order serial correlation. The Hansen J-test detects whether the instrumental variables are identified. Robust standard errors are provided in parentheses.

Abbreviations: FDI, foreign direct investment; LM, Lagrange multiplier.

*, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

While above specifications consider the differences in technology, human capital, and the size of the insurance and financial market to take into account the predetermination of N_2/N_1, the correlation between the lags across the right-hand-side variables and the reverse causality in the specification may still persist (Coe et al., 1997; Doytch & Uctum, 2011). Following Kose et al. (2011), Li and Tanna (2019), Aziz (2022) and others, we tackle such potential endogeneity and/or reverse causality concerns using a two-step system-GMM estimator by considering, as endogenous, the $GDPpc_2/GDPpc_1$, $lnFK$, and the interaction terms between $lnFK$ and differences in technology lnA^v and human capital lnh^v in the first-difference and level equations and applying their own lagged levels as use of instruments. This is an alternative approach that accounts for the unobserved heterogeneity and time-variant unobservables, thereby eliminating a possible source of omitted variable bias and controlling for the endogeneity bias. The results are provided in columns (13)–(16). Reassuringly, the system-GMM estimation yields qualitatively similar coefficients although relatively small compared to our previous results.[32,33] The estimated coefficients on $lnFK$ are significantly positive in columns (13) and (14) at the 1% significance level. They are consistent with our previous findings, confirming that the effects of N_2/N_1, as the relative level of capital stock in the leader country to the FDI stock in the follower country, shorten the gross output gap between the leader and follower countries.

4.2.3 | Inflation and institutions

There are existing studies that highlight the role played by the quality of host countries' institutions contingent on the FDI-growth relationship. The literature generally argues that the quality of institutions in the host countries may be of critical importance to generate benefits from FDI. For instance, Bekaert et al. (2011) and Kose et al. (2009) emphasise the importance of institutional quality in driving FDI-TFP growth-enhancing effects from financial openness, while Li et al. (2017) and Li and Tanna (2019) consider the relationship between inward FDI and TFP growth by controlling for political institutions and institutional quality. Additionally, both Tanna et al. (2018) and Li and Tanna (2019) emphasise that host countries' inflation could negatively affect the returns from FDI on growth.

Complementing these studies, we consider the potential for variation in institutions and inflation to drive both direct and indirect gains from FDI within our model specification. To make the process work, we collect data from three sources: (1) The World Bank Development Indicator[34] for data on *Inflation* (INF)[35] and institutions including *Women Business and the Law Index Score*; and (2) the Freedom House[36] for institutions including *Political Rights* and *Civil Liberties* and *Freedom Status*; and (3) Our World in Data for Democracy[37] data for *Electoral Democracy*.

To check the robustness of our results with respect to potential variations in relative quality of institutions and inflation, we repeat the exercise we carried out in Table 1. Table 5 shows the results

[32]Roodman (2009) remarks that GMM estimation only works properly when data contains a large sample size with a short time period. The dynamic panel bias becomes insignificant and a fixed effect estimator outperforms when time dimension is long.

[33]Roodman (2009) highlights that instrument proliferation in system-GMM may over-fit endogenous variables and weaken the power of the Hansen-J test. While Roodman (2009) suggests that a perfect Hansen-J statistic (1.00) is a telltale sign, Biørn and Han (2017) accept the perfect Hansen-J results in the context of FDI-GDP relationship. We, therefore, view our GMM results with caution.

[34]Data can be accessed here: World Bank Development Indicator.

[35]We employ the annual change in consumer price index, following Li et al. (2022).

[36]Data can be accessed here: Freedom House.

[37]Data can be accessed here: Freedom House.

TABLE 5 The gross-output-enhancing effects from *lnFK* controlled for Institutions and Inflation.

	Log gap in gross output per capita to the US					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
lnFK	0.061**	0.068*	0.180***	0.205***	0.433***	2.527**
	(0.028)	(0.037)	(0.064)	(0.065)	(0.123)	(1.038)
lnA^s	1.584***		1.702***		1.618***	
	(0.152)		(0.163)		(0.149)	
lnA^{st}		1.604***		1.778***		1.559***
		(0.170)		(0.203)		(0.168)
lnh^s	1.885***		1.528***		2.165***	
	(0.429)		(0.470)		(0.405)	
lnh^{st}		0.013		1.293		6.566**
		(2.349)		(1.990)		(2.729)
lnFK × lnA^s			−0.110**			
			(0.042)			
lnFK × lnA^{st}				−0.136***		
				(0.043)		
lnFK × lnh^s					−0.627***	
					(0.178)	
lnFK × lnh^{st}						−3.777**
						(1.575)
ED	−0.045	−0.025	−0.116	−0.130	−0.077	−0.036
	(0.095)	(0.100)	(0.098)	(0.108)	(0.098)	(0.098)
INF	0.001	−0.000	0.006	0.007	0.003	0.003
	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
WBLIS	−0.001	−0.002	−0.000	−0.001	−0.001	−0.003*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
PR	0.013	0.012	0.006	0.002	0.008	0.011
	(0.012)	(0.014)	(0.011)	(0.013)	(0.011)	(0.013)
CR	−0.016	−0.016	−0.011	−0.010	−0.013	−0.014
	(0.013)	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
FS	−0.008	0.001	−0.006	0.003	−0.007	−0.003
	(0.023)	(0.027)	(0.024)	(0.026)	(0.023)	(0.024)
Marginal effects	-	-	0.069***	0.068***	−0.194***	−1.249***
	-	-	(0.029)	(0.032)	(0.059)	(0.538)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes

TABLE 5 (Continued)

	Log gap in gross output per capita to the US					
	(1)	(2)	(3)	(4)	(5)	(6)
R-squared	0.641	0.570	0.694	0.644	0.672	0.604
Observations	1491	1491	1491	1491	1491	1491

Note: The INF refers to inflation measured as annual change in consumer price index. Institutions include WBLIS (Women Business and the Law Index Score, PR (Political Rights), CR (Civil Liberties), FS (Freedom Status), and ED (Electoral Democracy). Sqr refers to the quadratic term. Robust standard errors are provided in parentheses.

*, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

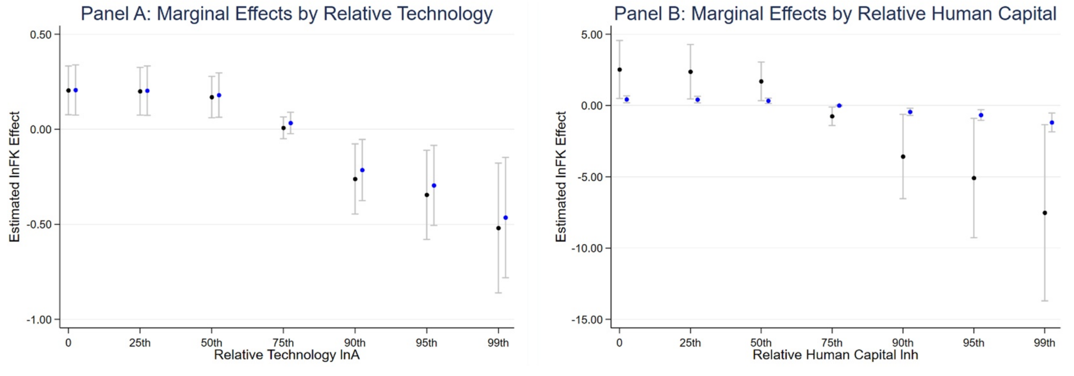

FIGURE 7 Marginal Effects of *lnFK* through Different lnA^v and lnh^v on *lny*. We calculate the conditional marginal effects of *lnFK* on the log differences in gross output per capita (*lny*) for different relative levels of technology (lnA^v) and human capital (lnh^v). Panel A refers to the conditional marginal effects of *lnFK* through different relative levels of technology (lnA^s, blue dot) and (lnA^{st}, black dot). Panel B refers to the conditional marginal effects of *lnFK* through different relative levels of human capital (lnh^s, blue dot) and (lnh^{st}, black dot). Robust standard errors for the marginal effects are calculated using the delta method.

based on the extra controls relative to the institutions and inflation changes for all countries over the sample period. While the estimated coefficient of *lnFK* is confirmed to be just slightly smaller compared to the one without controlling for the institutions and inflation, the sensitivity analysis suggests that the overall pattern remains unchanged and all our previous findings are robust with respect to the inclusion of host economy institutions and inflation on the gross-output-enhancing effect from FDI. In particular, the significance of the relative capacity interaction with FDI on relative output remains negative and significant after controlling for institutional quality and inflation. We again plot the marginal effects of *lnFK* through different lnA^v and lnh^v on *lny* in Figure 7 to show a consistent pattern throughout the estimates.

5 | CONCLUSION

Foreign direct investment is widely recognized as a crucial means of transferring technology and promoting economic development in the host country. Researchers have attempted to establish conclusive evidence by which FDI positively contributes to the economic development of the host country. Existing studies that apply growth empirics with FDI, however, have not properly accounted for the potential role played by the relative differences in human capital and technology in determining the relative gross-output-enhancing effects from FDI. In this paper, we fill out this gap by developing an FDI-output model that extends the leader-follower endogenous growth framework and then empirically explores the intermediary roles played by the differences in human capital and technology in determining direct and indirect gross-output-enhancing effects from FDI using stock and bilateral data. We make three major contributions to the existing literature.

First, while the results show a significant and positive gross-output-enhancing effect from FDI on shortening the gross output gap between the leader and follower countries, this gross-output-enhancing effect is confirmed to be triggered by the differences in technology and human capital between the leader and follower nations. Second, our results demonstrate that the gap between countries' abilities is crucial to the FDI-technology transfer nexus; the differences in technology and human capital between the countries reveal considerable heterogeneity among the effects of absorptive capacity across countries to reap the gross-output-enhancing effect from FDI. Third and importantly, we find that using the two internal instruments, as suggested by our model, with two external instruments eases the endogeneity issue of FDI.

Our work has two important policy implications. First, government policies need to put effort onto improving the stock of human capital and the level of technology as they are the key determinants of the benefits from FDI for the host country. Second, while FDI inflows bring advanced knowledge from world-leading nations and is still one of the best ways for developing countries to catch up with the world's advanced economies, countries with higher levels of technology and human capital should devote more resources to innovation for a long-term economic development.

ACKNOWLEDGEMENT

I am grateful to John McHale, Stephen ONeill, Jason Harold, Antonio Navas, Karl Taylor, Ian Gregory-Smith, Maria Garcia De La Vega, and the participants at the 12th FIW Austrian Institute for Economic Research Conference for their helpful comments, and Lucy Hampton for excellent research assistance. I also thank the anonymous reviewers and editor for their extremely helpful and insightful suggestions. I also gratefully acknowledge the travel grant supported by the Irish Economic Association and Whitaker Institute. This study received no funding support.

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest.

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REFERENCES

Alaali, F., Roberts, J., & Taylor, K. (2015). The effect of energy consumption and human capital on economic growth: An exploration of oil exporting and developed countries. SERPS (Sheffield Economics Research Papers Series). (015).

Alfaro, L., Chanda, A., Kalemli-Ozcan, S., & Sayek, S. (2004). Fdi and economic growth: The role of local financial markets. *Journal of International Economics*, *64*(1), 89–112. https://doi.org/10.1016/s0022-1996(03)00081-3

Aziz, O. G. (2022). Fdi inflows and economic growth in Arab region: The institutional quality channel. *International Journal of Finance & Economics*, *27*(1), 1009–1024. https://doi.org/10.1002/ijfe.2197

Azman-Saini, W., Baharumshah, A. Z., & Law, S. H. (2010). Foreign direct investment, economic freedom and economic growth: International evidence. *Economic Modelling*, *27*(5), 1079–1089. https://doi.org/10.1016/j.econmod.2010.04.001

Balasubramanyam, V. N., Salisu, M., & Sapsford, D. (1996). Foreign direct investment and growth in ep and is countries. *The Economic Journal*, *106*(434), 92–105. https://doi.org/10.2307/2234933

Baltabaev, B. (2014). Foreign direct investment and total factor productivity growth: New macro-evidence. *The World Economy*, *37*(2), 311–334. https://doi.org/10.1111/twec.12115

Barro, R. J., & Lee, J. W. (2013). A new data set of educational attainment in the world, 1950–2010. *Journal of Development Economics*, *104*, 184–198. https://doi.org/10.1016/j.jdeveco.2012.10.001

Barro, R. J., & Lee, J.-W. (2015). *Education matters. Global schooling gains from the 19th to the 21st century*. Oxford University Press.

Barro, R. J., & Sala-i Martin, X. (1997). Technological diffusion, convergence, and growth. *Journal of Economic Growth*, *2*(1), 1–26. Retrieved from. https://doi.org/10.1023/A:1009746629269

Barro, R. J., & Sala-i Martin, X. (2004). *Economic growth*. Mit press.

Bekaert, G., Harvey, C. R., & Lundblad, C. (2011). Financial openness and productivity. *World Development*, *39*(1), 1–19. https://doi.org/10.1016/j.worlddev.2010.06.016

Bengoa, M., & Sanchez-Robles, B. (2003). Foreign direct investment, economic freedom and growth: New evidence from Latin America. *European Journal of Political Economy*, *19*(3), 529–545. https://doi.org/10.1016/s0176-2680(03)00011-9

Benhabib, J., & Spiegel, M. M. (1994). The role of human capital in economic development evidence from aggregate cross-country data. *Journal of Monetary Economics*, *34*(2), 143–173. https://doi.org/10.1016/0304-3932(94)90047-7

Benhabib, J., & Spiegel, M. M. (2005). Human capital and technology diffusion. *Handbook of Economic Growth*, *1*, 935–966.

Bils, M., & Klenow, P. J. (2000). Does schooling cause growth? *The American Economic Review*, *90*(5), 1160–1183. https://doi.org/10.1257/aer.90.5.1160

Biørn, E., & Han, X. (2017). Revisiting the fdi impact on gdp growth in errors-in-variables models: A panel data gmm analysis allowing for error memory. *Empirical Economics*, *53*(4), 1379–1398. https://doi.org/10.1007/s00181-016-1203-4

Blomstrom, M., Lipsey, R. E., & Zejan, M. (1994). What explains the growth of developing countries? *Convergence of Productivity: Cross-National Studies and Historical Evidence*, 243–259.

Borensztein, E., De Gregorio, J., & Lee, J.-W. (1998). How does foreign direct investment affect economic growth? *Journal of International Economics*, *45*(1), 115–135. https://doi.org/10.5089/9781451853278.001

Campos, N. F., & Kinoshita, Y. (2002). Foreign direct investment as technology transferred: Some panel evidence from the transition economies. *The Manchester School*, *70*(3), 398–419. https://doi.org/10.1111/1467-9957.00309

Ciftci, C., & Durusu-Ciftci, D. (2022). Economic freedom, foreign direct investment, and economic growth: The role of sub-components of freedom. *Journal of International Trade & Economic Development*, *31*(2), 233–254. https://doi.org/10.1080/09638199.2021.1962392

Cipollina, M., Giovannetti, G., Pietrovito, F., & Pozzolo, A. F. (2012). Fdi and growth: What cross-country industry data say. *The World Economy*, *35*(11), 1599–1629. https://doi.org/10.1111/j.1467-9701.2012.01478.x

Coe, D., Helpman, E., & Hoffmaister, A. (1997). North-south r&d spillovers. *The Economic Journal*, *107*(440), 134–149. https://doi.org/10.1111/1468-0297.00146

Cohen, D. (1994). Foreign finance and economic growth: An empirical analysis. *Capital Mobility: The Impact on Consumption, Investment and Growth*, 217–236.

Cooray, A., Dutta, N., & Mallick, S. (2017). Trade openness and labor force participation in Africa: The role of political institutions. *Industrial Relations: A Journal of Economy and Society*, *56*(2), 319–350. https://doi.org/10.1111/irel.12175

Delgado, M. S., McCloud, N., & Kumbhakar, S. C. (2014). A generalized empirical model of corruption, foreign direct investment, and growth. *Journal of Macroeconomics*, *42*, 298–316. https://doi.org/10.1016/j.jmacro.2014.09.007

De Sousa, J., & Lochard, J. (2011). Does the single currency affect foreign direct investment? *The Scandinavian Journal of Economics*, *113*(3), 553–578. https://doi.org/10.1111/j.1467-9442.2011.01656.x

Doytch, N., & Uctum, M. (2011). Does the worldwide shift of fdi from manufacturing to services accelerate economic growth? A gmm estimation study. *Journal of International Money and Finance*, *30*(3), 410–427. https://doi.org/10.1016/j.jimonfin.2011.01.001

Durham, J. B. (2004). Absorptive capacity and the effects of foreign direct investment and equity foreign portfolio investment on economic growth. *European Economic Review*, *48*(2), 285–306. https://doi.org/10.1016/s0014-2921(02)00264-7

Easterly, W., Loayza, N., & Montiel, P. (1997). Has Latin America's post-reform growth been disappointing? *Journal of International Economics*, *43*(3), 287–311. https://doi.org/10.1016/s0022-1996(97)00004-4

Edwards, S. (1992). Trade orientation, distortions and growth in developing countries. *Journal of Development Economics*, *39*(1), 31–57. https://doi.org/10.1016/0304-3878(92)90056-f

Egger, P. (2001). European exports and outward foreign direct investment: A dynamic panel data approach. *Review of World Economics*, *137*(3), 427–449. https://doi.org/10.1007/bf02707625

Egger, P., & Pfaffermayr, M. (2001). A note on labour productivity and foreign inward direct investment. *Applied Economics Letters*, *8*(4), 229–232. https://doi.org/10.1080/135048501750103917

Figini, P., & Görg, H. (2011). Does foreign direct investment affect wage inequality? An empirical investigation. *The World Economy*, *34*(9), 1455–1475. https://doi.org/10.1111/j.1467-9701.2011.01397.x

Findlay, R. (1978). Relative backwardness, direct foreign investment, and the transfer of technology: A simple dynamic model. *Quarterly Journal of Economics*, *92*(1), 1–16. https://doi.org/10.2307/1885996

Fischer, S. (1993). The role of macroeconomic factors in growth. *Journal of Monetary Economics*, *32*(3), 485–512. https://doi.org/10.1016/0304-3932(93)90027-d

Ford, T. C., Rork, J. C., & Elmslie, B. T. (2008). Foreign direct investment, economic growth, and the human capital threshold: Evidence from us states. *Review of International Economics*, *16*(1), 96–113. https://doi.org/10.1111/j.1467-9396.2007.00726.x

Girma, S., & Görg, H. (2007). The role of the efficiency gap for spillovers from fdi: Evidence from the UK electronics and engineering sectors. *Open Economies Review*, *18*(2), 215–232. https://doi.org/10.1007/s11079-007-9031-y

Gönel, F., & Aksoy, T. (2016). Revisiting fdi-led growth hypothesis: The role of sector characteristics. *Journal of International Trade & Economic Development*, *25*(8), 1144–1166. https://doi.org/10.1080/09638199.2016.1195431

Grijalva, D. F. (2011). Inequality and economic growth: Bridging the short-run and the long-run.

Gupta, S., Kangur, A., Papageorgiou, C., & Wane, A. (2014). Efficiency-adjusted public capital and growth. *World Development*, *57*, 164–178. https://doi.org/10.1016/j.worlddev.2013.11.012

Hall, R. E., & Jones, C. I. (1999). Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics*, *114*(1), 83–116. https://doi.org/10.1162/003355399555954

Helpman, E. (1993). Innovation, imitation, and intellectual property rights. *Econometrica*, *61*(6), 1247–1280. https://doi.org/10.2307/2951642

Hermes, N., & Lensink, R. (2003). Foreign direct investment, financial development and economic growth. *Journal of Development Studies*, *40*(1), 142–163. https://doi.org/10.1080/00220380412331293707

Herzer, D., & Donaubauer, J. (2018). The long-run effect of foreign direct investment on total factor productivity in developing countries: A panel cointegration analysis. *Empirical Economics*, *54*(2), 309–342. https://doi.org/10.1007/s00181-016-1206-1

Iamsiraroj, S. (2016). The foreign direct investment–economic growth nexus. *International Review of Economics & Finance*, *42*, 116–133. https://doi.org/10.1016/j.iref.2015.10.044

Iamsiraroj, S., & Ulubaşoğlu, M. A. (2015). Foreign direct investment and economic growth: A real relationship or wishful thinking? *Economic Modelling*, *51*, 200–213. https://doi.org/10.1016/j.econmod.2015.08.009

Jones, C. I. (1995). R & d-based models of economic growth. *Journal of Political Economy*, *103*(4), 759–784. https://doi.org/10.1086/262002

Jones, C. I., & Vollrath, D. (2013). *Introduction to economic growth* (3rd ed.). Norton.

Kamps, C. (2006). New estimates of government net capital stocks for 22 oecd countries, 1960–2001. *IMF Staff Papers*, *53*(1), 120–150. https://doi.org/10.5089/9781451848939.001

Kaulihowa, T., & Adjasi, C. (2018). Fdi and income inequality in Africa. *Oxford Development Studies*, *46*(2), 250–265. https://doi.org/10.1080/13600818.2017.1381233

Kim, D.-H., Lin, S.-C., & Suen, Y.-B. (2013). Investment, trade openness and foreign direct investment: Social capability matters. *International Review of Economics & Finance*, *26*, 56–69. https://doi.org/10.1016/j.iref.2012.08.008

Kose, M. A., Prasad, E. S., & Taylor, A. D. (2011). Thresholds in the process of international financial integration. *Journal of International Money and Finance*, *30*(1), 147–179. https://doi.org/10.1016/j.jimonfin.2010.08.005

Kose, M. A., Prasad, E. S., & Terrones, M. E. (2009). Does openness to international financial flows raise productivity growth? *Journal of International Money and Finance*, *28*(4), 554–580. https://doi.org/10.1016/j.jimonfin.2009.01.005

Kottaridi, C., & Stengos, T. (2010). Foreign direct investment, human capital and non-linearities in economic growth. *Journal of Macroeconomics*, *32*(3), 858–871. https://doi.org/10.1016/j.jmacro.2010.01.004

Lee, C.-C., Lee, C.-C., & Cheng, C.-Y. (2022). The impact of fdi on income inequality: Evidence from the perspective of financial development. *International Journal of Finance & Economics*, *27*(1), 137–157. https://doi.org/10.1002/ijfe.2143

Lensink, R., & Morrissey, O. (2006). Foreign direct investment: Flows, volatility, and the impact on growth. *Review of International Economics*, *14*(3), 478–493. https://doi.org/10.1111/j.1467-9396.2006.00632.x

Li, C., Murshed, S. M., & Tanna, S. (2017). The impact of civil war on foreign direct investment flows to developing countries. *Journal of International Trade & Economic Development*, *26*(4), 488–507. https://doi.org/10.1080/09638199.2016.1270347

Li, C., & Tanna, S. (2019). The impact of foreign direct investment on productivity: New evidence for developing countries. *Economic Modelling*, *80*, 453–466. https://doi.org/10.1016/j.econmod.2018.11.028

Li, C., Tanna, S., & Nissah, B. (2022). The effect of institutions on the foreign direct investment-growth nexus: What matters most? *The World Economy*, *00*, 1–33. https://doi.org/10.1111/twec.13349

Li, X., & Liu, X. (2005). Foreign direct investment and economic growth: An increasingly endogenous relationship. *World Development*, *33*(3), 393–407. https://doi.org/10.1016/j.worlddev.2004.11.001

Luo, S., Shi, Y., Sun, Y., Zhao, Z., & Zhou, G. (2021). Can fdi and odi two-way flows improve the quality of economic growth? Empirical evidence from China. *Applied Economics*, *53*(44), 5028–5050. https://doi.org/10.1080/00036846.2021.1914318

Makki, S. S., & Somwaru, A. (2004). Impact of foreign direct investment and trade on economic growth: Evidence from developing countries. *American Journal of Agricultural Economics*, *86*(3), 795–801. https://doi.org/10.1111/j.0002-9092.2004.00627.x

Mariam, C., & Cecilio, T. (2004). Estimating the export and import demand for manufactured goods: The role of fdi. *Review of World Economics*, *140*(3), 347–375. https://doi.org/10.1007/bf02665980

Mei, J.-C. (2021). Refining vertical productivity spillovers from fdi: Evidence from 32 economies. *International Review of Economics & Finance*, *74*, 176–191. https://doi.org/10.1016/j.iref.2021.02.009

Moshirian, F. (1997). Foreign direct investment in insurance services in the United States. *Journal of Multinational Financial Management*, *7*(2), 159–173. https://doi.org/10.1016/s1042-444x(97)00010-8

Okada, K., & Samreth, S. (2014). How does corruption influence the effect of foreign direct investment on economic growth? *Global Economic Review*, *43*(3), 207–220. https://doi.org/10.1080/1226508x.2014.930671

Olofsdotter, K. (1998). Foreign direct investment, country capabilities and economic growth. *Review of World Economics*, *134*(3), 534–547. https://doi.org/10.1007/bf02707929

Oshima, K. (1973). Research and development and economic growth in Japan. In *Science and technology in economic growth* (pp. 310–334). Springer.

Rehman, F. U., & Islam, M. M. (2022). Financial infrastructure—Total factor productivity (tfp) nexus within the purview of fdi outflow, trade openness, innovation, human capital and institutional quality: Evidence from brics economies. *Applied Economics*, *55*(7), 1–19. https://doi.org/10.1080/00036846.2022.2094333

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5, Part 2), S71–S102. https://doi.org/10.1086/261725

Romer, P. M. (1993). Idea gaps and object gaps in economic development. *Journal of Monetary Economics*, *32*(3), 543–573. https://doi.org/10.1016/0304-3932(93)90029-f

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system gmm in stata. *Stata Journal*, *9*(1), 86–136. FOR ONLINE PUBLICATION. https://doi.org/10.1177/1536867x0900900106

Schaffer, M. (2015). xtivreg2: Stata module to perform extended iv/2sls, gmm and ac/hac, liml and k-class regression for panel data models.

Suliman, A. H., Elian, M. I., & Ali, H. E. (2018). Endogenous specification of fdi and economic growth: Cross-economies' evidence. *International Journal of Business*, *23*(1), 89–109.

Tanna, S., Li, C., & De Vita, G. (2018). The role of external debt in the foreign direct investment–growth relationship. *International Journal of Finance & Economics*, *23*(4), 393–412. https://doi.org/10.1002/ijfe.1628

Teece, D. J. (1977). Technology transfer by multinational firms: The resource cost of transferring technological know-how. *Economic Journal*, *87*(346), 242–261. https://doi.org/10.2307/2232084

UNCTAD. (2020). *Invesment trend monitor*. UNCTAD.

Wacker, K. M. (2016). (when) should we use foreign direct investment data to measure the activities of multinational corporations? Theory and evidence. *Review of International Economics*, *24*(5), 980–999. https://doi.org/10.1111/roie.12244

Walz, U. (1997). Innovation, foreign direct investment and growth. *Economica*, *64*(253), 63–79. https://doi.org/10.1111/1468-0335.00064

Wang, J.-Y. (1990). Growth, technology transfer, and the long-run theory of international capital movements. *Journal of International Economics*, *29*(3–4), 255–271. https://doi.org/10.1016/0022-1996(90)90033-i

Whalley, J., & Zhao, X. (2010). The contribution of human capital to China?s economic growth nber working papers (Tech. Rep.). Working paper 16592. Recuperado de http://www.nber.org/papers/w16592

Woo, J. (2009). Productivity growth and technological diffusion through foreign direct investment. *Economic Inquiry*, *47*(2), 226–248. https://doi.org/10.1111/j.1465-7295.2008.00166.x

Xu, B. (2000). Multinational enterprises, technology diffusion, and host country productivity growth. *Journal of Development Economics*, *62*(2), 477–493. https://doi.org/10.1016/s0304-3878(00)00093-6

How to cite this article: Mei, J.-C. (2023). Foreign direct investment and relative capacity: Theory and evidence. *Economics of Transition and Institutional Change*, 1–40. https://doi.org/10.1111/ecot.12369

APPENDIX A

Innovation in the Leader Country

Each variety of capital goods is produced by a unique producer using 1 unit of final output. Since each producer is the only supplier of that capital good, the producer settles the price that maximizes the profits:

$$\begin{aligned} \max_{P_{1j}} \quad & \left(P_{1j} - 1\right) X_{1j} \\ \text{s.t.} \quad & P_{1j} = A_1 \alpha H_1^{1-\alpha} X_{1j}^{\alpha - 1} \end{aligned} \tag{A1}$$

The producer of X_{1j} selects P_{1j} at each date to maximize the current profit at the date. Thus, to solve the problem, we substitute of Equation (3) into Equation (A1) and take the first-order condition with respect to P_{1j} to yield the monopoly price:

$$\max_{P_{1j}} \quad \pi_{1j}(v) = \left(P_{1j} - 1\right)\left(\frac{\alpha A_1}{P_{1j}}\right)^{\frac{1}{1-\alpha}} H_1 \tag{A2}$$

maximization of π_{1j} with respect to P_{1j} we obtain the monopoly price $P_{1j} = \frac{1}{\alpha}$. Note that the monopoly price is constant over time and it is the same for all intermediate goods, as the cost of production for all intermediate goods is the same, and each good enters symmetrically the production function. Substituting the price into Equation (3) to get the total quantity of the type j intermediate good, we obtain:

$$X_{1j} = \alpha^{\frac{2}{1-\alpha}} A_1^{\frac{1}{1-\alpha}} H_1 \tag{A3}$$

Therefore, the level of aggregate output is given by the following equation:

$$Y_1 = A_1^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} H_1 N_1 \tag{A4}$$

substitution of Equation (A3) into the objective function of Equation (A1), we obtain the profits that the intermediate producer obtains at each period of time, which is given as follows:

$$\pi_{1j} = \pi_1 = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} H_1 A_1^{\frac{1}{1-\alpha}} \tag{A5}$$

Since Equation (A5) implies that the profit flow is constant over time across goods, the present discounted value of profits associated with the invention of an intermediate good is given as follows:

$$V_1(t) = \pi_{1j} \int_t^{\infty} e^{\int_t^s -r_1(v)dv} ds \tag{A6}$$

where $r_1(v)$ is the real interest rate at time v in country 1. As we described, researchers will decide to enter the R&D sector if $V_1(t) > \eta_1$ (η_1 is the R&D cost). Since there is free entry in the R&D sector, in equilibrium, the net profit must be equal to zero. In equilibrium:

$$V_1 r_1 = \pi_1 + \dot{V}_1 \tag{A7}$$

Equation (A7) says that the investing V_1 of any resources in bonds will earn $V_1 r_1$; investing in innovation, by contrast, will obtain $\pi_1 + \dot{V}_1$. By using the free entry condition, which implies that $\dot{V}_1 = 0$ (since η_1 is constant), we have the following equations:

$$r_1 = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} H_1 A_1^{\frac{1}{1-\alpha}} \eta_1^{-1} \tag{A8}$$

where r_1 is the rate of return, which depends on the underlying technology A_1 and H_1.

Consumers in country 1 maximise a standard inter-temporal utility function, subject to the underlying households' aggregate budget constraint

$$\begin{aligned}
\text{Max} \quad & \int_0^{\infty} e^{-\rho t} \frac{C_1^{1-\theta} - 1}{1-\theta} dt \\
\text{s.t.} \quad & c_t + \dot{b}_t = w_t h_t + r_t b_t + \pi_t \\
& b_t \geq 0 \\
& b_0 > 0
\end{aligned} \tag{A9}$$

where b_t, w_t, h_t and r_t are households' assets, wage rate, labour and the rate of return. In Equation (A9), ρ refers to the rate of time preference and $\theta > 0$ so that the elasticity of marginal utility is a constant.

To solve the utility maximization problem by using the Hamiltonian, we obtain the usual formula for the growth rate of consumption in the leader country:

$$\frac{\dot{C}_1}{C_1} = \frac{1}{\theta}(r_1 - \rho) \tag{A10}$$

The growth rate of C_1 is constant since r_1 is constant.

In equilibrium, the households' aggregate assets equal the market value of firms' intermediate goods, so $b_t = \eta_1 N_1$ (implies that $\dot{b} = \eta_1 \dot{N}_1$ as η_1 is constant). The level of consumption is therefore given by

$$C_1 + \dot{b} = w_1 H_1 + r_1 \eta_1 N_1 + \Pi_1 \tag{A11}$$

In the steady state, C_1, y_1 and N_1 are growing at a constant rate and r_1, X_1, π_1, V_1 and b_t are constant (i.e., $\frac{\dot{C}_1}{C_1} = \frac{\dot{y}_1}{y_1} = \frac{\dot{N}_1}{N_1}$). The growth rate of this economy is given by

$$\gamma_1 = \frac{1}{\theta}\left((1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} H_1 A_1^{\frac{1}{1-\alpha}} \eta_1^{-1} - \rho\right) \tag{A12}$$

Equation (A12) shows that $\gamma_1 \geq 0$ if $(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} H_1 A_1^{\frac{1}{1-\alpha}} \eta_1^{-1} \geq \rho$ holds. It implies that the growth rate of output is consistent with the growth rate of N_1 at the constant rate of γ_1. In other words, the growth rate of the leader nation grows as the number of new types of intermediates increases. The growth rate is increasing in H_1 but decreasing in η_1.

Imitation in the Follower Country

As country 2 holds a low level of technology, imitation may be the best way for country 2 to improve their efficiency. The follower country can copy the intermediates invented in the leader country and then upgrade their present level of technology. Imitating new types of intermediate goods is costly; thus, the cost of imitation is set as follows:

$$m_2 = \left(\frac{N_2}{N_1}\right)^{\sigma} \tag{A13}$$

where N_1 and N_2 refer to the number of intermediates that are available in the leader and the follower country. Note that the cost of technology transfer rises with the current level of intermediates used by the country as it is the case in standard growth models of technology transfer (Jones, 1995; Barro & Sala-i Martin, 1997; Jones & Vollrath, 2013, Ch5); this reflects the idea that technologies are transferred from the easiest ones to the most complicated ones (i.e., $\sigma > 0$).

As country 2 will put the same monopoly price of type j intermediate good $\frac{1}{\alpha}$, Equations (A3) and (A4) therefore provide the equations as follows (parallels with the leader country):

$$X_{2j} = X_2 = \alpha^{\frac{2}{1-\alpha}} A_2^{\frac{1}{1-\alpha}} H_2 \tag{A14}$$

$$Y_2 = A_2^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} H_2 N_2 \tag{A15}$$

$$\pi_{2j} = \pi_2 = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} H_2 A_2^{\frac{1}{1-\alpha}} \tag{A16}$$

Through Equations (A14–A16), the present value of profits from imitation of intermediates j in country 2 is as follows:

$$V_2(t) = \pi_2 \int_t^{\infty} e^{\int_t^s -r_2(v)dv} ds \tag{A17}$$

where r_2 is the rate of return in country 2 at time t. Using the free-entry condition, the present value of profit from imitation in equilibrium must be equal to the cost of imitation at each point in time

$$V_2(t) = \left(\frac{N_2}{N_1}\right)^{\sigma} \tag{A18}$$

which implies that the profit gained from investing bonds equals the profit gained from imitation

$$r_2 m_2 = \pi_2 + \dot{m}_2 \tag{A19}$$

Consumers in the follower country are assumed to maximise the standard inter-temporal utility function and subject to the budget constraint. The Euler equation is therefore given as follows:

$$\frac{\dot{C}_2}{C_2} = \frac{1}{\theta}\left(\left(\frac{N_2}{N_1}\right)^{-\sigma}(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} H_2 A_2^{\frac{1}{1-\alpha}} - \rho\right) \tag{A20}$$

In the steady-state, the growth rate of Y_2 and C_2 equals the growth rate of N_2, which equals γ_1. Therefore, the rates of return in the two countries are the same, which imply that

$$\gamma_2^* = \gamma_1 \tag{A21}$$

Since the preference parameters ρ and θ are the same in both countries, Equations (A7), (A12), and (A20) imply that the rates of return in the two countries are the same

$$r_2^* = r_1 \tag{A22}$$

and from Equation (A19), we obtain

$$r_2^* = \left(\frac{N_2}{N_1}\right)^{-\sigma}(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} H_2 A_2^{\frac{1}{1-\alpha}} \tag{A23}$$

where m_2 is constant as in the steady state. Thus, from Equation (A23), we obtain

$$\frac{\pi_2}{m_2} = \frac{\pi_1}{\eta_1} \tag{A24}$$

where $\frac{\pi_2}{m_2} = r_2$ and $\frac{\pi_1}{\eta_1} = r_1$ as given. We can simplify Equation (A24) as follows:

$$(m_2)^* = \eta_1 \frac{H_2}{H_1}\left(\frac{A_2}{A_1}\right)^{\frac{1}{1-\alpha}} \tag{A25}$$

From Equation (A25), we obtain the steady-state value of $\left(\frac{N_2}{N_1}\right)^*$

$$\left(\frac{N_2}{N_1}\right)^* = \left[\eta_1 \frac{H_2}{H_1}\left(\frac{A_2}{A_1}\right)^{\frac{1}{1-\alpha}}\right]^{\frac{1}{\sigma}} \tag{A26}$$

Substitution of the steady-state value of $\left(\frac{N_2}{N_1}\right)^*$ to the common growth rate shows that the growth rate of the follower country and the leader country is the same

$$\begin{aligned}(\gamma_2)^* &= \frac{1}{\theta}\left[\left(\left(\eta_1 \frac{H_2}{H_1}\left(\frac{A_2}{A_1}\right)^{\frac{1}{1-\alpha}}\right)^{-1}(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} H_2 A_2^{\frac{1}{1-\alpha}}\right) - \rho\right] \\ &= \gamma_1\end{aligned} \tag{A27}$$

In the steady state, the gross output per capita for two countries is given as follows:

$$\left(\frac{y_2}{y_1}\right)^* = \left(\frac{A_2}{A_1}\right)^{\frac{1+\alpha}{(1-\alpha)\sigma}} \left(\frac{h_2}{h_1}\right)^{\frac{\sigma}{\sigma+1}} \eta_1^{\frac{1}{\sigma}} \tag{A28}$$

Thus, the ratio depends positively on the relative values of $\frac{A_2}{A_1}$, $\frac{h_2}{h_1}$ and $\frac{N_2}{N_1}$.

APPENDIX B

Our dataset contains 67 countries over the period 1977–2013. The selection of countries and time periods is based on data availability, and the final sample is restricted to observations with non-missing values for key variables, given a total of 1964 observations. Table B1 provides summary statistics.

Apart from our key variables explained in the main context, we control for a set of variables in our empirical model guided by the existing literature. First, we draw four additional controls from the Penn World Tables (PWT) (henceforth, PWT) since the PWT has long been employed in cross-country FDI studies, for example, Edwards (1992), Blomstrom et al. (1994), Fischer (1993), Campos and Kinoshita (2002) and Herzer and Donaubauer (2018). As previous empirical studies

TABLE B1 Summary statistics.

Variable	Definition	Mean	SD	Min	Max	Obs.
lny	The gross output per capita, relative to the U.S. in logarithm	−1.865	1.504	−5.537	0.788	1964
lnFK	The number of intermediates between countries in logarithm	0.931	1.073	8.21e–07	5.215	1964
ln^{hs}	Difference of human capital (in logarithm)	0.476	0.097	0.271	0.693	1964
ln^{hst}	Difference of human capital (in logarithm)	0.648	0.013	0.616	0.696	1964
lnA^s	Difference of technology (in logarithm)	0.844	0.593	0.025	3.095	1964
lnA^{st}	Difference of technology (in logarithm)	0.738	0.585	0.017	2.959	1964
$lnFK \times ln^{hs}$	The interaction term of *lnFK* and ln^{hs}	0.508	0.647	4.59e–07	3.615	1964
$\text{lnFK} \times ln^{hst}$	The interaction term of *lnFK* and ln^{hst}	0.609	0.711	5.25e–07	3.615	1964
$lnFK \times lnA^s$	The interaction term of lnA^s and *lnFK*	1.006	1.409	3.46e–07	6.962	1964
$lnFK \times lnA^{st}$	The interaction term of lnA^{st} and *lnFK*	0.927	1.344	3.14e–07	7.063	1964
Invest/GDP	The domestic investment rates measured in share of GDP	5.045	27.234	−0.4	396.774	1964
Pop growth	The population growth rates in level	1.120	4.036	−0.989	65.853	1964
Gov/GDP	The government expenditures measured in share of GDP	12.290	87.953	0.033	792.416	1964
lntgdp	The trade openness in logarithm	4.094	0.573	1.843	6.076	1964
lnExchange	The exchange rates in logarithm	1.443	3.616	−23.025	12.992	1964
Developed	The dummy 1 if developed country, 0 otherwise	0.327	0.469	0	1	1964

Note: lnFK is FDI stock divided by US capital stock. The average year of schooling is computed by using the educational attainment for the population aged 15 and above. lnh^s is constructed by using the average total schooling. lnh^{st} is constructed by using the tertiary schooling. lnA^s is the natural logarithm of A^s. lnA^{st} is the natural logarithm of A^{st}. Population aged 15–64. Government expenditures gov include the expenditures in health and education services. domi is gross capital formation at a constant price. lnExchange is measured by 1 US dollar with local currency (e.g., 1 US dollar to the Local Currency). lntgdp is measured as the sum of exports and imports of goods and services, measured as the share of gross domestic product, the percentage of GDP.

reported the effect of government macroeconomic stabilisation expenditures on growth (Barro & Sala-i Martin, 1997; Borensztein et al., 1998; Makki & Somwaru, 2004), we include this variable in the model. Government consumption is measured by government expenditures in education and health service at a constant price. We divide government consumption by GDP to control for its dependence on the size of the country. Second, while early studies generally find a negative effect from the growth rate of population, Jones and Vollrath (2013) remarked that the estimated coefficient of population growth rate in the growth regression should be positive as the technological improvement is associated with the growth rate of the population. Third, it is argued that a positive correlation between FDI, the domestic investment market, and subsequent growth may be one of the few consistent results to have emerged (Alfaro et al., 2004; Borensztein et al., 1998; Easterly et al., 1997; Makki & Somwaru, 2004). Therefore, we control for the domestic investment rate, which is measured as the relative level of gross domestic investment divided by GDP in the follower countries to that of in the leader country.

Another two additional controls are trade openness and exchange rates. The measure of the former is the sum of exports and imports of goods and services, while the latter is measured as a ratio of US dollars to the local currency. As Iamsiraroj and Ulubaşoğlu (2015) suggest, these two variables are expected to be correlated with FDI, GDP per capita and other macroeconomic variables. Thus, we include both variables in the model to avoid potential bias. Both data are drawn from the World Development Indicator (World Bank, 2016).

APPENDIX C

See Tables C1, and C2.

TABLE C1 The list of countries.

Developing country		Developed country
Argentina	Malaysia	Austria
Barbados	Mauritius	Belgium
Benin[c]	Mexico	Canada
Bolivia[a]	Morocco[b]	Denmark
Brazil	Mozambique[c]	Finland
Bulgaria	Venezuela	France
Cambodia[c]	Korea	Germany
Cameroon[a]	Kenya	Greece
Cote d'lvoire[a]	Trinidad and Tobago	Hong Kong
Colombia	Niger[c]	Ireland
Chile	Panama	Italy
China	Paraguay[b]	Japan
Costa Rica	Peru	Luxembourg
Dominican Republic	Philippines[a]	Netherlands
Ecuador	Poland	Norway
Egypt[b]	Romania	Portugal
El Salvador[b]	Russia	Spain
Fiji[b]	Senegal[c]	Sweden

(Continues)

TABLE C1 (Continued)

Developing country		Developed country
Ghana[a]	Tunisia[b]	Switzerland
Honduras[a]	Sri Lanka[b]	United Kingdom
India[a]	South Africa	United States
Indonesia[b]	Iraq	
Iran	Zimbabwe	
Least developed countries (LEADC)	7	
Middle and upper income developing countries (MUDC)	22	
Lower middle income developing countries (LMDC)	12	
Low income developing countries (LDC)	5	
Total developing countries	46	
Total developed countries	21	
Total countries	67	

[a]refers that the country is assigned as the least developed country.

[b]refers that the country is assigned as the lower middle income developing country.

[c]refers that the country is assigned as the lower-income developing country.

TABLE C2 First-stage regression.

	(1)	(2)	(3)	(4)	(5)	(6)
Insurance and financial services in log (%of commercial service imports)	0.058*** (0.027)					
Insurance and financial services in log (%of service imports)		0.062*** (0.027)				
laglnh^{s}			0.610 (1.849)			
laglnhst				35.764*** (9.625)		
laglnA^{s}					1.230*** (0.491)	
laglnAst						1.312*** (0.526)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1154	1154	1964	1964	1964	1964

Note: Pooled sample across 67 countries. Robustness standard errors are in parentheses.

*, ** and *** indicate the level of statistical significance at 10%, 5% and 1%, respectively.