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TECHNOLOGY GAP AND PRODUCTIVITY SPILLPOVERS FROM CHINESE OUTWARD FOREIGN DIRECT INVESTMENT

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Scholars were encouraged to research CAREC integration topics and undertake comparative analysis between (sub)regions to draw lessons for promoting and deepening regional integration among CAREC members, particularly as anticipated in the CAREC 2030 strategy and stated operational priorities.

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List of Acronyms and Abbreviations

BRI	Belt and Road Initiative
CAREC	Central Asia Regional Economic Cooperation
DPTM	dynamic panel threshold model
ETG	expected technology gap
FDI	foreign direct investment
GMM	generalized method of moments
MI	Malmquist Productivity Index
MNC	multinational corporation
MOFCOM	Ministry of Finance and Commerce
OTG	observed technology gap
PIM	Perpetual Inventory Method
PRC	People's Republic of China
R&D	research and development
SME	small and medium scale enterprises
TFP	total factor productivity
WTO	World Trade Organization

Abstract

Chinese outward foreign direct investment (FDI) and trade have shown exponential growth in the last two decades, particularly after the accession of the World Trade Organization (WTO) in 2001 and the execution of the Belt and Road Initiative (BRI) in 2013. Extant literature argued that international trade and investment produce technology spillovers for host economies. And many BRI host economies, including Central Asia Regional Economic Cooperation (CAREC) countries, are operating under low end economic models and placing foreign investment in the hope of improving their productivity, technical capacity, trade, and infrastructure. However, a few important questions remain unanswered; whether China, as an emerging economy, has enough technical capabilities to produce technology spillovers for developing or underdeveloped host countries, and what is the role of the technology gap to realize these spillovers? In response, this report contends that FDI induced technology spillovers are not direct or linear but rather conditional (non-linear) on the prevailing technology gap between China and FDI recipient countries. Initially, we describe different attributes of the technology gap that may possess distinct impacts, such as the observed technology gap (OTG) with perceived differences in learning abilities, while the expected technology gap (ETG) estimates a firm's capability to learn from leading edge technologies. We employ dynamic panel threshold regression for empirical analysis using annual data from 46 developing BRI countries (including CAREC economies) from 2004 to 2019. The main findings of this report show zthat FDI induced technology/productivity spillovers are mainly positive when OTG (ETG) is higher (lower) than a certain threshold. These findings imply that countries/enterprises with a lower ETG are better at absorbing advanced technology from foreign firms when faced with a higher OTG. Thus, a lower ETG channelizes optimal benefits from the prevailing OTG. Manifestly, most of the CAREC countries are falling within the optimal threshold levels, endorsing positive spillovers from FDI inflows. These results are consistent across different model specifications and suggest pertinent policy recommendations.

Keywords: Foreign direct investment; technology spillovers; technology gap; CAREC countries, Belt and Road Initiative

1. Introduction

In 2019, the world economy grew by 2.9 percent, the lowest growth since the financial crisis in 2008, while the growth in trade of goods dropped from 3.8 percent year on year in the previous year to 0.9 percent year on year (IMF). In contrast, outflows (out stocks) of foreign direct investment (FDI) increased by 33.2 percent year on year and reached USD1.31 (USD34.57) trillion after three consecutive years of decline. Among them, foreign investment in developed economies increased by 71.1 percent, while that of developing economies decreased by 10 percent (UNCTAD, 2019). According to world investment report, China's outward FDI flows (stocks) in 2019 represent 10.4 percent (6.45 percent) of the global share, ranking second (third) among all countries. This journey is primarily started from the preparation of World Trade Organization (WTO) accession when China boarded on a new drive of liberalization. In 2000, the going out strategy was projected. Afterward, China continued to relax regulations on outward FDI and assumed an increasingly prominent position in overseas investment. A more fundamental policy relaxation was made in 2014, which ushered in a 'registration based and approval supplemented' stage for China's outward FDI along with the introduction of the Belt and Road Initiative (BRI) (An et al. 2021; Wang and Gao, 2019).

Chinese outward FDI stock is distributed mainly in developing countries (87.3 percent), followed by developed (11.4 percent) and transition economies (1.3 percent). The cumulative flows across the developing BRI region from 2013 to 2019 reached USD1,011.3 billion, accounting for 46 percent of the total outward FDI stock. Manifestly, a large number of BRI host countries are relatively underdeveloped and looking for overseas investments and expecting positive fallouts such as technology transfer, productivity growth, trade, and infrastructure expansion (Razzaq et al. 2021; Kodzi, 2018). Among others, CAREC countries are the attractive destinations of Chinese outward FDI owing to geographic location and a potential gap in trade, transport, and technology infrastructure (Zhuang et al. 2021). Overall, the FDI inflows into developing countries are recognized as an important source of innovative technology; product knowledge generates direct (additional capital and employment) and indirect benefits (arise from externalities, demonstration effects, imitation effects) for the FDI receiving countries, which is also recognized as a spillover effect (Globerman, 1979; Razzaq et al. 2021). These benefits are backed largely by the famous endogenous growth theory, which undertakes that FDI facilitates technology diffusion from advanced countries to developing countries by establishing multinational corporations (MNCs) that translate into the long term growth of host countries (Borensztein et al., 1998; Sjöholm, 1999). Thus, policy makers consider FDI flows an imperative strategy to imitate foreign technologies and sustain their growth.

Figure 1 visualizes China as a leading CAREC country ranked among the top three countries in terms of outward FDI flows for eight consecutive years. Its contribution to the world economy has become increasingly prominent. The flows in 2019 were 51 times as much as the flows in 2002, with its global share being more than 10 percent for four consecutive years. The average annual growth rate reached 26 percent between 2002 and 2019. The highest growth rate is observed after the implementation of the BRI project in 2013, which is mainly distributed across neighboring BRI partnering countries. By the end of 2019, 27,500 Chinese domestic investors had established 44,000 FDI enterprises overseas.[4] The accumulated outward FDI net stock reached USD2,198.88 billion. About 88.4 percent (85.4 percent) FDI stocks (flows) are recorded in the non-financial (financial) sector (MOFCOM, 2019).

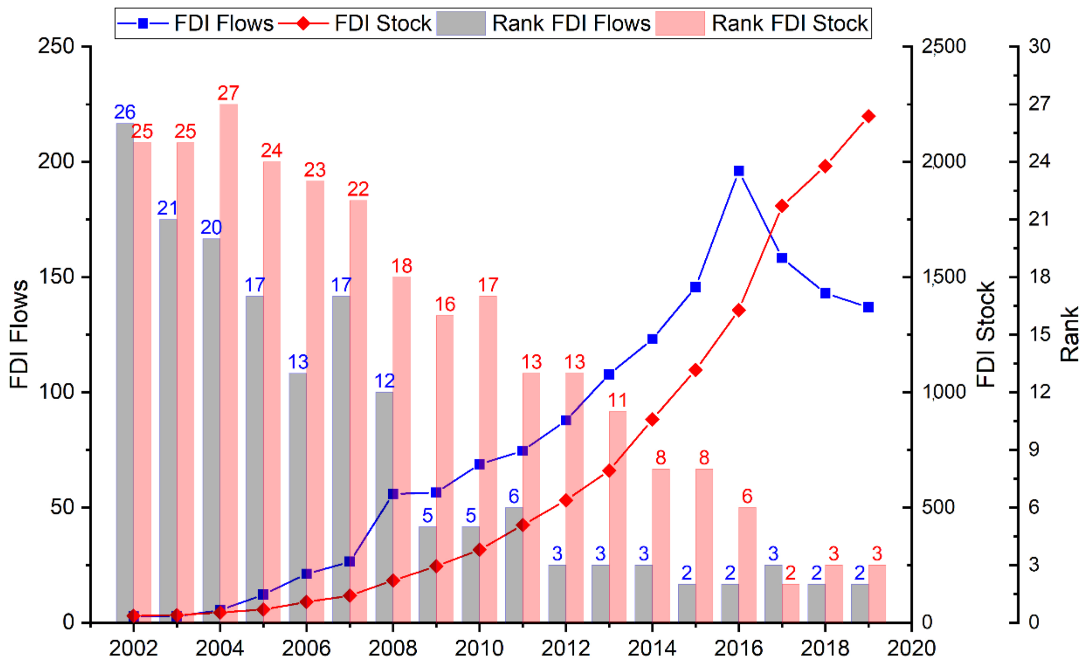


Figure 1: China's Outward FDI Stock and Flows (Billion USD)
Source: Authors' drawing using Origin software from MOFCOM (2019) and UNCTAD (2019)

The previous literature concluded that FDI induced technology spillovers are based on several direct and indirect channels. There are two main parties in the FDI framework. China as an FDI source country has certain objectives, which are not within the scope of this report; however, Chinese firms impact knowledge via FDI in receiving countries' indirect (additional capital and labor demand, intermediate goods and exports, increasing tax revenues) and direct (technical change, managerial skills, scale) channels. Nevertheless, FDI induced spillovers are also contingent on the targeting efforts of the host countries in terms of domestic absorption capacity, local R&D, infrastructure, human capital, and institutional quality (Farole et al., 2014; Espitia et al., 2017; Pegkas et al., 2020). Apart from that, the prevailing technology gap as an indicator of 'absorptive capacity' is an imperative factor that affects the direction and magnitude of FDI induced technology spillovers (Girma, 2005). The technology gap is defined as the technological differences between advanced and relatively underdeveloped economies. Findlay (1978) contended that countries with a broader technology gap enjoy a positive technology spillover compared to countries with a narrow technological gap. Figure 2 highlights the overall flow and channels of FDI spillovers (Sari et al. 2016), and this report further categorizes the observed and expected technology gap as a core absorptive capacity measure in realizing FDI induced spillovers for productivity growth in host countries (Hong et al. 2019). The flow chart shows that outward FDI flow generates direct and indirect benefits for productivity growth, which is also conditional on the technology gap among others (Wang et al., 2016; Kotikova and Vavrek, 2019).

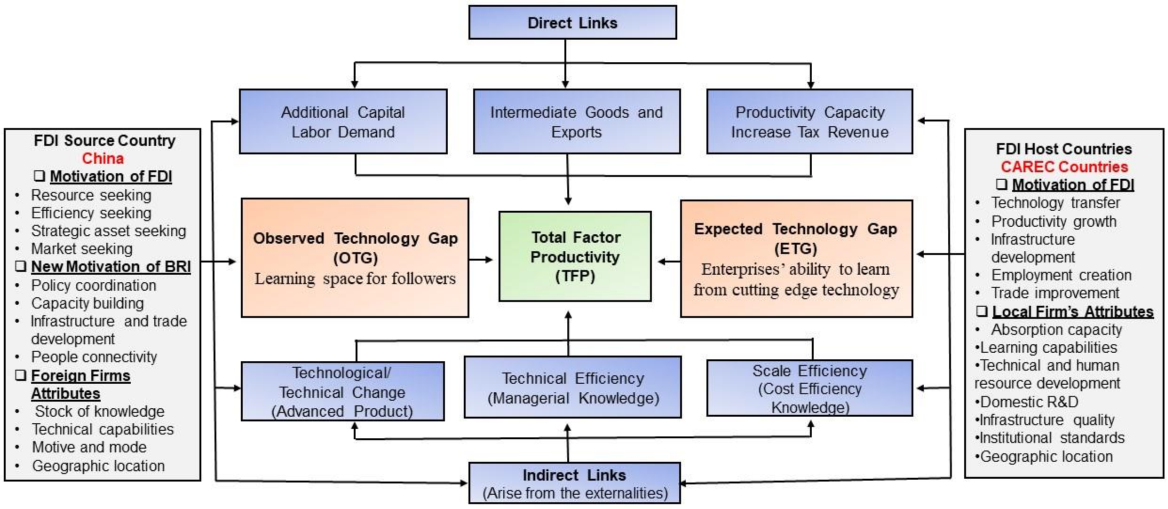


Figure 2: Theoretical Links Between FDI, Technology Gap, and Productivity
Source: Authors' compilation from literature (An et al., 2021; Sari et al., 2016; Du and Zhang, 2018; Hong et al., 2018; Herzer and Donaubauer, 2018)

1.1 Research Motivations and Objectives

Following the above discussion, it is derived that a significant share of outward FDI stocks is placed in developing BRI countries and many of these countries are embodied with lower technological levels and operating at lower end economic models[5] (Deng et al., 2020). According to Findlay (1978), relative backwardness in technological differences provides learning space and leads to higher productivity gains, while others argued that it is a double edged sword that may restrict technology spillovers if the differences are too great (Blomström and Sjöholm, 1999; Hong et al., 2019). Overall, there is no conclusive evidence regarding the technology gap and FDI spillovers, particularly from emerging/developing China to developing or underdeveloped host countries. Apart from that, Liu et al. (2000) and Hong et al. (2019) supported that the association between the technology difference and FDI spillovers realized by domestic firms (countries) may be non-linear and varies with the level of technology gap. Therefore, we construct a conditional hypothesis where it is argued that FDI induced technology spillovers are not directly linked with productivity, rather it is contingent on the prevailing technology gap. Based on the previous discussion, we raised two important questions:

- Whether China, as an emerging and developing country, has sufficient technological capabilities to generate technological spillovers for developing or underdeveloped BRI host countries?
- What is the role of the prevailing technology gap to realize these spillovers? Do FDI induced technology spillovers vary at a different level of technology gap?

The answer to these questions may set the foundation for developing countries to evaluate their productivity gain based on the prevailing technology gap. Manifestly, it guides all stakeholders towards optimizing technology imitation in the presence of higher and lower technological differences. The overall results of this report confirm that outward FDI induced technology spillovers are positive when there are wider (narrow) observed (expected) technical differences.

The rest of the study is organized as follows. Section II demonstrates stylized Chinese outward FDI facts, and section III reviews the existing literature and theoretical model. Section IV deals with the methodology and data construction. Section V interprets the results and discusses the findings. Section VI concludes the study and gives relevant policy implications.

2. Stylized Facts of China's Outward FDI

2.1 Evolution of China's Outward FDI

China has been a key player of the economic globalization era and is effectively integrating with the global economy through outward FDI, exhibiting primarily three phases of development: restricted (1978-1999); relaxed (2000-2016); and regulated (2017 onwards) where paradigm shifts at different stages are essentially based on major policy shifts. In 2000, China embarked upon a relaxed outward FDI regime by proposing the strategy of going out to attain WTO accession. As a part of this strategy, China kept on relaxing FDI regulations and attained a prominent position in the global market of overseas investment. A more pronounced policy relaxation in 2014 enabled a registration based and approval supplemented phase for China's outward FDI (MOFCOM, 2014; NDRC, 2014). This policy established a cut off limit, where only projects involving sensitive countries/industries or Chinese investment above USD1 billion were required to attain official approval. On the contrary, other projects needed a much simpler procedure for approval. These decentralizing approaches massively increased China's outward FDI, more than tripling it and making China the second largest FDI source country around the globe by 2019.

China's transition from a relaxed to a regulated outward FDI regime took place out of the conscious concerns of the Chinese government for rapidly depleting foreign exchange reserves by 2015 and a proportionally imbalanced FDI expansion. These concerns paved the way for establishing authority of outward FDI and called for closer attention to FDI generating irrational growth (investment in real estate, cinema, hotels, entertainment, sports, and so on) because of a weaker connection to the real economy. Owing to these measures, the Chinese outward FDI came down for the first time since 2003 to 19.3 percent in total, to USD158.3 billion in 2017 (MOFCOM–NBS–SAFE, 2018). However, irrational outward FDI was not the only problem. A number of Chinese enterprises—having a weak sense of corporate social responsibility and low levels of legal compliance in host countries—out of lack of awareness, resulted in the damaged reputation of Chinese firms internationally (Brautigam, 2009). Another problem existed in the shape of large scale Chinese outward FDI, adversely affecting the exchange rate stability and the country's balance of payment (BOP) framework. In this landscape, the realization of risks and counter risk mitigation efforts by the Chinese government reflected in devising new rules and essentially a new model of 'encouraged development plus negative lists' (State Council, 2017) that encompassed the relevant mechanisms to promote overseas investment, administrative streamlining, delegation of powers, and monitoring all phases of outward FDI.

Under this vision, Chinese outward FDI was classified into three distinct categories; encouraged, restricted, and prohibited (State Council, 2017). The encouraged category comprised outward FDI in; (a) infrastructure projects concerning BRI; (b) facilitating comparatively advantageous production capacity export, equipment, and tech standards; (c) collaboration with foreign high tech and high end manufacturing firms and the formulation of overseas R&D centers; (d) exploration of natural resources based on evaluation of economic benefits; and (e) agriculture, forestry, fisheries, financial institutions, trade, and culture, and so on. The restricted category includes: (a) FDI in countries having no diplomatic relations with China, or sensitive regions and countries where outward FDI must be limited guaranteed by multilateral/bilateral treaty; (b) irrational outward FDI; (c) FDI that is not up to the technical standards of host economies. The prohibited category included: (a) FDI comprising any process, technology, or product whose export is prohibited; (b) FDI in controversial industries; and (c) any other type of FDI that affects Chinese national security and interests.

2.2 Distribution of China's Outward FDI Across the BRI Region

By the end of 2019, China's outward FDI stock in countries along with BRI amounted to USD179.47 billion, accounting for 8.2 percent of Chinese outward FDI stocks. Figure 3 draws the FDI stock distribution across developing BRI countries for 2004 (base), 2014 (pre-BRI), 2019 (post-BRI), indicating that the top 12 countries in terms of stock were Singapore, Indonesia, Russia, Laos, Malaysia, United Arab Emirates, Kazakhstan, Thailand, Vietnam, Cambodia, Pakistan, and Myanmar. Figure 3 also visualizes that the range of investment significantly increased from USD22,000 million to USD55,000 million between 2014 to 2019, which presumably can be mainly attributed to BRI implementation. Up to 2019, Chinese domestic investors had set up nearly 11,000 overseas enterprises in 63 countries along with BRI and CAREC, involving 18 industry categories of the national economy, amounting to USD18.69 billion, up to 4.5 percent year on year, accounting for 13.7 percent of China's outward FDI flows in the same period.

On the other hand, developed economies remained the recipient of the growing share of Chinese outward FDI. For the top 10 destinations, the number of developed countries increased from four in 2003 to six in 2016, with a respective share from 4 percent to 13.1 percent. The increasing outward FDI chunks for developed countries and tech intensive industries show the importance of the tech seeking behavior of outward FDI, which facilities Chinese firms to enhance their competitiveness and role in their enterprise value chain. However, in 2019, these flows exhibited portfolio diversification in terms of recipient countries, and outward FDI was mainly directed towards a country mix of Singapore, Indonesia, Vietnam, Thailand, United Arab Emirates, Laos, Malaysia, Kazakhstan, Cambodia, and other member countries (MOFCOM, 2019).

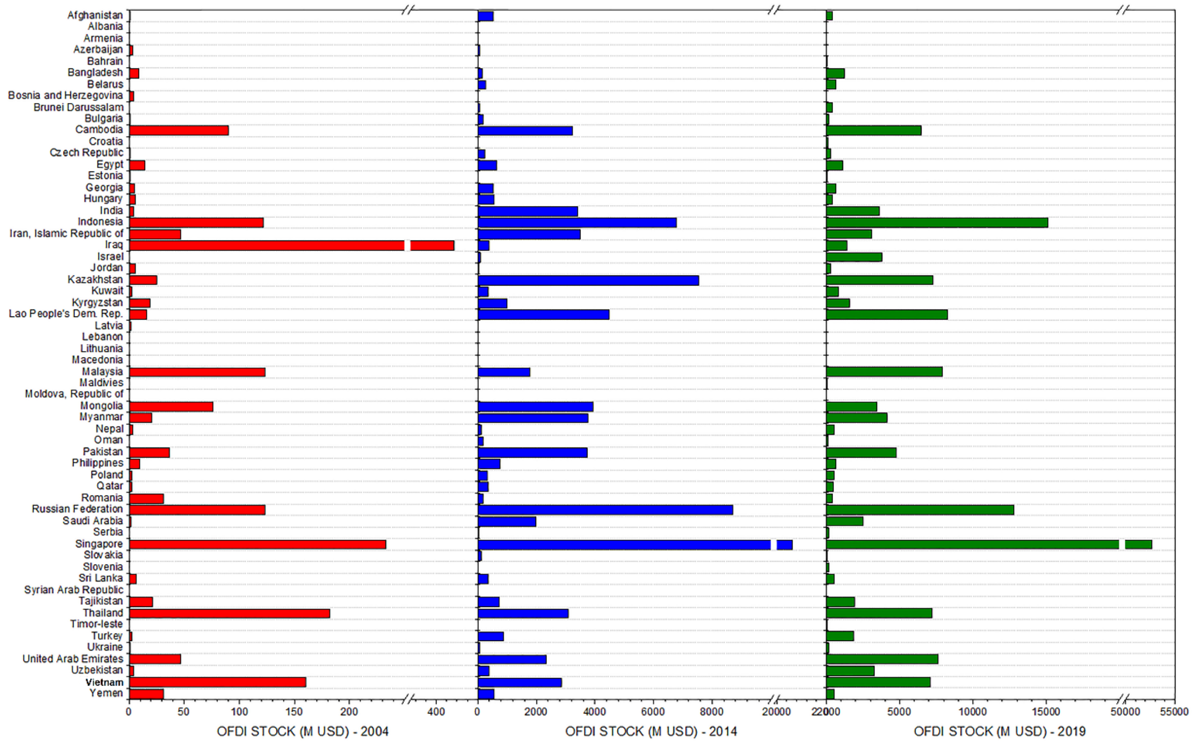


Figure 3: China's Outward FDI Stocks Before and After BRI
Source: Authors' drawing using Origin software from MOFCOM (2019) data

2.3 Distribution of China's Outward FDI Across the CAREC Region

China's outward FDI stock in transition economies,[6] including CAREC member countries by 2019 reached USD36.352 billion, accounting for 1.7 percent of the total stock. Among them, the Russian Federation received the highest number USD12.8 billion, accounting for 34.6 percent of the total stock in transition economies; Kazakhstan received USD7.25 billion, accounting for 19.6 percent; Pakistan received USD4.798 billion accounting for 13.1 percent; Mongolia received USD3.431 billion accounting for 9.3 percent; Uzbekistan received USD3.25 billion, accounting for 8.8 percent; Tajikistan received USD1.95 billion, accounting for 5.3 percent; Kyrgyzstan received USD1.55 billion, accounting for 4.2 percent; Georgia received USD0.67 billion, accounting for 1.8 percent; Belarus received USD0.65 billion, accounting for 1.7 percent; Afghanistan received USD0.419 billion accounting for 1.1 percent; Turkmenistan received USD0.23 billion, accounting for 0.62 percent; and Azerbaijan received USD0.008 billion accounting for 0.02 percent (MOFCOM, 2019). Figure 4 displays composite trends of Chinese FDI stocks in CAREC countries, indicating that Kazakhstan is the leading destination of Chinese FDI, followed by Pakistan, Mongolia, Uzbekistan, Kyrgyzstan, Georgia, and Belarus, while Afghanistan and Azerbaijan received less than USD1 billion up to 2019.

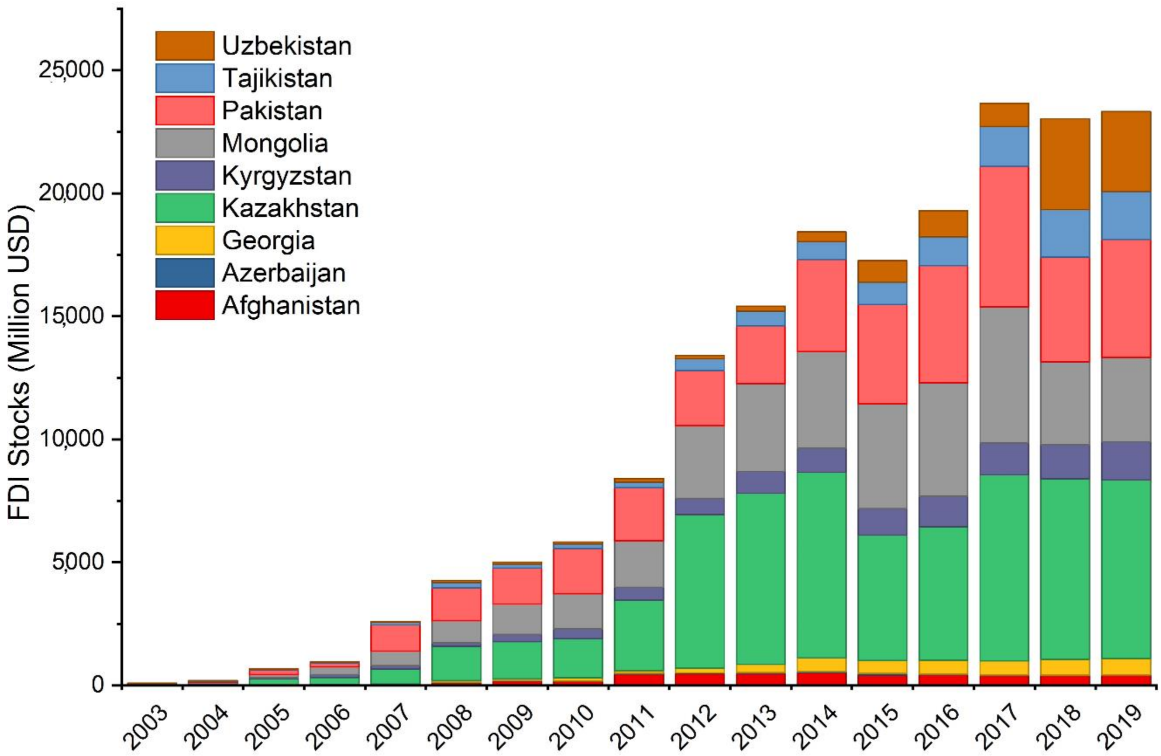


Figure 4: China's Outward FDI Stocks Across the CAREC Countries
Source: Authors' drawing using Origin software from MOFCOM (2019) data

Figure 4 further endorses that Chinese outward FDI is increasingly diversified in terms of investing abroad. In CAREC countries, Kazakhstan is clearly a 'chosen one' along with a clear investment inclination towards Mongolia, while the gradual FDI buildup in Pakistan in nearly two decades shows the trajectory of investment in the China–Pakistan Economic Corridor (CPEC). Chinese foreign investment and construction along the BRI route comprises six economic corridors, encompassing a large resource and an energy rich part of the globe and the prioritized countries for investment; Kazakhstan, Mongolia, and Pakistan essentially serve as the node points of the following main corridors under BRI.

New Eurasian Land Bridge: At the core of this corridor is the international rail line that links China with Central Asia, Russia, Eastern Europe, and further Western Europe by a route passing through Kazakhstan, Russia, Belarus, and Poland. It reduces the cost and time of transportation of goods and promises to promote the economies of China (Western) and Central Asia.

China–Mongolia–Russia Economic Corridor: Mongolia is at the heart of this corridor where rail networks and the steppe road will connect with the Land Bridge Corridor. Concerning this corridor, China is already serving as the largest source of exports and imports for Mongolia.

China–Central Asia–Western Asia Corridor: This economic corridor promotes connectivity between China, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Turkey, and Iran through a railway network from China to the range of the Mediterranean Sea.

China–Pakistan Economic Corridor: This is the smallest, yet the most important of the six corridors, with Pakistan as the focal point of entry and execution. This critical project links Kashgar city (free economic zone) in landlocked Xinjiang with the Pakistan port of Gwadar, a deep water port used for commercial and military purposes.

Table 1: Top Three Destinations of China's Outward FDI in the CAREC Region

Sector	Kazakhstan	Mongolia	Pakistan
Energy	21 (USD22.92 billion)	11 (USD4.53 billion)	50 (USD42.37 billion)
Chemicals	4 (USD3.91 billion)	-	-
Metals	6 (USD2.33 billion)	2 (USD2.05 billion)	-
Transport	6 (USD4 billion)	3 (USD0.52 billion)	19 (USD12.29 billion)
Real Estate	2 (USD0.35 billion)	1 (USD0.12 billion)	5 (USD0.87 billion)
Logistics	-	-	3 (USD0.52 billion)
Technology	-	-	7 (USD2.73 billion)
Total Projects	43 (USD34.12 billion)	19 (USD7.64 billion)	91 (USD59.96 billion)
# of Projects/Total	24	13	63

Source: Authors' calculation using China Global Investment Tracker (2005-2019)
Note: Number of projects shown with amount of FDI project in brackets

Table 1 depicts how Chinese outward FDI has been channelized in the top three CAREC countries from 2005 to 2019, in the prioritized sectors of energy, chemicals, metals, transport, real estate, logistics, and technology. Kazakhstan received USD34.12 billion of Chinese investment, Mongolia received USD7.64 billion, while Pakistan hosted FDI of approximately USD60 billion over the period. Investment in these resource rich countries has been majorly skewed towards the energy sector in general and subsectors of oil, gas, coal, hydropower, and alternative energy. On the contrary, Afghanistan, Azerbaijan, Georgia, and Kyrgyzstan received comparatively lesser shares of Chinese investments over a similar period. The detailed list of Chinese FDI projects in CAREC countries is presented in Appendix A1.

3. Literature Review and Theoretical Framework

3.1 Literature Review

The empirical literature concluded various deriving factors of technology innovation and productivity growth, and FDI is one of the imperative factors in growth economics. However, there is no consensus over the possible impact of FDI on productivity growth as few studies argued that it generates productivity gain through technology transfer (Potterie and Lichtenberg, 2001; Shen, 2005; Wang and Liu, 2008), while others argued that it crowds out the productivity of local firms (Jiang and Feng, 2012). Deng et al. (2020) explored that China's outward FDI positively affects the technological progress of the host countries with certain lags.

In contrast, (Wang and Liu, 2008) argued that outward FDI hinders local R&D activities and negatively affects technological progress. Similarly, Aitken and Harrison (1999) found that MNCs crowd out local enterprises, as local firms are sometimes unable to compete with MNCs. Jiang and Feng (2012) note that the technological spillover of the G7 countries crowds out local enterprises, and hence could not promote technological progress in China. Other important factors are local firm or country features that help to imitate these spillovers, such as local R&D allocations, market regulations, institutional governance, and infrastructure (Giroud et al., 2012; Wang et al., 2012; Park and Roh, 2019;). These factors are pronounced as absorptive capacity, which is considered a prerequisite to learn foreign technologies (Borensztein et al., 1998; Wang and Blomström, 1992; Girma and Wakelin, 2001; Baltabaev B., 2014). Using World Bank firm level data, Farole et al. (2014) explored three factors that facilitate technology transfers: institutions of host countries, the absorption capacity of host firms, and the nature of FDI. Likewise, Espitia et al. (2017) argued that institutional governance and the technology gap are two important factors of FDI spillovers using a panel of 62 developing countries.

Girma (2005) articulated that there is an absorptive capacity threshold that determines whether the technology spillover of FDI is negative or positive. FDI induced technologic spillover is considerably different from before, when the technology gap surpassed the threshold value. Wang and Blomström (1992) observed that the rate of technology diffusion is relatively faster if a country is away from a technology leading country; therefore, technology gap is one of the key drivers of productivity growth in host countries (Blomström et al., 1994; Castellani and Zanfei, 2007; Girma, 2005). Some scholars contended that the large technology gap refers to higher imitation and learning opportunities, which in return benefit domestic firms (Findlay, 1978; Keller and Yeaple, 2009). However, another group of researchers argues that the wider technology gap reduced the possibility of technology imitation (Girma et al., 2001; Kokko et al., 1996; Sohinger, 2005). Li et al. (2016) evaluated the impact of China's outward FDI on domestic productivity growth. The study notes that the minimum threshold level of 9.67 is necessary to produce positive spillover effects. However, if the technology gap is further narrowed to 5.52, a positive impact on productivity becomes salient. Similarly, Ramasamy et al. (2017) has observed that a wider technology gap negatively affects regional productivity in India. Further study notes that absorptive capacity plays a vital role in promoting the spillover effect.

Findlay (1978) suggested that a larger technology gap leads to a positive technology spillover, whereas a narrow technology gap means a lesser spillover. He contended that the potential for a positive spillover is greater when the technology gap between host and home country firms is bigger, as the marginal return on new information is greater for firms with more room to catch up than for those that are already competitive (Sjöholm, 1999b). However, literature is not conclusive about the level of technology gap desirable for technology spillover. For instance, Jordaan (2017) notes that a wide technological gap makes positive FDI spillover more likely for local providers. On the other hand, a smaller technology gap may reflect the higher learning ability and potential of local firms—that is, the ability to absorb and apply the knowledge that spills over. Local businesses cannot profit from technology transfer unless they meet a minimum level of technological or human capital or unless they spend sufficiently on nurturing absorptive capacity. Similarly, Pittiglio et al. (2016) discovered that domestic enterprises with at least a basic degree of technology find it easier to adapt to new technologies. Alternatively, other academics argue that local businesses are better at absorbing knowledge, skills, and technology when there is a moderate technological gap (Blomström et al., 2001; Kokko et al., 1996).

Another strand of literature argued that it is important to differentiate between the observed and expected technology gap to understand the technology spillover (Castellani and Zanfei, 2007). OTG arises owing to observable disparities in knowledge, technology, and management abilities between home and host country firms. It simply represents the objective gap in technological efficiency, knowledge or technology level, management abilities, and therefore productivity between host and home country businesses. Thus, a noticeable technological gap depicts the objective condition of how much one business or region lags behind another. With the widening of a perceived technological gap, domestic businesses have greater room to study, mimic, and engage in knowledge and technology transfer. An observable technological difference provides a learning environment for followers, but it does not explain when or how followers may eventually catch up to leaders. If the observed technology gap is too small, the restricted learning space will not be adequate for the technology spillover.

ETG, on the other hand, represents the ability of organisations to learn from cutting edge technology and the skills of international firms. Firms with a lower ETG are better at mimicking and learning, and they have a stronger incentive to catch the leaders up (Kokko et al., 1996). The ETG does not explain the objective difference in technology level, but it demonstrates the capacity and effort of organisations to catch up with technology. When confronted with a big OTG, organisations with a lower projected technology gap are better at absorbing advanced technology from upstream and downstream enterprises or competitors. Companies with a smaller ETG are better at organisational learning and internalising external knowledge (Kokko et al., 1996). When emerging MNCs operate in foreign nations, those with strong organisational learning capacity and a modest predicted technological gap can effectively center the internal transmission of tacit knowledge. Local experience, human capital endowment, market demand, collaboration with local firms, and economies of scale and scope, particularly in knowledge management, can all assist in innovation. Hence, ETG and OTG both serve an important role in the technological spillover of FDI.

Literature suggests that developing countries can catch up with speedy economic growth through technological progress, which is possible through technological innovation. To control the heterogeneity of innovations, R&D expenditure is commonly used as a control variable (Deng et al., 2020). However, the literature is inconclusive about the effect of R&D investment on technological progress. Some studies contended that R&D investment has no explicit effect on technological progress (Liu and Xin, 2019) or may have a repressive effect (Sun et al., 2012). It can be because (1) innovation is a long term process. Its effects cannot be captured in the same period, and therefore it requires a certain lag (Zhang et al., 2019); (2) China has not yet entered the innovation driven stage. It is still in the investment driven stage, hence its R&D investment is ineffective; (3) a country's efforts towards local innovation are not confined to R&D input.

Human capital plays a critical role in enhancing the spillover effects of outward FDI. When multinationals spend on the training of local workers, it increases their productivity and transfers knowledge from MNEs to the local firms (Miyamoto, 2003; Ramasamy et al., 2017). Arrow (2015) suggests that 'learning by doing' plays a substantial role in economic growth. It implies that the introduction of new technologies owing to OFDI increases efficiency. Moreover, the endogenous growth theories emphasize the importance of human capital development (Romer, 1990); hence human capital development is expected to play a considerable part in productivity growth.

In the context of FDI across the BRI region, certain studies depicted that China's outward FDI promotes economic growth in the BRI countries through promoting human capital (Zhang et al., 2019). However, it takes a one year lag to reflect the impact of technological progress on human capital. On the other hand, it takes almost three years to reflect the outward FDI spillover effect on technical efficiency. In the initial years of investment, the impact is insignificant; later on, it reaches its peak at the end of the third year. However, this report does not incorporate the prevailing gaps and assumes a direct link between FDI and growth. As per the Potterie and Lichtenberg (LP) (2001) model, it is essential to integrate the FDI source country's attributes to estimate potential spillovers or knowledge transfer through trade or FDI. According to Blomström et al. (1994), a higher technology gap facilitates technology transfer; however, if the gap is too wide, then these spillovers turn negative (Blomström and Kokko 2001).

There is a plethora of research on FDI and growth; however, little is known regarding FDI induced technology spillover conditional on different attributes of the technology gap. There is strong theoretical and empirical rationality that FDI spillover is not direct or linear, as it varies across different levels of technology gap. Lastly, China is itself a developing and emerging economy and most of the BRI host countries are relatively underdeveloped in technology and infrastructure (An et al., 2021a), which highlights a key issue, whether these prevailing gaps stimulate or restrict possible gains from inward FDI flows from China.

3.2 Theoretical Framework

Different growth theories do not essentially substitute each other but describe unlike features of the same phenomenon. Hence FDI would not be characterized by a single theory but a wider combination of theories. Primarily, this report follows endogenous growth theory (EGT), also known as new growth theory by Romer (1990), that stresses the importance of human capital, skills, knowledge, and technological innovation, which were considered exogenous in the neoclassical growth models and treated as a Solow residual (Jorgenson and Griliches, 1967). EGT framework is useful in understanding the role of FDI. The international R&D spillover has gained significant recognition after the new growth models introduced by Romer (1990), Grossman and Helpman (1991), Coe and Helpman (1995), and Coe et al. (1997). EGT assumes that foreign investment stimulates economic growth by generating technological diffusion from the developed world to developing economies through MNCs (Borensztein, De Gregorio, and Lee, 1998; Sjöholm, 1999). FDI encourages R&D and human capital formation. Even if firms are experiencing diminishing returns, FDI produces positive externalities through technology spillovers that raise the quality and quantity of the product and speed up new intermediate product varieties. Further, it promotes R&D and collaboration with international firms. Moreover, EGT postulates that technology (knowledge) transfer helps in avoiding the decline of marginal product of capital and promotes long term growth. Following EGT, it is implicit that the overall production of sample countries is consistent with the Cobb-Douglas production function as described:

$$Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{\beta} \quad (1)$$

where Y_{it}, A_{it}, L_{it}, K_{it} represent the total output of a country, technological level, labor input, and fixed capital stock of each sample country i and period t, respectively. Coe and Helpman (1995) (C-H) introduced a thoeratical framework of technology spillovers through trade. A similar model is extended by Pottelsberghe and Lichtenberg (2001) (L-P) using FDI as a prime channel of technology transfer. The final reduced form of L-P model is as follows:

$$Y_{it}(S) = A_{i0} e^{\lambda_i t} \left(S_{it}^{d}\right)^{a^d} \left(S_{it}^{f}\right)^{a^f} \quad (2)$$

where S^d signifies domestic knowledge capital and S^f shows capital acquired through foreign (China) technology spillover channels in period t in country i. It specifies that the productivity growth of host countries is driven mainly by domestic and foreign knowledge stocks. This report considers both channels of technology spillovers foreign (FDI and trade) and local (R&D); however, our focus is mainly on FDI, which is part and parcel of the BRI project. To represent productivity and technology growth at the host country, we use total factor productivity (TFP), which is an appropriate measure of economic efficiency and considered as a gauge for technical advancement (Pottelsberghe and Lichtenberg 2001), with $TFP_{it}=A_{it}$ and:

$$TFP_{it} = A_{it} = \frac{Y_{it}}{L_{it}^{a} K_{it}^{\beta}} = A_{i0} e^{\lambda_i t} \left(S_{it}^{d}\right)^{a^d} \left(S_{it}^{f}\right)^{a^f} \quad (3)$$

The above derived model is usually followed in extant literature to study technology spillovers from FDI. However, the core objective of this report is to integrate the prevailing technology gap while estimating FDI induced technology spillovers. In doing so, we have extended Romer's and the L-P model in light of Findlay's (1978) hypothesis of relative backwardness, which is based on the Veblen effect and postulates that a wider technology gap (distance to technology frontier) between advanced and developing countries increases the FDI induced spillovers for host countries. Findlay contended that the countries (firms) with a wider technology gap enfold high marginal returns of new knowledge thanks to the available learning space and therefore embrace a higher FDI induced technology spillover. In contrast, countries (competitive firms) with a narrow technology gap have less room to catch up as compared with the former (Sjöholm, 1999; Wang and Blomström, 1992).

Findlay trailed the seminal work of Nelson and Phelps (1966) to integrate the lag between best practices and actual technology to formalize the Veblen effect, which assumed that global economies are divided into two distinct groups: advanced and backward. In the equation below, A (t) assumes technical efficiency compatible with equation 3—for example, scale parameter of an aggregate production function in the advanced group.

$$A\,(t) = A_0 e^{nt} \quad (4)$$

Thus, technical efficiency in a relatively advanced group of countries increases at a constant rate n, and if B(t) is the corresponding level in the backward region, then the Veblen hypothesis can be specified as:

$$\frac{dB}{dt} = \lambda[A_0 e^{nt} - B\,(t)] \quad (5)$$

Where λ signifies any positive value of constant, and its magnitude is based on exogenous parameters akin to the expertise, knowledge, education, and skills of the labor force and management.
The differential of equation 5 leads to the following:

$$B\,(t) = \frac{\lambda}{(n+\lambda)} A_0 e^{nt} + \frac{(n+\lambda)\beta_0 - \lambda A_0}{(n+\lambda)} e^{-\lambda t} \quad (6)$$

In the backward region, the initial level of efficiency is represented by Bo. Equation 6 expresses that, when time reaches to infinity, the ratio of B(t) to A(t) tends to reach an equilibrium gap of λ /(n + λ), which changes negatively with n and positively with λ. If λ /(n + λ) is higher than B_0/A_0, the rate of technical improvement in the backward region surpasses n but descent to its asymptotically as the equilibrium gap λ /(n + λ) is approached from below. Simply, this framework argued that a higher technology gap between advanced and backward regions leads to higher productivity gain. The detailed formation of the above theoretical model can be found in the seminal paper of Findlay (1978).

4. Empirical Framework

4.1 Panel Threshold Model

Considering the non-linear association between the technological gap and TFP, we assume that increase in productivity growth is a piecewise function of technological differences between advanced and underdeveloped regions (Lai et al., 2009). Further, it integrates that the coefficient of FDI induced technology spillovers remains unaffected or insignificant (either positive or negative) until the technology gap reaches (exceeds) a specific threshold based on different attributes of the technology gap.

Two common methods are generally followed in the extant literature to study the empirical links between technology spillover and technological gap. The first method is exogenous grouping, where the overall sample is divided into subsamples based on *ad hoc* values such as median of selected observation or some declared measures for the technological gap. However, exogenous splitting of samples leads to various issues owing to selection bias (Hansen, 2000). The second frequently used way out is to add a linear moderation term between FDI and technology gap. But the interaction models possess three obvious deficiencies. First, they failed to calculate the exact threshold value from the data driven process. Second, a linear interaction term is based on the hypothesis that technology spillovers are monotonously decreasing (or increasing) with the different values of technological gap, which is not a plausible assumption. Third, the interaction term of two independent variables may lead to severe multiple collinearities, which would increase the variances of the parameter and resultantly less efficient estimates. Apart from that, there is serious endogeneity and reverse causality in productivity and FDI nexus because FDI is more inclined towards highly productive countries. Also, FDI accelerates domestic investment and infrastructure improvement that creates positive externalities for productivity growth.

To address endogeneity issues and possible biases that arise from artificial or *ad hoc* threshold, we employ the Dynamic Panel Threshold Model (DPTM) introduced by Kremer et al. (2013). It applies panel settings to Caner and Hansen (2004)'s instrumental variable and cross sectional model and can deal efficiently with possible endogeneity and reverse causality. Unlike the static or traditional panel threshold model, which assumes threshold as a purely exogenous variable, DPTM considers threshold as endogenous and produces a robust estimate using a two step generalized method of moments (GMM). The detailed derivation of DPTM can be found in the seminal paper of Kremer et al. (2013). To empirical test the threshold effect of the technology gap, the following equation is formed:

$$TFP_{it} = u_{it} + \delta TFP_{it-1} + a_1 S_{it}^{FDI}\, I(Gap_{it} \leq \gamma) + a_2 S_{it}^{FDI} I(Gap_{it} > \gamma) + a_3 BRI_{it} + a_4 S_{it}^{D} + a_5 REG_{it} + a_6 INF_{it} + a_7 S_{it}^{Exp} + \varepsilon_{ii} \quad (7)$$

Where i (i=1, 2, … n) and t (t=1, 2, … T) denotes the country and time respectively, *TFP* represents total factor productivity (explained variable derived through Malmquist productivity index), TFP_{it-1} shows lagged TFP, S^F *is* the stock of R&D capital gained from Chinese outward FDI, Gap specifies different attributes (observed and expected) of technology gap between China and BRI host countries as threshold variable. I(.) is an indicator function that takes 1 if the value of the threshold variable *Gap* is below a certain value of γ and takes 0 otherwise, α1 and α2 denote the degree of impact of S^{FDI} on TFP for the case of $Gap_{it} \leq \gamma$ and $Gap_{it} > \gamma$, μi denotes country specific effect and ε_{ii} represents error term which is independently and identically distributed (0,σ2). *BRI*, S^D, *REG, INF*, S^{EXP} represent BRI year dummy (equal 1 after 2013 and zero otherwise), domestic research intensity (DRI), infrastructure development index, and export oriented technology spillovers. As per equation 2, TFP is the function of domestic and foreign knowledge stock. In equation 7, S^{FDI} represents foreign stock, while S^D is domestic knowledge stock. (See below for detailed construction and definition of variables.)

4.2 Sample and Variables Description

China ranked second in FDI stocks spread over 180 countries, accounting for 81 percent of the entire world (UNCTAD, 2018). Since the inception of BRI in 2013, the pace of Chinese outward FDI increased 30 percent along the route which runs through Eurasia, connecting the Asia Pacific and the western European economies, comprising over 65 nations, which occupied 39 percent of the worldwide land area, representing 30 percent of global GDP, 35 percent of international trade, and 64 percent of the worldwide population (Razzaq et al. 2021; Du and Zhang 2018). Apart from that, China is also a leading economy of the CAREC region and a major source of FDI in other CAREC countries owing to geographic links. Most of the developing BRI countries—especially CAREC countries—are relatively underdeveloped, and China as an emerging CAREC country might have the technical capacity to produce technology spillovers for host countries. Also, these countries are lagging behind in terms of technology, human resources, and infrastructure. In doing so, we chose 46 developing BRI host economies that also include all CAREC countries and analyses annual data from 2004 to 2019. We chose a relatively broader sample because the threshold model required a larger number of heterogenous countries to efficiently estimate threshold of technology gap in realizing FDI induced technology spillovers. Moreover, we compare the thresholds of BRI and CAREC region to highlight the CAREC country dynamics. A summary of variables is given in Table 2, while a list of sample countries is added in Appendix A2.

4.2.1 Total Factor Productivity

Total factor productivity is estimated using the Malmquist productivity index (MI). MI index is estimated through a 'non-parametric data envelopment analysis' where the real gross domestic product is taken as output in L-P model, while gross fixed capital stock and employed labor force at year end are taken as input sourced from world development indicators and Penn World Table 9. Moreover, we used the perpetual inventory method (PIM) to estimate capital stocks as per the following formula:

$$K_{it} = I_{it} + K_{it\text{-}1}\,(1-\delta) \quad (8)$$

where K_{it} and $K_{it\text{-}1}$ denotes capital stock in the current year (t) and lag year (t-1) in country i, I_{it} shows new fixed capital formation (constant US dollars) in country i and time t, and δ is depreciation percentage (10.96 percent) following Dong and Liang (2013). For calculation of base year capital stock K_{i0}, we apply a procedure defined by Hall and Jones (1999).

$$S_{t2003} = \frac{S^{f}_{t,2003}}{\delta+g} \quad (9)$$

g represents the average annual growth rate from 2003 to 2019

Figure 5 draws the estimated values of total factor productivity as of 2019, representing significant variations across the BRI sample. Notably, Iran, Lebanon, Bahrain, Oman, Saudi Arabia, Yemen, Kuwait, Qatar, and Syria are the bottom ten countries in terms of TFP, while Kazakhstan, Armenia, Tajikistan, Mongolia, Bangladesh, Myanmar, Georgia, India, Vietnam, and Commodian are the top ten countries.

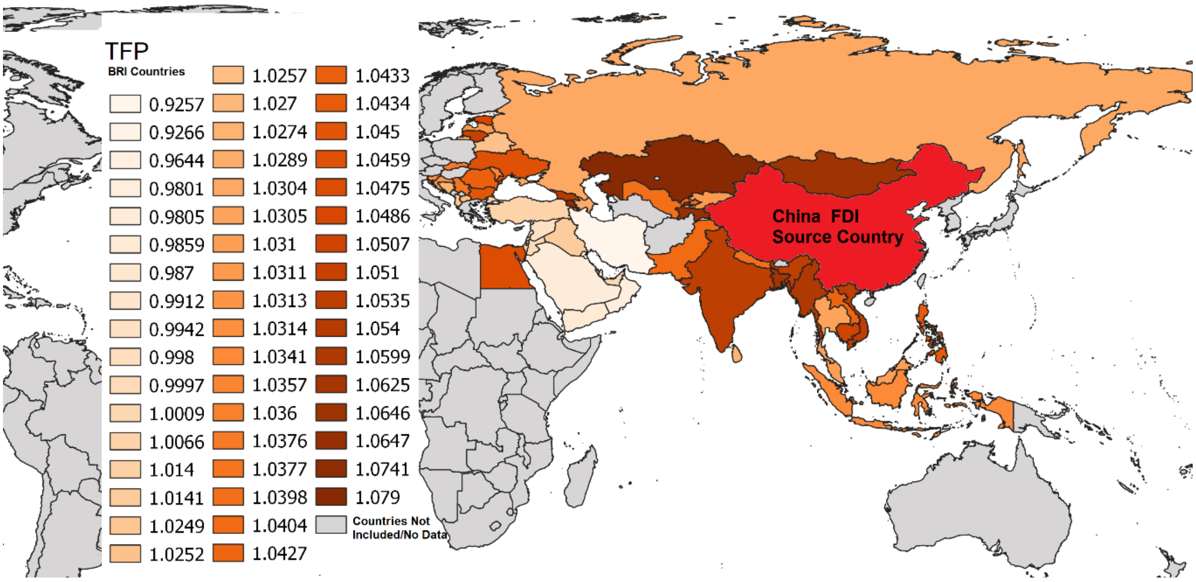


Figure 5: Spatial Distribution of Total Factor Productivity

Source: Authors' estimation and drawing using QGIS Mapping Desktop (version 3.14)

4.2.2 Foreign R&D Capital Stock (Technology Spillovers Through FDI and Exports)

Following equation 2, foreign R&D capital stock can be transferred through two important channels. First through foreign direct investment and second through exports from technologically advanced countries to relatively underdeveloped countries. This report mainly focuses on FDI induced technology spillovers, which are considered a prime source of technology transfer. The FDI induced capacity of technology spillovers is measured based on source country (China) knowledge stock. So, the L-P model comprises the following specification:

$$S_{it}^{FDI} = \frac{FDI_{it}}{K_{China,\,t}} S_t^f \quad (10)$$

Where S^{FDI} is the stock of R&D capital gained from Chinese outward FDI, FDI is stock of Chinese outward FDI in constant dollars, $K_{China,t}$ is Chinese total fixed capital formation in constant dollars, S_t^f is China's domestic R&D stock in constant dollars, i is country and t represents time. The data of China's domestic R&D is extracted from the China Statistical Yearbook. $R_{China,t}$ stock variable is generated using perpetual inventory method using 10.96 percent rate of depreciation (Dong and Liang 2013).

$$S_t^f = R\&D_t + S_{t-1}^f\,(1-\delta) \quad (11)$$

where S_t^f represents R&D capital stock, and δ is depreciation rate as per equation 9. $R\&D_t$ is the capital input in terms of R&D in China in year t. For estimating R&D capital stock, we use a similar procedure as explained in equation 10. Figure 6 illustrates Chinese OFDI stock 2019 across BRI host countries, signifying that Singapore, Indonesia, Russia, Lao PRD, Malaysia, United Arab Emirates, Kazakhstan, Thailand, Vietnam, and Cambodia are the top ten destinations of Chinese investment, accounting for 74 percent of total stocks.

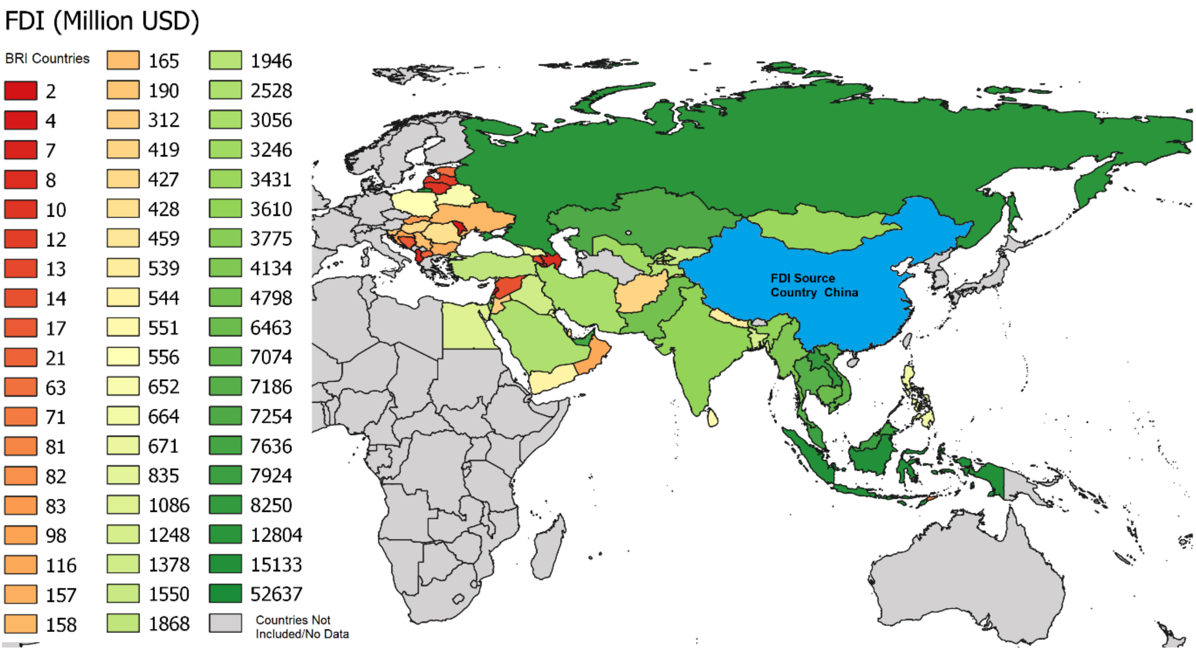


Figure 6: Spatial Distribution of China's Outward FDI Stocks
Source: Authors' drawing from MOFCOM (2019) dataset using QGIS Mapping Desktop (version 3.14)

From the overall BRI sample, the CAREC countries embraced USD23.32 billion inward FDI from China in less than two decades. The sectoral distribution of FDI is very distinct in the CAREC region. Most of the investment and construction is attributed to the energy and transport sectors (see Appendix A2 for a list of FDI projects in the CAREC region). Figure 7 indicates the sectoral distribution of Chinese FDI across industries in the CAREC region, suggesting that FDI stocks significantly increase after BRI in contrast to before BRI, despite the fact that the pre-BRI time period is greater than post-BRI.

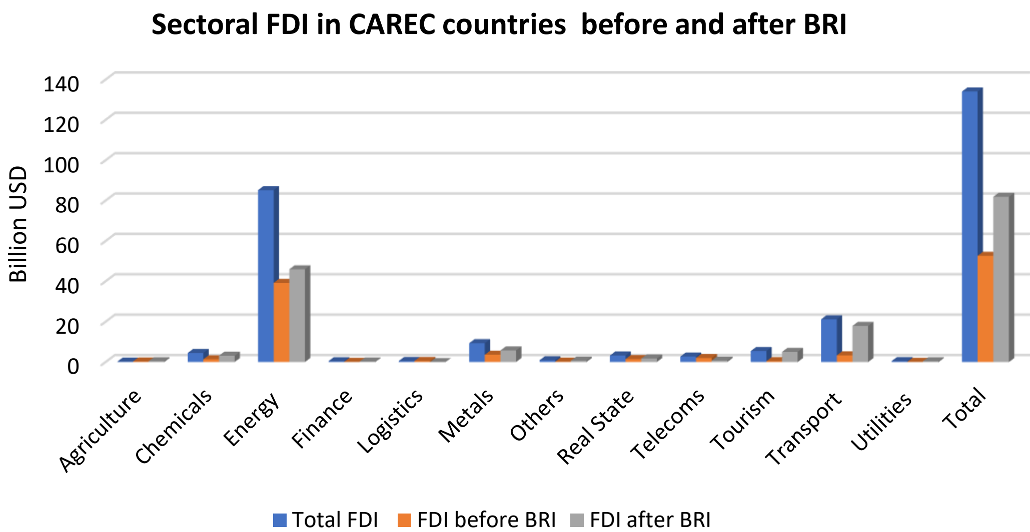
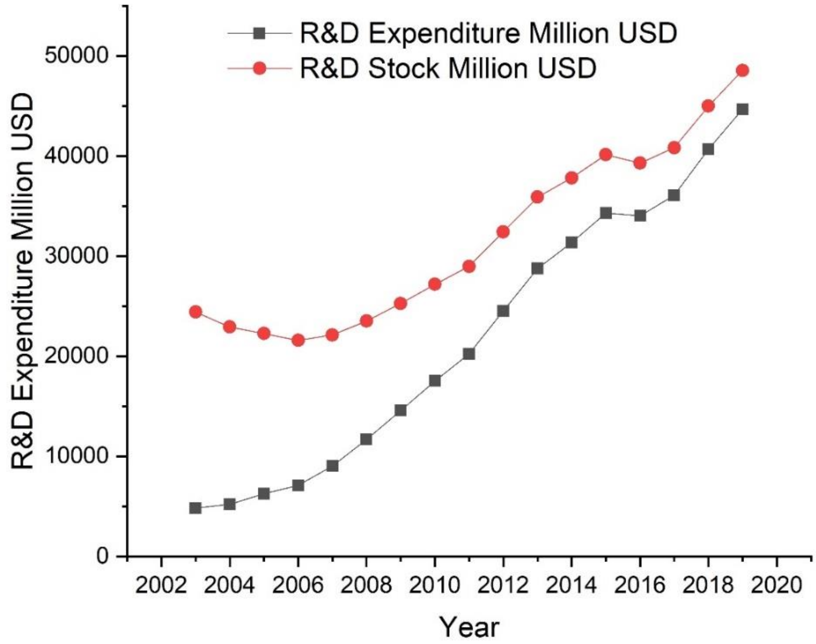


Figure 7: Sectoral Distribution of Chinese Outward FDI in the CAREC Region

On the other hand, Figure 8 shows exponential growth in R&D annual expenditure and stocks in China, indicating a higher potential for transmission or dissemination of Chinese knowledge spillovers to other countries through investment and trade.



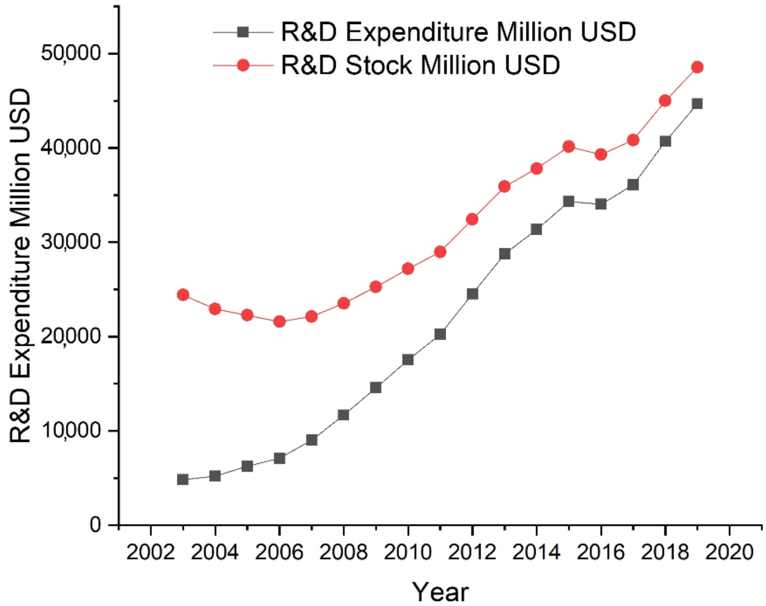


Figure 8: China's Domestic R&D Expenditure and Stocks (Million USD)
Source: Authors' drawing using Origin software from China Statistical Yearbook 2019

The second important channel of international technology spillovers is exports as per L-P model (Bai et al., 2017). Although we have focused on the FDI channel, controlling trade oriented productivity gain is also important for reliable estimates. Similar to equation 11, the R&D capital stock S_{it}^{Exp} for the BRI economies included R&D capital stock, which is carried by Chinese exports as a contagion disease expressed as follows:

$$S_{it}^{Exp} = \frac{Exp_{it}}{Y_{China,\,t}} S_t^f \quad (12)$$

Where S^{Exp} is the stock of R&D capital gained from Chinese exports to BRI host countries, Exp is Chinese exports to BRI host countries (constant USD 2010), $Y_{China,t}$ is Chinese GDP (constant USD 2010) in period t, S_t^f is China's domestic R&D stock in the constant dollar. Figure 9 visualizes total exports from China to BRI host countries, showing that India, Russia, Thailand, Singapore, Indonesia, and Malaysia are the top export markets.

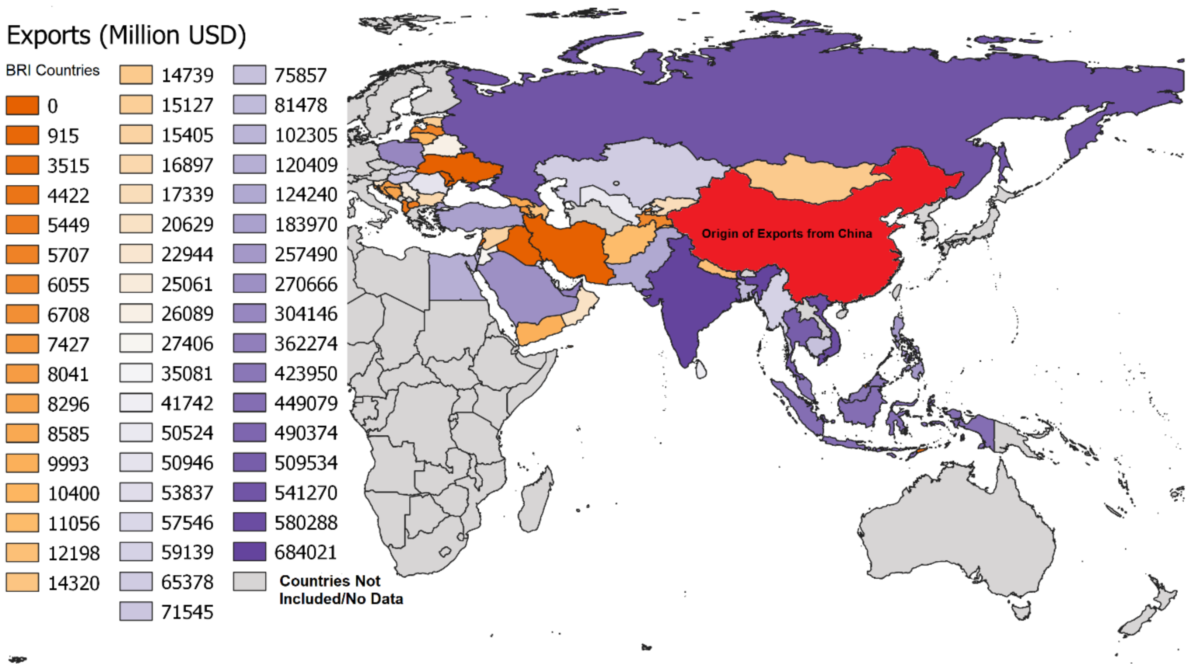


Figure 9: Spatial Distribution of China's Total Exports

Source: Authors' drawing from UNCTAD (2019) dataset using QGIS Mapping Desktop (version 3.14)

Zooming out of the above map and integrating time trends, Figure 10 reveals that the goods flow from China to the CAREC countries steadily increases over time, particularly after 2016, except for Pakistan, which shows a declining trend after 2017. However, the highest growth rate is observed in Pakistan from 2013 to 2017, where exports increased from USD6,626 million to USD15,404 million. Overall, Chinese trade flows increased in the CAREC region, highlighting possible spillovers through traded goods.

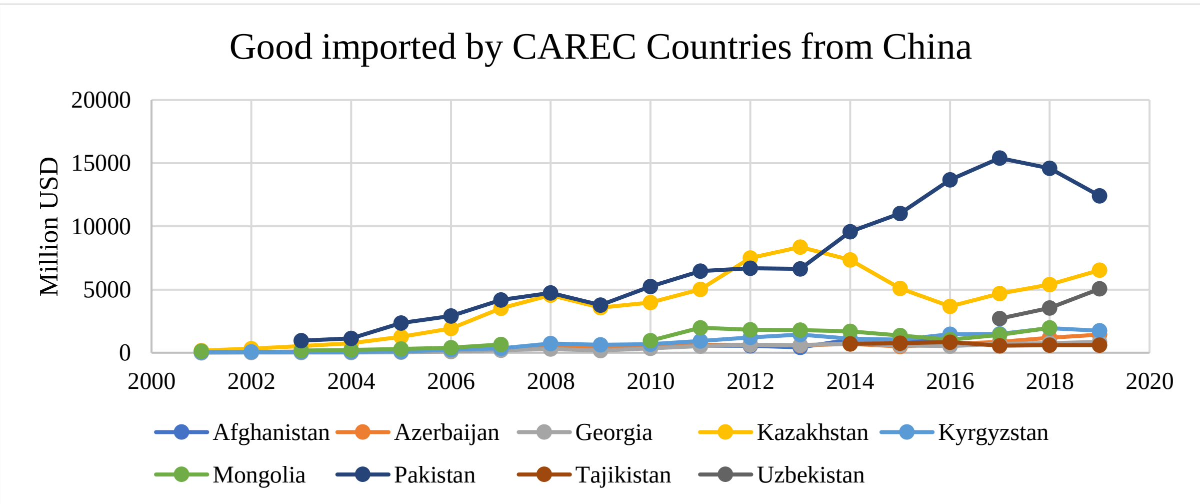


Figure 10: China's Exports to the CAREC Countries

4.2.3 Technology Gap

The technology gap has two different types, which may have differing impacts on productivity spillovers owing to their distinct natures. First, OTG is the observed differences in learning abilities such as managerial skills, technology, and knowledge between advanced (FDI source) and underdeveloped (FDI host) countries. It simply shows the objective distance between source and host economies in terms of technological efficiency, managerial capabilities, technical level, or knowledge. OTG offers 'learning space' for ladders (followers); however, it is unable to explicate whether, how, and when the ladders will eventually catch up with the leaders (Findlay, 1978). In particular, if OTG is too narrow, there is a limited learning space that is insufficient to instigate technical development in local firms. The formula of OTG_{it} is as follows:

$$OTG_{it} = \frac{\frac{Y_t}{Emp_t}}{\frac{Y_{it}}{Emp_{it}}} \quad (13)$$

OTG_{it} is the ratio of labor productivity (LP) in China and BRI host countries, which is estimated by dividing real output (Y) by total employed labor force (Emp). For robustness, OTG is also constructed using real per capita income ratio between China and BRI host countries (see Table 2).

The second type of technology gap is ETG, which measures a firm's capabilities of acquiring leading edge skills and technologies from overseas enterprises. Notably, enterprises with a lower ETG are better at learning and imitating, and have a stronger motivation to catch up with leading firms (Kokko et al., 1996). The expression of ETG is as follows:

$$ETG_{it} = \frac{\frac{Fix_t}{Emp_t}}{\frac{Fix_{it}}{Emp_{it}}} \quad (14)$$

where Fix_{it} and Emp_{it} signify fixed capital stock and annual employment of sample countries *i* in year t, while Fix_t and Emp_t represent fixed capital stock and employment in China. For robustness, ETG is also constructed using a ratio of human capital index China and BRI host countries using similar expression (see Table 1).

4.2.4 Domestic R&D Capital Stock (Intensity)

R&D intensity shows the domestic R&D levels in host countries. As per equation 2, FDI induced technology spillovers are largely dependent upon the knowledge stock of the host countries measured in terms of R&D capital. However, most of the CAREC and BRI host countries have no data on public/private R&D stocks; therefore, we have taken an alternative measure, 'domestic research intensity' (DRI) to control the effect of domestic research capabilities. This measure is superior to R&D, which is an input of knowledge stock, while DRI measured in terms of patents per worker represents the output of knowledge stock (Farhadi, 2015). However, as technology evolves, the research advantages and the economic and societal benefits provided by older technologies are diminishing. Aging technologies will be gradually phased out in favor of new ones. Therefore, we have adjusted domestic technology decay and depreciation effects (Popp, 2002; Lin and Zhu, 2019) and formed the following specification:

$$DPAT_{i,t} = \sum_{s=0}^{t} e^{\beta_1(t-s)} \left(1 - e^{\beta_1(t-s)}\right) PAT_{i,\,t} \quad (15)$$

where PAT represents the number of registered resident patents of BRI host countries. Following Popp 2002, β1 and β2 designate the decay rate and diffusion effects by taking values equal to 0.36 and 0.03, respectively. For adjusted domestic R&D intensity, DPAT index is divided by the employed labor force to derive per labor research intensity as follows:

$$S_{it}^{D} = \frac{DPAT_{it}}{Emp_{it}} \quad (16)$$

Where S_{it}^{D} represent domestic R&D intensity (knowledge stock) in host country *i* in year *t,* While DPAT is decay and diffusion adjusted patents index, and Emp is employed labor force at the end of the year.

4.2.5 Control Variables

When estimating empirical models, it is imperative to control other important factors such as institutional governance and domestic infrastructure quality. First, institutions play an essential role in determining the relevance of any economic variable. A better regulation encourages industrial output and growth. There are two aspects of governance: overall political governance and business related regulations or governance. Both are highly collinear (>0.75) and are used interchangeably. By considering the MNC FDI and productivity nexus, business regulations are more pragmatic to accelerate the growth of productivity in domestic firms. Therefore, the ease of doing business index as a proxy of regulations (REG) is employed that measures the degree of economic freedom present in five major areas: [1] size of government; [2] legal system and security of property rights; [3] sound money; [4] freedom to trade internationally; [5] regulation scaled from 0 to 10. A high ease of doing business ranking means the regulatory environment is more conducive to the starting and operation of local firms (Nguyen, 2016).

Moreover, the endogenous growth theory postulates that productivity growth is also based on infrastructure levels of host countries as it stimulates business opportunities, promotes market competition, and helps to drive innovation (Arif, Javid, and Khan, 2021). Thus, we have included a cumulative infrastructure quality index (INF) as a control variable, representing the transport, ICT, energy, and financial infrastructure. It contains several subindicators of infrastructure quality following Donaubauer et al. (2016). The detailed description, acronyms, definition, and sources of all variables are shown in Table 2.

Table 2: Detailed Description of Variables

Variables	Proxy	Status	Detail	Source
TFP	Total factor productivity change	Dependent variable	Malmquist Index through data envelopment analysis (used real capital stock, and labor as input while economic growth as output)	Penn World Table (PWT) 9[7], and world development indicators (WDI)[8]
S^F	Spillovers of Chinese FDI	Regime dependent variable	OFDI embodied foreign R&D capital stock from China	Calculated through L-P model using data from WDI, Annual Statistical Bulletin of China,[9] and National Bureau of Statistics of China (CSY)[10]
OTG	Observed technology gap	Threshed variables	Labor productivity differences between China and BRI host countries	PWT9 and WDI
ETG	Expected technology gap		Differences in capital employed to labor employed between BRI host countries and China	PWT9 and WDI

Variables	Proxy	Status	Detail	Source
OTG1	Observed technology gap (alternative proxy)		Differences in real per capita income (USD constant 2010) between BRI host countries and China	PWT9 and WDI
ETG1	Observed technology gap (alternative proxy)		Differences in human capital (average year of schooling and rate of return on education) between BRI host countries and China	PWT9 and WDI
BRI	Belt and Road Policy	Dummy variable	BRI Policy is a dummy variable, which equals to one after year 2013 and zero otherwise	Liu et al. (2017)
SD	Domestic R&D (knowledge) intensity	Control variables	Number of patents per labor adjusted with decay and depreciation effects	PWT 9, CSY, and WDI
Reg	Business regulations		Average index of 5 dimensions; government size, trade freedom, legal system and security of property rights, regulations, and sound money. Scaled 0-10 (lower-higher)	Fraser Institute[11]
INF	Cumulative index of domestic infrastructure quality		Cumulative weighted index of telecommunication, transport, energy, and financial infrastructure indexes Scaled -1.0 to +2.0 (lower-higher)	Donaubauer et al. (2016)
S^F	Spillovers of Chinese exports		Export embodied foreign R&D	Calculated through L-P model using data from WDI and CSY

5. Results and Discussion

5.1 Descriptive Statistics

Table 3 reports descriptive statistics of the developing BRI and CAREC regions. The range of productivity growth in the developing BRI region shows a relatively higher spread from 0.266 to 1.834 compared to the CAREC region, from 0.384 to 1.203. Similarly, the average observed and expected technology gap in the BRI region is 2.802 and 2.707. In contrast, the CAREC region shows relatively higher values of 3.106 and 3.285, suggesting a higher technology backlog in CAREC countries than their counterparts. Alternative proxies of observed and expected technology (OTG1 and ETG1) echoed similar phenomena. The FDI spillover term shows a relatively higher mean value in the CAREC sample compared to the overall developing BRI sample. The average FDI stock in CAREC countries is USD1,288 million, which is significantly higher than the overall developing BRI sample. It is noteworthy that the average DRI is 1.354 in the CAREC region, which is almost half of the overall BRI sample—namely 2.558. Similarly, the CAREC region is lagging behind in terms of cumulative infrastructure ranging from -1.265 to -0.069 as compared to the overall BRI score ranging from -1.264 to 1.643. This index is scaled from lowest to highest score (negative to positive). An average score of CAREC countries is negative at -0.593, which indicates a weaker infrastructure in terms of quality and quantity. The mean value of business regulations is slightly higher in the CAREC region than the overall BRI sample. The regulation index is scaled between 0 to 10, suggesting worst to best business regulations in different dimensions (see Table 2 for details).

Table 3: Descriptive Statistics

Variable	Mean		Standard Development		Minimum		Maximum	
	Full Sample	CAREC	Full Sample	CAREC	Full Sample	CAREC	Full Sample	CAREC
TFP	1.011	1.0224	0.112	0.115	0.266	0.3841	1.834	1.2031
OTG	2.802	3.106	0.641	0.446	2.038	2.285	6.964	3.872
ETG	2.707	3.285	2.729	2.774	0.001	0.077	9.516	8.893
OTG1	2.951	3.432	10.125	2.323	0.037	0.371	142.299	7.693
ETG1	1.724	2.174	0.782	0.966	0.99	1.17	3.566	3.566
S^{FDI}	-0.993	0.333	2.937	1.932	-10.204	-4.045	4.031	3.296
S^{D}	2.558	1.354	3.149	2.461	-6.278	-4.09	8.227	6.076
INF	-0.176	-0.593	0.655	0.226	-1.264	-1.265	1.643	-0.069
Reg	6.598	6.647	0.698	0.691	3.826	5.677	8.269	8.269
S^{Exp}	4.078	2.942	2.599	2.657	-9.384	-4.937	8.024	6.426
FDI*	974.929	1288.2	1986.41	1811.2	0.008	2.4	14261.2	7070.3

*Gross values of real stock of Chinese outward FDI in host countries. Number of observations: 728 for full sample and 128 for CAREC

Moreover, Appendix A3 and A4 include regional as well as countrywise mean, median, and interquartile range (IQR) to provide detailed insights of the variables. The countrywise averages (A4) indicate that Azerbaijan has the highest TFP (1.049), followed by Kazakhstan (1.043), and Georgia (1.037), while Pakistan (1.003), Kyrgyzstan (1.005), Tajikistan (1.012), and Uzbekistan (1.012) show moderate TFP. Similarly, the highest OTG is observed in Kyrgyzstan (3.610), followed by Mongolia (3.588), and Tajikistan (3.345), confirming the highest potential of possible technology transfers in these countries. In contrast, the lowest ETG values are observed in Azerbaijan (0.385), Georgia (0.435), and Tajikistan (0.486), indicating a higher technology imitation rate; however, Mongolia (7.987) and Uzbekistan (6.690) possess the highest ETG, which narrowed the FDI induced productivity spillovers. Also, the other variables show significant heterogeneity within or across the CAREC region. The average score will be discussed in the subsequent section with respect to the estimated threshold and coefficients.

5.2 Results of Dynamic Panel Threshold Model

Table 4 reports the threshold values and confidence intervals of OTG and ETG and confirms that the threshold effects of both variables are statistically significant. The estimated threshold of OTG is 2.680, while ETG is relatively higher at 4.336. It is reiterated that these thresholds test the conditional hypothesis, which indicates how FDI induced technology spillovers vary at different levels of technology gap. Overall, the results confirm that technology gap stimulates technology (productivity) spillovers (gain) from FDI; however, these effects are conditional on the prevailing gap. Table 5 shows the outcome of the dynamic panel threshold model and provides the following key findings.

1. The outcome of Model 1 indicates that FDI induced technology spillovers are weakly negative if OTG is less than threshold 2.680; however, these effects turn positive if OTG is higher than 2.680. These results imply that, for a positive technology spillover, FDI receiving countries (CAREC or other BRI host countries) should be lagging twice in terms of OTG compared with FDI source country (China). The coefficient of S^F indicates that OTG less than the threshold (2.680) leads to weakly negative spillovers by 0.0147 percent, while OTG greater than the threshold (2.680) leads to significant positive spillovers by 0.0359 percent.

2. In contrast, the findings of Model 2 report that FDI induced technology spillovers are only positive when ETG is less than the threshold value of 4.336. If ETG increases beyond the threshold value the FDI induced technology spillovers are neutralized, implying that a relatively lower ETG helps to embrace higher technology spillovers. The estimated coefficients of S^F display significant positive spillovers by 0.0438 percent when ETG is less than the threshold. However, insignificant negative spillovers are found if ETG is higher than threshold values.

3. Figure 11 visualizes the conditional impact of OTG on TFP, indicating positive spillovers if OTG is higher than the threshold and vice versa. Notably, the average OTG in BRI is 2.803 and 3.106 in CAREC countries. Both are higher than the threshold value of 2.680, suggesting the opportunity of positive spillovers in both sample countries. Figure 10 shows that countries with lower OTG do not have enough learning space, thus producing lower or no productivity spillovers; however, a reasonable technology gap (2.680) is imperative to embrace positive spillovers from FDI.

4. Figure 12 shows that FDI spillovers are conditional on the ETG threshold, where a lower threshold leads to positive spillovers and vice versa. It is worth mentioning that the average ETG in BRI developing countries is 2.707 and 3.285 in CAREC countries, which are less than the ETG threshold value 4.336. These results imply that the expected technology gap in overall BRI sample countries and the CAREC region is not too wide to produce negative or no spillovers—rather, it is within the threshold limit, under which FDI induced technology spillovers are positive. However, there is significant heterogeneity among CAREC countries. Mainly, ETG in Mongolia and Uzbekistan is too wide (7.987 and 6.690) and higher than the threshold value, after which the possible spillovers from FDI are either neutralized or less pronounced. Fext

5. Overall, the findings suggest that enterprises with a lower ETG are better at absorbing the advanced technology from downstream and upstream firms when faced with a higher OTG. A lower ETG channelizes optimal benefits from the prevailing OTG. For example, industries with lower knowledge, managerial and labor skills, and weak technological levels may hinder output capacity and efficiency; however, they may attract more foreign investment to fill the potential gap and, in the meantime, if firms are embodied with basic capital infrastructure and human capital then firms embrace relatively higher technology spillovers.

6. As per endogenous growth theory, FDI induced technology spillovers are not only dependent upon foreign knowledge stock but also contingent on domestic knowledge stocks. Therefore, both models included DRI measures as S^D and exhibit a weak but significant positive relationship, suggesting that a 1 percent increase in domestic research capacity leads to an increase in TFP by 0.0028 percent and 0.0043 percent in Model 1 and Model 2, respectively. The lower coefficient magnitude of S^D may attribute to our adjustment of decay and depreciation effect of domestic technologies. A large extent of literature does not make this adjustment. They may overestimate the impact of technologies against the fact that technologies are obsoleting quickly and new technologies take time to generate positive spillovers.

7. Ease of doing business/business regulations (REG) improved TFP by 0.0312% in Model 1; however, in Model 2, REG produces a positive but insignificant effect. These results imply that ease of doing business operations facilitate higher productivity growth.

8. The infrastructure quality index (INF) significantly improves TFP by 0.0737 percent and 0.221 percent in Model 1 and 2, respectively. The coefficient magnitude of cumulative infrastructure index is greater than FDI induced technology spillovers, DRI, and business regulations, confirming the importance of infrastructure quality in realizing higher productivity growth.

9. Export induced technology spillover (S^{EXP}) is added to control possible spillovers through the trade channel. The coefficient of S^{EXP} is although negative but produces a weaker impact. The results indicate that trade from China to BRI and CAREC countries reduces TFP by 0.006 percent and 0.0104 percent in both models. These outcomes attribute to the crowding out effect, where Chinese goods may replace domestic production or they do not have enough absorption capacity to imitate embodied technology from imported goods. Also, the nature of exported goods is another factor, which needs to dig down to unveil these impacts.

10. To ensure the validity of GMM estimates, Table 5 reports the test statistics and probability values of the Sargan test, which confirms that the model is perfectly specified and the utilized instruments are valid. Notably, P values of the Sargan test are higher than 0.05, therefore accepting the null hypothesis 'instruments are valid and there is no over-identification problem.' Moreover, P values of AR-2 test accept the null hypothesis 'no second order autocorrelation.' These tests endorse the reliability of model parameters.

11. The dynamic trend is confirmed from the statistically significant and positive coefficient of the lag dependent variable (TFP_{t-1}), which implies that changes in current TFP are also reliant on its own past realization. These findings also endorse the rationality of using the dynamic model.

Table 4: Results of Threshold Effects (Without BRI Policy)

Model Description	Threshold	Estimated Value	90 Percent Confidence Interval
Model 1 (OTG)	θ_1	2.680	2.49151, 2.8147
Model 2 (ETG)	θ_1	4.336	2.05535, 7.1649

Table 5: Results of Dynamic Panel Threshold Model (Without BRI Effect)

Description	Model 1	Description	Model 2
TFP_{t-1}	0.2596***	TFP_{t-1}	0.2557***
	(0.0307)		(0.0245)
S^{FDI}	-0.0147**	S^{FDI}	0.0438**
(OTG≤2.680)	(0.0051)	(ETG≤4.336)	(0.0051)
S^{FDI}	0.0359***	S^{FDI}	-0.0010
(OTG>2.680)	(0.0061)	(ETG>4.336)	(0.0020)
S^{D}	0.0028***	S^{D}	0.0043***
	(0.0009)		(0.0008)
REG	0.0312**	REG	0.0216
	(0.0142)		(0.0172)
INF	0.0737*	INF	0.2221**
	(0.0428)		(0.0517)

Description	Model 1	Description	Model 2
S^{EXP}	-0.0067** (0.0028)	S^{EXP}	-0.0104** (0.0028)
Constant	0.5606*** (0.1225)	Constant	0.6860*** (0.1342)
No. of Countries	46	No. of Countries	46
Arellano Bond Test AR(1)	-3.9387	AR (1)	-4.0517
P-Value	0.0001	P-Value	0.0001
Arellano Bond Test AR(2)	-0.5966	AR (2)	-0.5553
P-Value	0.5507	P-Value	0.5787
Sargan Test	31.266	Sargan Test	35.872
P-Value	0.5035	P-Value	0.293

*,**,*** represent significance level at 10 percent, 5 percent, and 1 percent respectively
Note: No external instruments were used in this analysis

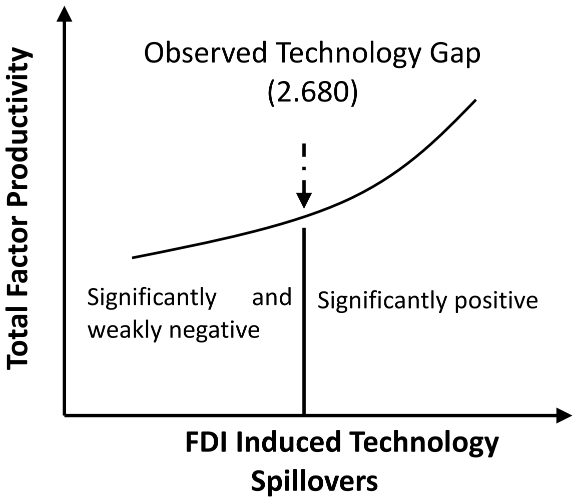


Figure 11: Illustrative Representation of the Threshold Impacts of OTG on TFP
(The figure is drawn without any scale)

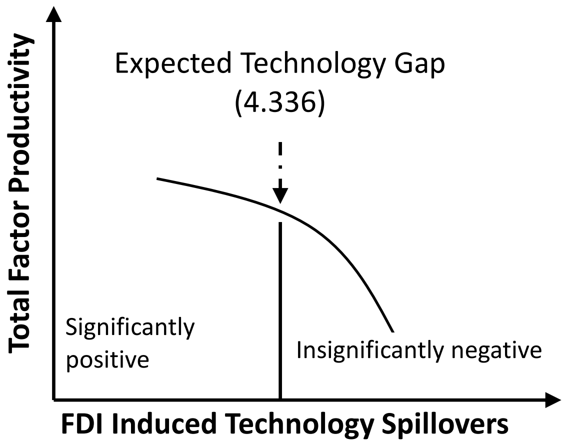


Figure 12: Illustrative Representation of the Threshold Impacts of ETG on TFP
(The figure is drawn without any scale)

The BRI project was unveiled in September and October 2013, after which the movement of Chinese OFDI flow increased exponentially across BRI host countries, which may also affect the productivity growth. Therefore, Table 6 and Table 7 incorporate the BRI policy dummy to capture the BRI policy effect. The results of threshold variables and other regressors are consistent with former estimations and the BRI policy dummy is statistically significant and positive, indicating that the BRI policy produces a positive impact on TFP.

Table 6: Threshold Results (With BRI Policy)

Model Description	Threshold	Estimated Value	90 Percent Confidence Interval
Model 1 (OTG)	θ_1	2.6804	2.49151, 2.8147
Model 2 (ETG)	θ_1	4.3818	2.01878, 7.1644

Table 7: Results of Dynamic Panel Threshold Model (With BRI Policy)

Description	Model 1	Description	Model 2
TFP_{t-1}	0.2353***	TFP_{t-1}	0.2363***
	(0.0317)		(0.0264)
S^{FDI}	-0.0208***	S^{FDI}	0.0603***
(OTG≤2.680)	(0.0056)	(ETG≤4.3818)	(0.0066)
S^{FDI}	0.0329***	S^{FDI}	-0.0091***
(OTG>2.680)	(0.0062)	(ETG>4.3818)	(0.0018)
BRI Policy	0.0093**	BRI Policy	0.0170**
	(0.0032)		(0.0066)
S^{D}	0.0022**	S^{D}	0.0048***
	(0.0008)		(0.0008)
REG	0.0296**	REG	0.0353*
	(0.0129)		(0.0176)
INF	0.0571	INF	0.2060**
	(0.0441)		(0.0613)
S^{EXP}	-0.0041	S^{EXP}	-0.0119***
	(0.0029)		(0.0027)
Constant	0.5748***	Constant	0.6158***
	(0.1143)		(0.1331)
No. of Countries	46	No. of Countries	46
Arellano Bond Test AR(1)	-4.0204	AR (1)	-3.6727
P-Value	0.0001	P-Value	0.0002
Arellano Bond Test AR(2)	-0.7360	AR (2)	-0.3095
P-Value	0.4617	P-Value	0.7569
Sargan Test	30.4172	Sargan Test	35.1284
P-Value	0.4958	P-Value	0.2787

Although BRI policy was implemented in late 2013, the complete possible benefits would take at least a couple of years, if not more, to see the impact of BRI on various sectors (and other macro and micro level indicators) of its member countries. In economics, we often see a delay between an economic action and a consequence. This is known as a time lag, and we incorporate the same in Tables 8 to 9 and Tables 10 to 11, where one and two year lags of FDI induced technology spillovers are taken and found to have a similar outcome. The direction of variables remains the same; however, magnitude and statistical significance marginally varied. The results imply that FDI induced technology spillovers improve current productivity and affect future productivity growth owing to certain lags.

Table 8: Results of Models Threshold (One Year Lag of FDI Spillovers)

Model Description	Threshold	Estimated Value	90 Percent Confidence Interval
Model 1 (OTG)	θ_1	2.6245	2.4854,2.8147
Model 2 (ETG)	θ_1	4.0480	2.03407,7.5821

Table 9: Results of Dynamic Panel Threshold Model (One Year Lag of FDI Spillovers)

Description	Model 1	Description	Model 2
TFP_{t-1}	0.146***	TFP_{t-1}	0.240***
	0.025		0.022
L1. S^{FDI}	-0.013***	L1.S^{FDI}	0.049***
(OTG≤2.680)	0.002	(ETG≤4.0480)	0.005
L1. S^{FDI}	0.017***	L1. S^{FDI}	-0.008***
(OTG>2.680)	0.003	(ETG>0480)	0.002
S^{D}	0.001	S^{D}	0.001*
	0.000		0.001
REG	0.029***	REG	0.012*
	0.006		0.015
INF	0.165***	INF	0.176***
	0.025		0.036
S^{EXP}	0.000	S^{EXP}	-0.006**
	0.001		0.003
Constant	0.707***	Constant	0.740***
	0.058		0.105
No. of Countries	46	No. of Countries	46
Arellano Bond Test AR(1)	-3.4846	AR (1)	-3.8004
P-Value	0.0005	P-Value	0.0001
Arellano Bond Test AR(2)	-1.620	AR (2)	-1.1544
P-Value	0.1052	P-Value	0.2483
Sargan Test	35.3421	Sargan Test	37.334
P-Value	0.7903	P-Value	0.2372

Table 10: Threshold Results (Two Year Lag of FDI Spillovers)

Model Description	Threshold	Estimated Value	90 Percent Confidence Interval
Model 1 (OTG)	θ_1	2.6245	2.20207,2.8653
Model 2 (ETG)	θ_1	4.0480	2.03407,7.5821

Table 11: Results of Dynamic Panel Threshold Model (Two Year Lag of FDI Spillovers)

Description	Model 1	Description	Model 2
TFP_{t-1}	0.206***	TFP_{t-1}	0.280***
	0.014		0.022
L2. S^{FDI}	-0.007***	L2.S^{FDI}	0.056***
(OTG≤2.6245)	0.002	(ETG≤4.0480)	0.010
L2. S^{FDI}	0.005*	L2.S^{FDI}	-0.010***
(OTG>2.66245)	0.003	(ETG>4.0480)	0.002
S^{D}	0.001	S^{D}	0.000
	0.000		0.001
REG	0.049***	REG	0.025*
	0.006		0.013
INF	0.208***	INF	0.189***
	0.027		0.058
S^{EXP}	0.000	S^{EXP}	0.001
	0.002		0.002
Constant	0.521***	Constant	0.571***
	0.047		0.098
No. of Countries	46	No. of Countries	46
Arellano Bond Test AR(1)	-3.9856	AR (1)	-3.7389
P-Value	0.0001	P-Value	0.0002
Arellano Bond Test AR(2)	-1.2564	AR (2)	-0.72961
P-Value	0.2090	P-Value	0.4656
Sargan Test	35.4809	Sargan Test	32.1104
P-Value	0.7511	P-Value	0.4114

5.3 Robustness Regressions

To ensure the robustness of variables, we have adopted various options. First, in order to isolate the BRI pre- and post-policy impacts, we have divided our sample into two time spans. From 2004 to 2013 as the pre-BRI period, and from 2014 to 2019 as the post-BRI period. Second, we use alternative measures of OTG1 and ETG1 to ensure the consistency of estimates.

5.3.1 Pre- and Post-BRI Period

Table 12 reports the estimated threshold values in the post-BRI sample. Unlike previous estimations, the OTG threshold level increased from 2.68 to 3.51, and the ETG threshold level decreased from 4.33 to 2.187. The results may be attributed to the phenomenon that the technical skills of Chinese enterprises have increased exponentially in the last five years, which is endorsed in the Global Innovation Index, where China is the leading emerging country that secured the second highest rank in innovation output in 2019. Similarly, the ETG decreases, which may be attributed to higher capital investment into BRI host countries. Capital investment improves the learning ability of those countries and the skewed prevailing gap from China or other technology leading countries. Table 13 shows that the results are approximately or substantially the same as prior estimations; however, the magnitude of coefficients varied. FDI induced technology spillovers increased from 0.0359 percent to 0.0379 percent in Model 1 and decreased from 0.0438 percent to 0.0244 percent in Model 2 if OTG (ETG) is higher (lower) than the threshold. The coefficients of other control variables are marginally varied, yet they produce a similar outcome.

Table 12: Threshold Results After BRI

Model Description	Threshold	Estimated Value	90 Percent Confidence Interval
Model 1 (OTG)	θ_1	3.5182	2.69628, 3.57791
Model 2 (ETG)	θ_1	2.1874	0.102836, 4.94425

Table 13: Results of Dynamic Panel Threshold Model After BRI

Description	Model 1	Description	Model 2
TFP_{t-1}	0.2752***	TFP_{t-1}	0.2630***
	(0.0089)		(0.0278)
S^{FDI}	-0.0044	S^{FDI}	0.0244***
(OTG1≤3.518)	(0.0038)	(ETG1≤2.187)	(0.0030)
S^{FDI}	0.0397***	S^{FDI}	-0.0089**
(OTG1>3.518)	(0.0029)	(ETG1>2.187)	(0.0030)
S^{D}	0.0016**	S^{D}	0.0020***
	(0.0005)		(0.0005)
REG	0.0413***	REG	-0.0119
	(0.0068)		(0.0105)
INF	0.1386*	INF	0.1708**
	(0.0705)		(0.0755)
S^{EXP}	-0.0009*	S^{EXP}	-0.0028**
	(0.0005)		(0.0009)
Constant	0.4741***	Constant	0.8667***
	(0.0456)		(0.0715)
No. of Countries	46	No. of Countries	46
Arellano Bond Test AR(1)	-3.534	AR (1)	-3.3396
P-Value	0.0004	P-Value	0.0008
Arellano Bond Test AR(2)	-0.4882	AR (2)	-0.01438
P-Value	0.6254	P-Value	0.9885
Sargan Test	39.3645	Sargan Test	33.9538
P-Value	0.9181	P-Value	0.9806

Table 14 reports the estimated threshold values in the pre-BRI period. The OTG threshold level in the pre-BRI period is 2.674 in contrast to post-BRI at 3.518. The ETG threshold level in the pre-BRI sample is 6.807 in contrast to post-BRI at 2.187. These results imply that before BRI the OTG is relatively lower, and ETG is relatively higher. This may happen owing to the larger time span before BRI and early years of the sample—for example, from 2004 to 2008 the technological levels of China itself were not too high and FDI receiving countries lagged behind in terms of capital investment, human resources development, and R&D allocations. However, these gaps are expected to narrow over the years. Table 15 reports the outcome of the pre-BRI sample, suggesting that the FDI induced technology spillovers are lower in magnitude with a coefficient value of 0.007 percent in contrast to the post-BRI coefficient of 0.0397 percent. The results of other variables are approximately the same in terms of the direction of the relationship; however the coefficient magnitude has marginal variations.

Table 14: Threshold Results Before BRI

Model Description	Threshold	Estimated Value	90 Percent Confidence Interval
Model 1 (OTG)	θ_1	2.6740	2.30629,2.84562
Model 2 (ETG)	θ_1	6.8079	4.33606, 7.04802

Table 15: Results of Dynamic Panel Threshold Model Before BRI

Description	Model 1	Description	Model 2
TFP_{t-1}	0.054***	TFP_{t-1}	0.071***
	(0.014)		(0.011)
S^{FDI}	-0.010	S^{FDI}	0.064***
(OTG1≤2.674)	(0.010)	(ETG1≤6.8079)	(0.005)
S^{FDI}	0.007***	S^{FDI}	-0.011***
(OTG1>2.674)	(0.002)	(ETG1>6.8079)	(0.001)
S^{D}	0.004***	S^{D}	0.006***
	(0.001)		(0.001)
REG	0.045***	REG	0.038***
	(0.006)		(0.007)
INF	0.106***	INF	0.091***
	(0.028)		(0.021)
S^{EXP}	-0.004***	S^{EXP}	-0.008***
	(0.001)		(0.001)
Constant	0.680***	Constant	0.704***
	(0.043)		(0.041)
No. of Countries	46	No. of Countries	46
Arellano Bond Test AR(1)	-3.5515	AR (1)	-3.4683
P-Value	0.0004	P-Value	0.0005
Arellano Bond Test AR(2)	-1.3652	AR (2)	-1.4057
P-Value	0.1772	P-Value	0.1598
Sargan Test	36.8460	Sargan Test	37.52783
P-Value	0.5227	P-Value	0.4911

5.3.2 Regression with Alternative Proxies

For robustness, we also employ alternative proxies of OTG and ETG. It is noteworthy that OTG1 is measured in terms of income gap, while ETG is measured in terms of human capital gap. Owing to different measures, Table 16 reports a relatively higher threshold value of OTG and a lower value of ETG. Because China's per capita income significantly increased over the years compared to other BRI developing countries, it therefore shows a relatively higher gap. In contrast, the human capital index is relatively better in BRI developing countries, and China's values are lower, thus producing a relatively lower ETG1. However, Table 17 echoed a similar finding, where FDI induced technology spillovers are only positive (negative) and significant when OTG (ETG) is higher (lower) than a specific threshold value. The outcome of other control variables is also complementing the previous outcomes. To incorporate the decay effects, lag 1 and lag 2 of FDI induced technology spillovers are also confirmed, but not reported for brevity.

Table 16: Results of Models Threshold (With Alternative Proxies)

Model Description	Threshold	Estimated Value	90 Percent Confidence Interval
Model 1 (OTG)	θ_1	6.4876	0.03565, 6.61933
Model 2 (ETG)	θ_1	1.5802	1.38117, 3.28217

Table 17: Results of Dynamic Panel Threshold Model (With Alternative Proxies)

Description	Model 1	Description	Model 2
TFP_{t-1}	0.1463***	TFP_{t-1}	0.1553***
	(0.0174)		(0.0225)
S^{FDI}	-0.0110***	S^{FDI}	0.008**
(OTG1≤6.4876)	(0.0025)	(ETG1≤1.580)	(0.0020)
S^{FDI}	0.0882***	S^{FDI}	-0.0095*
(OTG1>6.4876)	(0.0128)	(ETG1>1.580)	(0.0058)
S^{D}	0.0015**	S^{D}	0.0014***
	(0.0005)		(0.0004)
REG	0.0094	REG	0.0363***
	(0.0059)		(0.0062)
INF	0.1489***	INF	0.1468***
	(0.0296)		(0.0311)
S^{EXP}	-0.0029*	S^{EXP}	-0.0032*
	(0.0015)		(0.0014)
Constant	0.8157***	Constant	0.6542***
	(0.0450)		(0.0576)
No. of Countries	46	No. of Countries	46
Arellano Bond Test AR(1)	-3.4819	AR (1)	-3.8284
P-Value	0.0005	P-Value	0.0001
Arellano Bond Test AR(2)	-1.1622	AR (2)	-1.5425
P-Value	0.2451	P-Value	0.1230
Sargan Test	38.003	Sargan Test	41.709
P-Value	0.6874	P-Value	0.8686

6. Conclusion and Policy Recommendations

6.1 Conclusion

This report estimates outward FDI induced technology spillovers across developing and underdeveloped Belt and Road and CAREC host countries. Unlike traditional models, we develop a conditional hypothesis, where it is argued that technology/productivity gain from FDI is contingent on the technology gap. In doing so, we have extended Romer's and the L-P model in light of Findlay's (1978) hypothesis of relative backwardness which states that a wider technology gap between advanced and developing countries provides a learning space, thus increasing the FDI induced spillovers for host countries. We have constructed two indicators of technology gap to integrate different attributes of the phenomena. First, OTG as a prevailing difference in learning abilities, while ETG as a firm’s capability to learn from leading edge technologies. To accomplish these objectives, this research used dynamic panel threshold regression with endogenous regressors using the annual data of 46 host countries (developing and underdeveloped) from 2004 to 2019 and provided the following key findings:

1. Most of the CAREC members are embracing technology spillovers from FDI and show positive growth in domestic productivity. These results are consistent after adjusting lag structure and alternative proxies.

2. Productivity or technology spillovers from Chinese outward FDI are positive and significant for those countries lagging behind China in terms of OTG. The threshold value suggests that countries with a wider observed technology gap (>2.68) realize positive spillovers.
3. In contrast, a lower expected technology gap is imperative to gain from technology spillovers from FDI. Countries lagging far behind technology frontier countries (China) in terms of ETG failed to catch up with productivity gain from inward FDI flows. Notably, most of the developing countries are falling lower (<4.33) than the acceptable limit of ETG. However, two CAREC countries (Mongolia and Uzbekistan) are facing the highest expected technology differences that neutralize possible spillovers from FDI in those countries. The results imply that the FDI induced productivity spillovers are significantly positive in Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Pakistan, and Tajikistan in the presence of technology differences. Conversely, the other two countries—Mongolia and Tajikistan—despite receiving a significant amount of Chinese FDI, failed to materialize possible or optimal benefits from FDI owing to their lower level of basic technologies and skills required to learn from foreign technologies.

4. The overall results suggest that countries with narrower ETG and wider OTG are more likely to benefit from FDI owing to higher imitation rates and broader learning spaces. These findings partially support Findlay's (1978) and Wang and Blomstrom's (1992) convergence theory, which states that technologically backward economies embrace higher benefits from overseas technologies. This preposition is varied across different attributes of technology gap, such as a wider gap in human capital or physical capital restricts the possible technology spillovers (imitation), while observed differences in labor and managerial skills help to gain from foreign firms through various channels as described in Figure 2.

5. The export channel of technology spillovers is also analyzed. Export induced technology spillovers are either weakly negative or insignificant across different model specifications, indicating that Chinese exports to BRI and CAREC host countries are not improving the productivity of the host countries. Thus, only the FDI channel of technology transfer is confirmed in this report. It may be owing to the aggregation of exports data; therefore, a detailed analysis of sectoral exports can help to answer this question.

6. The R&D intensity of domestic host countries has a weak contribution to productivity growth. Although positive, the coefficient magnitude is too weak, indicating that R&D allocation in the BRI and CAREC region is not enough to give a big push to productivity growth. Among CAREC countries, a higher R&D intensity is observed in Georgia, Azerbaijan, and Uzbekistan, while Kazakhstan, Kyrgyzstan, Mongolia, and Tajikistan report the lowest R&D in terms of available labor force.

7. The infrastructure quality of host countries substantially increases productivity, which implies that the infrastructure of host countries is as important as increasing productivity. The infrastructure quality of the CAREC region is significantly lower than other developing BRI countries; however, in the CAREC region, Kyrgyzstan, Georgia, Tajikistan, and Azerbaijan report the lowest quality of cumulative infrastructure.

8. Regulations and a lucrative business environment are key contributors of domestic productivity growth. Among the CAREC countries, Georgia, Mongolia, Kazakhstan, and Kyrgyzstan have higher ease of doing business scores, while Pakistan, Tajikistan, and Uzbekistan perform least well.

In conclusion, the productivity growth of host countries is contingent on several socioeconomic factors, and optimal growth can be achieved only by stimulating all drivers. Almost every CAREC country is lagging in a certain dimension—for example, a country is embracing higher FDI, but embodied with lower technical skills, weak business regulations, or lower infrastructure is failing to achieve optimal productivity growth. Similarly, a country with better infrastructure, reasonable human capital, and regulations, fails to achieve optimal productivity spillovers if there are no or lower FDI inflows. Thus, an integrated policy is imperative for each CAREC country to push their lagging areas.

6.2 Policy Recommendations

The overall results imply that legislatures should devise policies to minimize the expected technology gap between China and the CAREC economies by strengthening the innovation process, encouraging talent, higher R&D allocations, and integrating effectively with ongoing investment projects. Also, the prevailing OTG is considered a blessing rather than a curse owing to the higher learning space in developing CAREC countries. The following are some direct policy interventions by the government, the private sector, and multilateral development partners (MDPs):

1. Expected technology differences can be reduced by investing in human capital development and introducing policies to instigate fixed asset investment. In the CAREC region, reasonable steps should be taken to encourage R&D investment, innovative performance, technological workability, creation of digital infrastructure, and protection of intellectual property rights. Small and medium-sized firms have failed to meet the increased demand for digital funding owing to greater capital costs of technology infrastructure and longer payback times of R&D budgets, necessitating support from the government and MDPs. Owing to the higher capital cost of technology infrastructure and the longer payoff time of R&D allocations, small and medium-sized enterprises failed to cope with the growing demand for funds; thus, they need assistance from both the government and MDPs. There are significant infrastructure and technology gaps in the CAREC region, for which international agencies, respective governments, and industries should collaborate to provide financial assistance, legislative support, and integration with the national innovation strategy by fostering closer links between business, industry, and academia. Moreover, public–private partnerships or joint ventures in R&D and technology sectors could help firms to remove these bottlenecks and enhance the research output.

2. Apart from the above, a formal agreement between FDI source (China) and FDI host (CAREC) countries is required to advance the collaboration between local and Chinese firms. A particular proportion of human resources (local employees and engineers in host countries) should be employed in construction and other foreign projects that aid in replicating advanced technologies. Manifestly, FDI in joint ventures provides higher spillovers in contrast to others.

3. In order to maximize technology spillovers, domestic R&D intensity is as important as foreign embodied technologies through FDI. The R&D intensity of BRI host countries is very low (2.5) owing to lower allocation for R&D expenditure. Notably, the R&D intensity of CAREC countries is almost half (1.3) that of BRI countries overall, implying a significant gap in domestic R&D allocations. The marginal contribution of domestic R&D can be improved only through the higher allocation of public and private R&D in different sectors. Figure 8 visualizes a significant increase in China's domestic R&D expenditure since the last decade, translating to higher technology and productivity. Other member countries should encourage local firms to have private R&D, and a significant portion of the annual budget should be allocated to public R&D. These measures are equally important for all CAREC countries—particularly for Kazakhstan, Kyrgyzstan, Mongolia, and Tajikistan, which have very low R&D intensity compared to the others.

4. Another important option for transferring industrial capabilities at business level is establishing special economic zones along the corridors. The real benefits of infrastructure led FDI projects can be maximized only if participating countries expand industrial depth and width, and utilize upgraded logistics infrastructure to improve their industrial output. Although several economic zones are already being placed across the region, however they are lagging behind their potential.For example, Pakistan embrace more than USD60 billion outward FDI, which significantly improved its infrastructure (transport, energy, logistics, and so on); however, the special economic zones are scant even after seven years of BRI.

5. Owing to the potential logistics and infrastructure gap in the CAREC region, the sectoral distribution of Chinese outward FDI is unbalanced and more inclined towards infrastructure (energy and transport). Especially, FDI allocations in industrial related technologies are negligible. Therefore, the legislators from CAREC countries should devise integrated policies where FDI is equally disbursed in industrial and construction sectors.

6. Investment in several resource rich CAREC countries has been majorly skewed towards the energy sector, essentially in the core subsectors of oil, gas, coal, hydropower, and alternative energy. There is a need to redirect this excessive inclination toward the energy sector, especially investment in fossil energy generation, as climate change and safeguarding commitments globally are calling for a shift from this paradigm. Hence, outward FDI portfolio diversification needs to be considered in this context.

7. The effect of institutional quality on productivity growth is more substantial than FDI, implying that a wider technological gap fails to imitate foreign technologies if host countries fail to meet specific conditions of absorption capacity. Therefore, an institutional rearrangement is imperative to create a conducive environment for firms and businesses in the CAREC region, mainly for Pakistan, Tajikistan, and Uzbekistan, which have relatively low scores in the ease of doing business index. It can only be improved through the intervention of the government in liberalizing business processes.

8. The developing CAREC countries can learn from their neighbor China, which is following long term reforms and a modernization plan through a dedicated ministry—the National Development and Reform Commission (NDRC)—and executed its 14 five year plans where a long

term ten year research strategy is announced to maximize the R&D to GDP ratio. Thus, investing in capacity building is a lifeline for any economy, and R&D is the optimal solution to learn new technology and sustain long term productivity growth.

6.3 Study Limitations and Future Directions

Although this report attempts to investigate productivity spillovers from Chinese FDI at a national level, there are certain inter- and intra-industry spillovers, vertical and backward links that may produce distinct effects within or across industries in a country. Thus, future research should be directed towards the industrial level or sectoral level analysis of FDI. The mutual trade channel also requires further investigation in terms of productivity growth and regional development.

Footnotes

[4] FDI enterprises refer to foreign enterprises that are directly owned or have 10 percent (or above) voting rights or equivalents controlled by domestic investors
[5] Most of the BRI economies relied on natural resources and exports of primary products. In contrast, China has diversified industries in all UN industrial classification in high tech and medium tech industries, yield to higher possibility of technology transfer. (Deng et al. 2020)
[6] Most of the BRI economies relied on natural resources and exports of primary products. In contrast, China has diversified industries in all UN industrial classification in high tech and medium tech industries, yield to higher possibility of technology transfer. (Deng et al. 2020)
[7] https://www.rug.nl/ggdc/productivity/pwt/pwt-releases/pwt9.0?lang=en
[8] https://databank.worldbank.org/source/world-development-indicators
[9] http://hzs.mofcom.gov.cn/article/date/201512/20151201223578.shtml
[10] http://www.stats.gov.cn/english/Statisticaldata/AnnualData/
[11]https://www.fraserinstitute.org/economic-freedom/dataset?geozone=world&year=2018&page=dataset&min-year=2&max-year=0&filter=0

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Appendix

A1: List of China's Outward FDI Projects in the CAREC Countries

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
1	2007	Afghanistan	MCC, Jiangxi Copper	2870	Metals	Copper		G
2	2011	Afghanistan	CNPC	400	Energy	Oil		G
3	2017	Afghanistan	China Communications Construction	210	Transport	Autos	1	
4	2007	Azerbaijan	Sinomach	210	Energy	Gas		
5	2008	Azerbaijan	Sinoma	440	Real estate	Construction		
6	2011	Azerbaijan	China National Building Material	100	Real estate	Construction		
7	2018	Azerbaijan	Sinomach	1170	Metals	Steel	1	
8	2019	Azerbaijan	Sinomach	270	Transport	Autos	1	G
9	2008	Georgia	MCC	200	Tourism			
10	2010	Georgia	Xinjiang Hualing, Shanghai Boda	100	Other	Industry		G
11	2011	Georgia	China Railway Construction	340	Transport	Rail		
12	2012	Georgia	Xinjiang Hualing	100	Finance	Banking		
13	2012	Georgia	Power Construction Corp	130	Transport	Autos		
14	2012	Georgia	Hualing	170	Real estate	Property		G
15	2015	Georgia	Power Construction Corp	100	Transport	Autos	1	
16	2016	Georgia	China National Chemical Engineering	160	Energy	Gas	1	
17	2017	Georgia	Dongfang Electric	250	Energy	Coal	1	
18	2019	Georgia	State Construction Engineering	120	Transport	Autos	1	
19	2019	Georgia	China Railway Construction	390	Transport	Autos	1	
20	2005	Kazakhstan	CNPC	4200	Energy	Oil		
21	2005	Kazakhstan	China Nonferrous	300	Metals	Aluminum		
22	2006	Kazakhstan	CITIC	1910	Energy			
23	2007	Kazakhstan	CNPC	1310	Energy	Gas		

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
24	2008	Kazakhstan	China National Building Material	170	Real estate	Construction		
25	2008	Kazakhstan	Xinjiang Guanghui	250	Energy			G
26	2009	Kazakhstan	CNPC	2600	Energy	Gas		
27	2009	Kazakhstan	CIC	940	Energy	Gas		
28	2010	Kazakhstan	Gezhouba, Xinjiang International Economic Cooperation	730	Energy	Hydro		
29	2010	Kazakhstan	Sinopec	1260	Chemicals			
30	2010	Kazakhstan	Jinchuan	120	Metals	Copper		
31	2010	Kazakhstan	CITIC	150	Transport	Autos		
32	2011	Kazakhstan	Sinopec	850	Energy	Oil		
33	2012	Kazakhstan	Three Gorges	360	Energy	Hydro		
34	2012	Kazakhstan	Sinomach	190	Energy			
35	2012	Kazakhstan	CNPC	150	Energy	Gas		
36	2012	Kazakhstan	CNPC	500	Energy	Gas		G
37	2012	Kazakhstan	CNPC	900	Energy	Gas		
38	2013	Kazakhstan	CNPC	5300	Energy	Oil		
39	2014	Kazakhstan	China Nonferrous	490	Metals	Copper	1	
40	2014	Kazakhstan	Geo-Jade Petroleum	530	Energy	Oil	1	
41	2014	Kazakhstan	Sinopec	1090	Energy	Oil	1	
42	2014	Kazakhstan	China Nonferrous	560	Metals	Copper	1	
43	2014	Kazakhstan	CITIC	550	Chemicals		1	
44	2015	Kazakhstan	China Railway Engineering	150	Metals		1	
45	2015	Kazakhstan	Geo-Jade Petroleum	350	Energy	Oil	1	
46	2015	Kazakhstan	Geo-Jade Petroleum	120	Energy	Oil	1	
47	2015	Kazakhstan	China National Chemical Engineering	1870	Chemicals		1	
48	2016	Kazakhstan	Power Construction Corp	340	Energy	Alternative	1	
49	2016	Kazakhstan	China Energy Engineering	180	Real estate	Construction	1	G
50	2017	Kazakhstan	CITIC	940	Transport	Autos	1	

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
51	2017	Kazakhstan	China Railway Engineering	1170	Transport	Rail	1	
52	2017	Kazakhstan	CITIC	110	Finance	Banking	1	
53	2017	Kazakhstan	Norinco	710	Metals	Steel	1	
54	2018	Kazakhstan	Sanghai Safbon	100	Utilities		1	
55	2018	Kazakhstan	Power Construction Corp	160	Energy	Alternative	1	
56	2018	Kazakhstan	CITIC	860	Transport	Autos	1	
57	2018	Kazakhstan	Qifeng New Material	160	Other	Timber	1	
58	2019	Kazakhstan	Sinomach	240	Agriculture		1	
59	2019	Kazakhstan	Genertec	560	Transport	Autos	1	
60	2019	Kazakhstan	Power Construction Corp	140	Energy	Alternative	1	
61	2019	Kazakhstan	China National Building Material	230	Chemicals		1	
62	2020	Kazakhstan	State Construction Engineering	320	Transport	Rail	1	
63	2011	Kyrgyzstan	Tebian Electric Apparatus	390	Energy			
64	2014	Kyrgyzstan	Shaanxi Coal and Chemical	430	Energy	Oil	1	G
65	2014	Kyrgyzstan	CNPC	1400	Energy	Gas	1	
66	2014	Kyrgyzstan	Tebian Electric Apparatus	390	Energy	Coal	1	
67	2014	Kyrgyzstan	Beijing Urban Construction	990	Transport	Aviation	1	
68	2014	Kyrgyzstan	Sinomach	300	Transport	Aviation	1	
69	2014	Kyrgyzstan	Rongsheng Heavy Industries	280	Energy	Oil	1	
70	2015	Kyrgyzstan	Zijin Mining	150	Metals		1	G
71	2015	Kyrgyzstan	China Communications Construction	400	Transport	Autos	1	
72	2005	Mongolia	State-Owned Enterprise Investment Company, Beijing Jingdeshun	200	Energy	Oil		G
73	2008	Mongolia	Hopu Investment	150	Metals	Steel		
74	2009	Mongolia	CNPC	500	Energy	Oil		G
75	2009	Mongolia	China National Building Material	120	Real estate	Construction		
76	2009	Mongolia	CIC	250	Energy	Coal		
77	2011	Mongolia	Shenhua	1010	Energy	Coal		G

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
78	2015	Mongolia	Zhongrun Resources	1940	Metals	Steel	1	
79	2015	Mongolia	Power Construction Corp	510	Energy	Coal	1	G
80	2015	Mongolia	China National Nuclear	990	Energy	Coal	1	
81	2016	Mongolia	China Energy Engineering	100	Energy	Hydro	1	G
82	2016	Mongolia	China Railway Engineering	110	Other	Education	1	
83	2017	Mongolia	Tebian Electric Apparatus	120	Energy		1	
84	2017	Mongolia	Sinomach	100	Energy	Alternative	1	
85	2018	Mongolia	Henan Senyuan	180	Energy	Coal	1	
86	2018	Mongolia	China Railway Engineering	140	Transport	Autos	1	
87	2019	Mongolia	Minmetals	160	Transport	Autos	1	
88	2019	Mongolia	China Railway Engineering, Beijing Construction Engineering	270	Utilities		1	
89	2019	Mongolia	Sinosteel	570	Energy	Coal	1	
90	2019	Mongolia	State Construction Engineering	220	Transport	Autos	1	
91	2005	Pakistan	China National Nuclear	490	Energy			
92	2006	Pakistan	Huawei	550	Technology	Telecom		
93	2006	Pakistan	China Communications Construction	490	Transport	Autos		
94	2007	Pakistan	China Mobile	280	Technology	Telecom		
95	2007	Pakistan	Shanghai Shengong, Shanghai Municipal Government	100	Utilities			
96	2007	Pakistan	China Mobile	180	Technology	Telecom		
97	2007	Pakistan	Sinomach	150	Energy			
98	2008	Pakistan	Three Gorges	120	Transport	Autos		
99	2008	Pakistan	Three Gorges	320	Transport	Shipping		
100	2009	Pakistan	Three Gorges	180	Real estate	Construction		
101	2009	Pakistan	Dongfang Electric	150	Energy	Gas		
102	2009	Pakistan	Harbin Electric	600	Energy			
103	2009	Pakistan	China Mobile	500	Technology	Telecom		G

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
104	2010	Pakistan	Sinomach, Gezhouba	2690	Energy	Hydro		
105	2010	Pakistan	Sinomach	160	Energy	Coal		
106	2010	Pakistan	Sinohydro	110	Energy	Hydro		
107	2010	Pakistan	China Communications Construction	160	Logistics			
108	2010	Pakistan	China Communications Construction	280	Transport	Autos		
109	2011	Pakistan	State Construction Engineering	450	Transport	Aviation		
110	2011	Pakistan	United Energy	750	Energy			
111	2011	Pakistan	Three Gorges	240	Energy	Hydro		
112	2011	Pakistan	Three Gorges	130	Energy	Alternative		G
113	2012	Pakistan	Three Gorges	270	Agriculture			
114	2012	Pakistan	United Energy	200	Energy	Gas		
115	2012	Pakistan	State Construction Engineering	230	Tourism			
116	2012	Pakistan	Huawei	500	Technology	Telecom		
117	2013	Pakistan	China Communications Construction	300	Energy	Hydro		
118	2013	Pakistan	Three Gorges	260	Logistics			
119	2013	Pakistan	China Communications Construction	100	Logistics		1	
120	2014	Pakistan	Power Construction Corp	240	Energy	Hydro	1	
121	2014	Pakistan	China Communications Construction	230	Transport	Aviation	1	
122	2014	Pakistan	Shandong Ruyi	120	Other	Textiles	1	
123	2014	Pakistan	Three Gorges	900	Energy	Hydro	1	
124	2014	Pakistan	China Communications Construction	220	Transport	Shipping	1	
125	2014	Pakistan	China Mobile	520	Technology	Telecom	1	
126	2014	Pakistan	China Communications Construction	130	Transport	Shipping	1	
127	2014	Pakistan	Power Construction Corp	130	Energy	Alternative	1	
128	2014	Pakistan	China National Chemical Engineering	240	Energy	Oil	1	
129	2014	Pakistan	Sinomach	1130	Energy	Coal	1	
130	2014	Pakistan	China Energy Engineering	140	Transport	Autos	1	
131	2014	Pakistan	Sinomach	100	Energy	Alternative	1	

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
132	2014	Pakistan	China National Nuclear	6500	Energy		1	
133	2015	Pakistan	China Railway Construction, China Energy Engineering	160	Transport	Autos	1	
134	2015	Pakistan	China Energy Engineering	250	Energy	Alternative	1	
135	2015	Pakistan	Power Construction Corp	1070	Energy	Coal	1	G
136	2015	Pakistan	China Railway Corp, Norinco	1620	Transport	Rail	1	
137	2015	Pakistan	Huaneng Power	1810	Energy	Coal	1	G
138	2015	Pakistan	Power Construction Corp	120	Energy	Alternative	1	G
139	2015	Pakistan	ZTE	460	Energy	Alternative	1	G
140	2015	Pakistan	Harbin Electric	1100	Energy	Gas	1	
141	2015	Pakistan	Sinomach	150	Energy		1	
142	2015	Pakistan	Zhuhai Port Holdings, State Construction Engineering	1620	Transport	Shipping	1	G
143	2015	Pakistan	China Railway Construction	1460	Transport	Autos	1	
144	2015	Pakistan	State Construction Engineering	2890	Transport	Autos	1	
145	2015	Pakistan	Power Construction Corp	100	Energy	Alternative	1	
146	2016	Pakistan	China Energy Engineering	360	Energy	Hydro	1	
147	2016	Pakistan	Three Gorges	2400	Energy	Hydro	1	
148	2016	Pakistan	China Communications Construction	1320	Transport	Autos	1	
149	2016	Pakistan	Power Construction Corp	220	Transport	Shipping	1	
150	2016	Pakistan	Three Gorges	1650	Energy	Hydro	1	G
151	2016	Pakistan	Power Construction Corp	910	Energy	Gas	1	
152	2016	Pakistan	Three Gorges	220	Energy	Alternative	1	G
153	2016	Pakistan	China Energy Engineering	530	Energy	Coal	1	
154	2016	Pakistan	CITIC	190	Real estate	Construction	1	
155	2016	Pakistan	State Grid	1760	Energy		1	
156	2016	Pakistan	Power Construction Corp	1080	Energy	Coal	1	
157	2017	Pakistan	China Energy Engineering	1720	Energy	Hydro	1	

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
158	2017	Pakistan	China Mobile	200	Technology	Telecom	1	G
159	2017	Pakistan	China National Building Material	130	Real estate	Construction	1	
160	2017	Pakistan	Power Construction Corp	130	Energy	Alternative	1	
161	2017	Pakistan	China National Building Material	190	Real estate	Construction	1	
162	2017	Pakistan	State Power Investment	1480	Energy	Coal	1	G
163	2017	Pakistan	China National Building Material	180	Real estate	Construction	1	
164	2017	Pakistan	China Energy Engineering	910	Energy	Hydro	1	
165	2017	Pakistan	China Communications Construction	470	Energy	Coal	1	G
166	2017	Pakistan	State Construction Engineering	380	Transport	Aviation	1	
167	2017	Pakistan	Minmetals	200	Energy	Alternative	1	
168	2017	Pakistan	China Railway Engineering	100	Transport	Rail	1	
169	2017	Pakistan	Sinomach	520	Energy	Gas	1	
170	2017	Pakistan	China Communications Construction	140	Transport	Autos	1	
171	2018	Pakistan	Alibaba	180	Finance	Banking	1	
172	2018	Pakistan	Alibaba	150	Other	Consumer	1	
173	2018	Pakistan	Harbin Electric	280	Energy	Coal	1	
174	2018	Pakistan	Sinomach	260	Energy	Coal	1	
175	2019	Pakistan	Datang	970	Energy	Coal	1	G
176	2019	Pakistan	China Energy Engineering	1290	Energy	Hydro	1	
177	2019	Pakistan	Shanghai Electric	1460	Energy	Coal	1	
178	2019	Pakistan	Power Construction Corp	340	Energy	Hydro	1	
179	2020	Pakistan	Power Construction Corp	1930	Energy	Hydro	1	
180	2020	Pakistan	China Energy Engineering	1230	Energy	Hydro	1	G
181	2020	Pakistan	China Communications Construction	130	Other	Industry	1	
182	2006	Tajikistan	Tebian Electric Apparatus	400	Energy			
183	2006	Tajikistan	China Communications Construction	300	Transport	Autos		
184	2009	Tajikistan	China Communications Construction	260	Transport	Autos		
185	2012	Tajikistan	China National Building Material	300	Real estate	Construction		G

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
186	2012	Tajikistan	Tebian Electric Apparatus	350	Energy	Coal		
187	2016	Tajikistan	Power Construction Corp	170	Energy	Hydro	1	
188	2019	Tajikistan	Sinomach	540	Metals	Aluminum	1	
189	2007	Turkmenistan	CNPC	150	Energy	Gas		
190	2009	Turkmenistan	CNPC	3130	Energy	Gas		
191	2012	Turkmenistan	CNPC	2920	Energy	Gas		
192	2014	Turkmenistan	CNPC	600	Energy	Gas	1	G
193	2007	Uzbekistan	CITIC	110	Chemicals			
194	2007	Uzbekistan	CNPC	880	Energy	Gas		
195	2010	Uzbekistan	Baiyin Non-Ferrous, CITIC, Chang Xin	190	Metals			
196	2010	Uzbekistan	Jinsheng Trading	100	Other	Industry		G
197	2012	Uzbekistan	CNPC	2040	Energy	Gas		
198	2012	Uzbekistan	Harbin Electric	230	Energy	Coal		
199	2013	Uzbekistan	China Railway Engineering	460	Transport	Rail		
200	2014	Uzbekistan	Sinomach, China National Chemical Engineering	480	Chemicals		1	
201	2014	Uzbekistan	China Poly	180	Agriculture		1	
202	2016	Uzbekistan	China Singyes	150	Energy	Alternative	1	
203	2017	Uzbekistan	Ming Yuan Silu	110	Real estate	Construction	1	G
204	2017	Uzbekistan	China National Building Material	160	Real estate	Construction	1	
205	2017	Uzbekistan	Power Construction Corp	110	Energy	Hydro	1	
206	2017	Uzbekistan	CNPC	190	Energy	Gas	1	G
207	2018	Uzbekistan	Jiangsu Hengyuan	200	Real estate	Construction	1	G
208	2019	Uzbekistan	Anhui Conch	140	Real estate	Construction	1	G
209	2019	Uzbekistan	Huaxin Cement	150	Real estate	Construction	1	G
210	2019	Uzbekistan	Minmetals	110	Real estate	Construction	1	
211	2020	Uzbekistan	China Railway Construction	100	Transport	Autos	1	
212	2020	Uzbekistan	Power Construction Corp-led Unit	120	Energy	Alternative	1	

No.	Year	Country	Chinese Entity	USD Million	Sector	Subsector	BRI	Greenfield
Total				**129,510**	Project under BRI 132 out of total 212, 37 Green field investment projects			
Source: China Global Investment Tracker, 2020 Note: G denotes green field investments and 1 specify the projects under BRI.								

A2: List of Sample Countries

Chinese outward FDI Receiving Countries	
Albania	Maldives
Armenia	Moldova, Republic of
Azerbaijan*	Mongolia*
Bahrain	Myanmar
Bangladesh	Nepal
Belarus	Oman
Bosnia and Herzegovina	Pakistan*
Brunei Darussalam	Philippines
Cambodia	Qatar
Egypt	Romania
Georgia*	Russian Federation
India	Saudi Arabia
Indonesia	Serbia
Iran Islamic Republic	Sri Lanka
Iraq	Syrian Arab Republic
Jordan	Tajikistan*
Kazakhstan*	Thailand
Kuwait	Turkey
Kyrgyzstan*	Ukraine
Lao People's Dem. Rep.	United Arab Emirates
Lebanon	Uzbekistan*
Macedonia	Viet Nam
Malaysia	Yemen
Note: China is FDI source Country not included in the list and * denotes CAREC Countries	

A 3: Interquartile Range of Data

Variables	p25		p50		p75		iqr	
	Full Sample	**CAREC**	**Full Sample**	**CAREC**	**Full Sample**	**CAREC**	**Full Sample**	**CAREC**
TFP	0.993	1.021	1.025	1.042	1.051	1.058	0.058	0.036
OTG	2.348	2.718	2.654	3.181	3.116	3.517	0.768	0.800
ETG	0.182	0.518	2.051	2.995	4.371	4.814	4.189	4.296
OTG1	0.560	1.148	1.225	3.193	3.020	5.243	2.460	4.095
ETG1	1.314	1.475	1.434	1.518	1.521	3.330	0.207	1.855
S^{FDI}	-2.986	-1.151	-0.467	0.574	1.153	1.903	4.139	3.054
S^{D}	-0.093	-0.736	3.242	1.174	4.878	3.416	4.971	4.152
INF	-0.677	-0.774	-0.364	-0.600	0.320	-0.372	0.997	0.403
Reg	6.124	6.062	6.692	6.523	7.074	7.084	0.951	1.022
S^{Exp}	3.084	2.434	4.281	3.457	5.721	4.547	2.636	2.113
FDI	9.668	64.461	132.257	503.281	818.797	1581.695	809.129	1517.234

A4: Countrywise Mean, Median, and IQR of Variables

Country	**Mean**								
	Azerbaijan	**Georgia**	**Kazakhstan**	**Kyrgyzstan**	**Mongolia**	**Pakistan**	**Tajikistan**	**Uzbekistan**	**Total CAREC**
TFP	1.049	1.037	1.043	1.005	1.018	1.003	1.012	1.012	1.022
OTG	2.607	2.839	2.389	3.610	3.588	3.308	3.345	3.161	3.106
ETG	0.385	0.435	3.115	3.622	7.987	3.563	0.486	6.690	3.285
OTG1	0.985	1.402	0.531	5.497	4.935	4.959	6.255	2.894	3.432
ETG1	3.407	3.407	1.513	1.515	1.450	1.195	1.497	3.407	2.174
S^{FDI}	-2.741	-0.536	2.080	0.481	1.778	1.793	0.199	-0.392	0.333
S^{D}	3.496	5.192	-1.877	-0.273	-0.112	1.205	0.336	2.866	1.354
INF	-0.737	-0.807	-0.355	-0.891	-0.354	-0.562	-0.626	-0.413	-0.593
Reg	6.123	7.977	6.918	6.889	7.181	5.933	6.077	6.077	6.647
S^{Exp}	3.170	2.701	5.216	3.488	3.765	5.659	1.515	-1.978	2.942

FDI	20.451	262.066	3602.005	625.709	2219.645	2327.025	604.080	644.993	1288.247

Median

Country	Azerbaijan	Georgia	Kazakhstan	Kyrgyzstan	Mongolia	Pakistan	Tajikistan	Uzbekistan	Total CAREC
TFP	1.031	1.044	1.037	1.042	1.059	1.023	1.049	1.049	1.042
OTG	2.596	2.859	2.394	3.662	3.599	3.357	3.394	3.188	3.181
ETG	0.336	0.409	3.063	3.695	7.928	3.722	0.420	6.752	2.995
OTG1	0.942	1.419	0.527	5.709	5.172	5.194	6.692	3.071	3.193
ETG1	3.389	3.389	1.510	1.511	1.446	1.194	1.493	3.389	1.518
S^{FDI}	-2.864	-0.529	2.592	0.781	2.168	2.097	0.306	-0.580	0.574
S^{D}	3.754	5.444	-2.062	-0.225	-0.146	1.574	-0.273	3.210	1.174
INF	-0.772	-0.882	-0.366	-0.935	-0.312	-0.495	-0.601	-0.372	-0.600
Reg	6.136	8.056	6.960	6.875	7.171	5.952	6.066	6.066	6.523
S^{Exp}	3.269	3.108	5.300	3.764	3.898	5.674	0.562	-3.282	3.457
FDI	11.080	141.377	3684.760	546.595	2230.405	2022.595	324.293	139.176	503.281

IQR

Country	Azerbaijan	Georgia	Kazakhstan	Kyrgyzstan	Mongolia	Pakistan	Tajikistan	Uzbekistan	Total CAREC
TFP	0.060	0.027	0.043	0.088	0.056	0.025	0.031	0.011	0.036
OTG	0.199	0.204	0.125	0.299	0.052	0.452	0.222	0.185	0.800
ETG	0.235	0.425	1.456	1.303	1.342	1.460	0.666	1.514	4.296
OTG1	0.350	0.393	0.210	2.024	0.139	2.572	1.698	0.465	4.095
ETG1	0.207	0.207	0.031	0.099	0.083	0.019	0.034	0.207	1.855
S^{FDI}	1.110	1.915	1.677	1.655	1.306	0.892	1.717	2.533	3.054
S^{D}	0.605	0.816	0.161	0.954	0.134	0.414	2.379	0.279	4.152
INF	0.112	0.130	0.038	0.277	0.159	0.220	0.058	0.062	0.403
Reg	0.281	0.358	0.290	0.222	0.177	0.163	0.049	0.049	1.022
S^{Exp}	0.561	1.146	0.465	1.007	1.262	1.003	2.889	0.930	2.113
FDI	19.759	462.619	5739.477	951.211	2815.757	2801.253	853.029	805.423	1517.234

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