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The Relationship between sectoral FDI and ICT: Empirical evidence from China

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The massive FDI inflows and the development of the ICT sector in China are the two crucial phenomena that the world witnessed during the past couple of decades. This paper seeks to understand the interplay between sectoral FDI and ICT by addressing key issues that were previously ignored, which include the omitted variable bias and the nexus of sectoral FDI-ICT. We explore these by using the ARDL and VECM approaches under the multilevel specification framework and a comprehensive index of ICT, which covers both quality and quantity indicators. From this analysis, we find that a stable long-term relationship exists between ICT and the sectoral distribution of FDI. The Granger causalities substantiate the ARDL results and reveal that a two-way causal relationship exists between the aforementioned variables. The parameter estimates of the control variables were found to be consistent and robust in the analysis. Our research makes for fertile ground for policymakers as well as academic researchers on these topics.

Keywords: *FDI; ICT; ARDL*

JEL CLASSIFICATION: F1; L96; C22

Introduction

The massive inflow of foreign direct investment (FDI) to China is an interesting phenomenon worthy of investigation. China is opening up to international business on an unprecedented scale, hence it became the second largest recipient nation of FDI in 2018 (UNCTAD, 2019). In the meantime, the ICT (Information and Communication Technology) coverage has been expanded significantly, despite the competitive dynamics of the Chinese economy. In this regard, ICT can become an instrument for human well-being and sustainable economic development. Considering the short contextual backdrop and the promise of this approach, this study aims to investigate the ICT-FDI nexus in China.

Several factors affect the location choice of foreign firms, including large *market size* (Bevan and Estrin, 2004; Bhaumik and Co, 2011), *better institutional quality* (Blonigen et al., 2005; Chakrabarti, 2001; Wei, 2000), the abundance of *natural resources* (Buckley et al., 2007; Deng, 2004; Kang and Jiang, 2012), *technology* (Buckley et al., 2007; Kang and Jiang, 2012), *taxes* (Azémar and Desbordes, 2013; Bilgili et al., 2012; Blonigen and Davies, 2004; Dharmapala and Hines, 2009), and *trade openness* (Doytch and Eren, 2012; Nagano, 2013; Wheeler and Mody, 1992). However, only a small number of studies have been presented based on FDI effects of ICT (Choi, 2003; Gani and Sharma, 2003; Gholami et al., 2006). Nevertheless, the further expansion of these research directions would be indispensable for economically and industrially viable policies.

China has emerged as the world's fastest-growing economy (Khan et al., 2020). This process started with the opening-up policy, which was launched under the leadership of Deng Xiaoping in 1978. Today, China is no longer an isolated country and has been the focus of the international community as a global player on the world stage. The emergence of new players in the world economy, such as Brazil, India, and China, has accelerated the process of globalisation. Over the past few decades, China has attracted many foreign firms. In 2018, China emerged as the second largest recipient of MNEs (multinational enterprises) and grew by 3.7 % over the previous year to $139 billion in 2018. FDIs are unevenly distributed across various sectors and great changes are visible in their patterns during 2007-2018, i.e., financial intermediation (3283% increase), health (2508% increase), ICT (685% increase), and vice versa.

Similarly, the development of the ICT sector is believed to have had a significant impact on China's high level of economic sophistication and product space. Although there is still a vast gap between the developed countries and China in the development of the ICT industry, yet the fantastic pace of its progress shows promise for the country's economic growth (Li et al., 2019; Meng and Li, 2002). The Chinese ICT sector positively affects economic sectors as well as other industries through information transformation and technology diffusion (Li et al., 2019). Moreover, domestic firms are expected to increase their contributions to the process of

technology upgrading. The contribution is possible due to the positive role of ICT in the transmission belts that carry international manufacturing technologies and know-how into the Chinese companies (Li and Wu, 2020; Stiroh, 2002) (see Fig. A1. for ICT intensive industries in China).

Previous studies have focused on the cross-country analysis (Choi, 2003; Gholami et al., 2006; Sinha and Sengupta, 2019), which may produce misleading results due to heterogeneity and cross-sectional dependence issues. Other studies have used a single indicator of ICT (Choi, 2003), and hence may not be feasible for policy considerations. We also noticed that some researchers have used very limited and quantitative indicators in preparing the ICT index (David, 2019), where they ignored the qualitative aspects of information and communication technology, thus the results may be prone to omitted variable bias. To the best of our knowledge, there is no existing study for examining the interplay between overseas capital inflows and ICT expansion on a macro level. To cope with the shortcomings in the existent literature, this study put forward a comprehensive index of ICT in relation to FDI. The ICT index consists of various indicators which may yield more interesting insights for policymakers. Our work bridges the gap in the FDI literature by examining the causal relationships and spill over effects of ICT and sectoral FDI on each other. Moreover, the previous studies are based on a single specification, hence may not produce consistent results. Thus, multilevel specification is reasonable.

Our study is divided into several sections. Section 2 explains the theoretical framework. Section 3 shows the data and methodology of the study. Section 4 reports empirical results followed by the concluding remarks.

Theoretical framework and hypothesis development

Previous literature shows that ICT acts as a determinant of FDI (Gholami et al., 2006). Alternatively, it can positively affect FDI through various channels, and where its presence, in host economies, may enhance the influence of FDI spill overs on the host economies. Communication technologies bridge different communities connected with FDI's activities to contribute positively to economic development, and hence, their diffusions are among the crucial pull factors that may influence MNEs (Gani and Sharma, 2003). ICT plays a vital role in influencing the efficiency and productivity of many economies; hence, it attracts FDIs and may impact their business operations (Gholami et al., 2006).

There is growing concern regarding ICT and economic development where the former leapfrogs the stages of development through information flow, thus positively affects competency, efficiency and productivity of firms. In general, information technologies can influence efficiencies and productivities in reducing search time and other similar costs. The ICT sector is helpful in employing B2C (Business-to-Consumer), B2B (Business-to-Business), and B2G (Business-to-Government) approaches in the sense that it reduces search times and

the costs of the transactions. This implies that the reduced cost can increase efficiency, productivity and ease of entry into the foreign markets (Addison and Heshmati, 2004). Similarly, it creates efficiency and contributes positively to the well-functioning of export and domestic markets, and hence, it may originate positive externalities. In other words, in the presence of positive network externalities, the profits of embarking on an investment endeavour would be high. The absence of it may result in the negative externalities which can lead to deter FDI inflows (Ko, 2007). Choi (2003) argues that a 10 percent increase in internet users can increase FDI by 2 percent.

ICT remained an influential driver in reducing time cost by successfully fostering competency, productivity and efficiency of foreign and domestic enterprises. The ICT sector may benefit from both kinds of FDI (e.g., horizontal and vertical) through reduction in coordination costs due to its activities across different countries. MNEs easily make alliances and production networks through digital technologies, where the reduction of "staying connected" costs encourage foreign firms to expand their operations cross-border. By enabling MNEs to make inter-firm and intra-firm alliances and vertically integrate their activities across the borders, the ICT applications (e.g., email, groupware systems, workflow systems, data transfer through videoconferencing, internet, and vice versa) play a crucial role in international business (Rao, 2001). For instance, teams in an organisation that are physically distant from each other can schedule their activities, such as delivery, logistics, supply chain, and product design, to accomplish them on time.

Undoubtedly, the ICT sector contributes positively to the MNEs which are engaged in R&D (Research & Development) activities (Santangelo, 2001), where the focus is on asset-seeking motives when undertaking investments in order to benefit from the innovation centres and skilled labour force. The host economies can benefit from the internationalisation of R&D in terms of positive spill overs. MNEs undertake the R&D activities together with public/ private entities (research centres and universities), other MNEs (strategic alliance), and parent firms. Despite an increase in intra-firm's R&D activities in the developing countries, the developing East Asia takes benefit from these activities with appropriate ICT infrastructure.

Investment promotion intermediaries (IPIs) use ICT, specifically internet-based technologies, as a tool to realise their plans into action, and the internet provides a feature to their promotional literature. To obtain maximum benefits, the IPIs use various features of ICT to attract foreign investment. The presence of ICT may help the IPIs to devise more sophisticated investment promotion plans that may contribute to the economic development of host countries. IPIs use ICT as a tool to provide information about the effectiveness of investment to the policymakers. Ease of doing business and information technology are important conditions for foreign investors to enter a foreign market, where the later may enable the investors to connect with IPIs through internet-based instruments. IPIs mention all their relevant details and use ICT to speedily respond to the queries of investors, and hence facilitate the IPIs to locate the right investment.

A well-developed ICT sector can also reduce the cost of small and medium enterprises (SMEs), the internet especially allows them to reduce the search costs associated with the location choice of their investments. Information on the web is free, so it is helpful for the SMEs to obtain the needed information for the project evaluation and expand their operations abroad. Moreover, information technology helps in improving transparency, which can lead to encouragement of the business environment, efficiency and productivity. The extensive use of ICT, particularly the internet, may help in reducing corruption in host economies which, in turn, affects productivity and efficiency (Vinod, 1999). Therefore, it is viewed that foreign firms choose those countries as their investment destination where there is better ICT infrastructure (Choi, 2003).

With the above discussion in mind, this paper aims to test the following hypotheses:

H1: The presence of ICT is positively related to the sectoral distribution of FDIs in China

H2: The presence of FDIs is positively related to the ICT expansion in China

Materials and methods

Empirical framework

Our empirical work links ICT and FDI in multilevel specifications and a broad set of control variables, such as GDP and human capital (HC). For this purpose, our baseline models are as follows:

In Eq. (1) and (2), FDI and ICT represent foreign direct investment (aggregate and sectoral FDI) and information and communication technology, respectively. X shows the vector of control variables, which are mentioned above. Based on the above frameworks, all betas are expected to produce positive coefficients. If the coefficients of >0, then they confirm the spill overs and ICT diffusion hypotheses. The validity of >0 highlights the fact that skilled labour (human capital) and GDP are very important in improving productivity and reducing business risks and economic uncertainty, thus enabling business entities to reduce their transactions and other costs.

The construction of the ICT index involves the PCA methodology which considers the issue of multidimensionality, where each principal component is a linear combination of the observed variables. The orthogonal transformation entails to retain the components with maximum Eigen value (Kaiser rule). The previous literature used a limited number of indicators and/or ignored the qualitative aspects of the ICT measure. A single indicator of ICT may produce biased results and hence may not be feasible for policy making (David, 2019). Moreover, the indicators may be correlated when put into a single regression equation. The

ICT index composes the number of internet users, the number of personal computers, mobile phone subscriptions, number of fixed telephone, lines, and the number of ISDN subscriptions. Considering the quality measure, we use faults per 100 fixed telephone lines per year. Related data for the preparation of ICT index is extracted from the World Bank.

Data

Table 2 documents the data related to our study. The sample selection dictates the availability of data and consists of N = 29, e.g., 1990-2018.

Table 2. Data elaboration and sources.

Variable	Description	Details	Main/control	Source
PRI	FDI in the primary sector	FDI in agriculture, forestry, animal husbandry, fishery, and mining	Main	China Statistical Yearbook
SEC	FDI in the manufacturing sector	FDI in manufacturing, construction, production and supply of electricity, gas and water	Main	China Statistical Yearbook
TER	FDI in the services sector	FDI in finance, health, ICT, and vice versa.	Main	China Statistical Yearbook
ICT	Information and communication technology	Comprehensive index	Main	Various sources
GDP	Gross Domestic Product	GDP (constant 2010 US$) per capita	Control	World Bank
HC	Human capital	Secondary school enrolment (percent gross)	Control	World Bank

Note. One is being added to actual values before taking logs.

Econometric approach

In this study, we rely on the ARDL methodology which is developed by Pesaran et al. (2001). This method is superior to other methods which rely on the large samples, where in case of small samples they produce misleading results. The ARDL method can result in unbiased estimates in case of both large as well as small samples (Pesaran et al., 2001). Another advantage of this method lies in the fact that it is equally applicable in case the variables are integrated of order zero, one, or a mix of both; however, the method results in a biased estimate in case some where the variables are integrated of two or higher order. Along the same lines, it is also applicable even though some of the regressors are endogenous (Narayan, 2005). The error-correction model (ECM) in the ARDL framework is represented as follows:

The terms like t, s, s in Eq. (3) and (4) express time, long-run coefficients, and difference operators, respectively. The rest of the terms were already discussed earlier. Cointegration among the variables can be viewed by applying the Wald test on the long-run coefficients, i.e., s, in order to know the joint significance of the estimates. The resulting F-statistic can be checked against the critical values (i.e., upper and lower bounds) provided by Pesaran et al., (2001). The critical values defined by Pesaran et al., (2001) support the large samples and they are not applicable to small samples. Addressing this issue, Narayan (2005) provided new critical values for small samples (e.g., 30–80 observations) by replicating the original Monte Carlo study of Pesaran et al. (2001). The calculated values F-statistics that are above the upper bound critical values indicate cointegration, while the lower bound critical values assume no cointegration and the values between the upper and lower bound indicate an inconclusive region. The long-run relationship between the variables of interest entails the estimation of the long-run coefficients by re-parameterising the equations that show cointegration. The following is its representation in the ARDL framework:

However, the existence of the cointegration indicated by F-statistics does not show the direction of causalities by promising that it is a necessary condition but not sufficient one. Thus, in the framework of VECM, the Granger causality test suggests the direction of causalities; hence, we can formulate it as follows:

In Eq. (7) and (8), ECT is the error-correction term, which indicates the speed of adjustment towards the long-run equilibrium.

Results

We report the unit-root testing results in Table 3 which shows that the variables under this study are either I (0) or I (1) and none of them are I (2), thus allow us to use the ARDL approach (Pesaran et al., 2001). In this regard, we applied ADF (Augmented Dicky Fuller), PP (Philips and Perron), and ZA (Zivot-Andrews) tests. The ZA test provides useful insights about the

structural breaks, where China has experienced major changes in its economy, such as its accession to the WTO (World Trade Organization) and introduction of opening-up reforms.

Table 3. Unit root and stationary test results.

	ADF		PP		ZA					
Variable	I(0)	I(1)	I(0)	I(1)	Zd	Breaks	Zt	Breaks	Zdt	Breaks
FDI	-3.503*	-5.66***	-3.47*	-5.66***	-3.111	2014	-5.173***	1994	-4.106	2009
PRI	-2.32	-4.99***	-2.49	-5.07***	-4.627*	2009	-2.419	2013	-4.919*	2009
SEC	-1.83	-5.94***	-1.82	-5.98***	-3.834	2007	-3.130	2013	-4.891*	2007
TER	-3.57*	-5.26**	-2.97	-4.92***	-4.707*	2006	-3.473	2004	-3.020	2002
ICT	-3.492*	-7.36***	-3.56*	-7.25***	-3.985	1995	-4.086	2000	-4.166	2008
GDP	-2.67	-3.22*	-2.22	-3.68**	-4.710*	2005	-5.241***	2014	-4.964*	2014
HC	-2.21	-4.34***	-1.70	-3.462*	-4.381	1999	-4.699**	2005	-4.882*	1999

Note. *** p<0.01, ** p<0.05, * p<0.10. Augmented Dicky Fuller and Phillips- Perron tests include trend and intercept. The Zivot-Andrews tests are the minimum Dicky–Fuller statistics with one structural break in trend (Zt), intercept (Zd), as well as both trend and intercept (Zdt). Breaks indicate the years when minimum DF statistics are found.

After knowing the order of integration of the variables, the bound testing procedure is applied in order to the long-run relationships among them. Results of the bound test are reported in Table 4 where the upper-panel (Panel A) indicates the results of FDI equation while the lower-panel (Panel B) shows ICT equation. One can see that the F-statistics are significant in the equations. We employed GDP and HC as control variables in Model 2 and 3. The F-statistics revealed that cointegration exists between sectoral distribution of FDI and ICT.

Table 4. Bound test result.

Specifications	Lag order	F-stat.	Lag order	F-stat.	Lag order	F-stat.	Lag order	F-stat.
Panel A.								
	ICT to FDI		*ICT to PRI*		ICT to SEC		ICT to TER	
Model 1. FDI /(ICT)	(1,1)	5.67**	(3,1)	6.0**	(1,1)	3.26	(4,0)	1.54
Model 2.FDI/(ICT, GDP)	(3,0,2)	8.49***	(4,3,3)	5.63**	(1,0,2)	5.71**	(3,0,2)	5.84**
Model 3.FDI/(ICT, GDP, HC)	(2,4,3,4)	6.98***	(4,3,4,2)	5.83***	(4,3,4,2)	5.83***	(4,4,4,4)	4.77**
Panel B.								
	FDI to ICT		PRI to ICT		SEC to ICT		TER to ICT	
Model 1.ICT/(FDI)	(1,1)	9.85***	(4,2)	59.5***	(3,0)	39.29***	(3,4)	40.22***
Model 2.ICT/(FDI, GDP)	(1,4,4)	16.37***	(3,2,1)	20.70***	(1,0,0)	31.63***	(1,4,1)	19.38***
Model 3.ICT/ FDI, GDP, HC)	(1,4,4,4)	31.25***	(3,2,4,4)	12.15***	(2,4,4,4)	16.17***	(3,4,3,2)	13.96***

Notes: ***, **, and * denote significance at 1%, 5%, and 10%, respectively. Lag selection is based on the AIC. Case II: restricted intercept and no trend. No cointegration hypothesis is test

on the basis of critical values provided by Narayan (2005). The upper and lower bounds of 1 k at 1% = 5.2 and 6.3, at 5% = 3.5 and 4.4, at 10% = 2.9 and 3.7. The upper and lower bounds of 2 k at 1% = 4.6 and 6.0, at 5% = 3.3 and 4.3, at 10% = 2.7 and 3.6. The upper and lower bounds of 3 k at 1% = 4.3 and 5.8, at 5% = 3.1 and 4.2, at 10% = 2.5 and 3.6.

The Johansen multivariate cointegration test is conducted to check for robustness (see Table 5). The results show that three cointegrating vectors are there to connect these variables in the long-term, thus we can say that our results are reliable and robust.

Table 5. The Johansen cointegration analysis.

Hypothesis	Trace statistic	Max. Eigen value
R=0	175.09***	67.66***
R≤1	107.42***	57.53***
R≤2	49.89**	22.31**
R≤3	27.58*	14.32**
R≤4	13.25	8.60
R≤5	4.650	4.65

Note. * p<0.10, ** p<0.05, *** p<0.01

After identifying the long-term relationship between ICT and FDI (aggregate and sectoral FDI), we estimate the long-term effects. In this regard, we have Table 6 which consists of two panels (Panel A and B). Panel A shows the estimation results when FDI is used as a dependent variable, while Panel B indicates where ICT is employed as a dependent variable. Here we see that the coefficients of ICT are significant and positive in all specifications of FDI. The effect of ICT on FDI is such that if ICT is achieved by one percent, there will be an increase of 0.66 - 2.07 percent in aggregate FDI, 0.76 - 1.36 percent in agricultural sector FDI, 0.57 - 0.80 percent in manufacturing sector FDI, and 0.34 - 1.67 percent in services sector FDI, respectively ($0.1 < p < 0.01$). This may be due to the fact that the ICT sector provides efficient and effective ways of producing goods and services in all walks of business operations. For example, the use of agbots is increasing to help with the shortage of human farm labour. Robots are being used to pick fruit, milk cows, and other jobs that formerly required human labour. These agbots have specialised arms that can perform a variety of farm duties.

The Digital Transformation of the agricultural industry started many years ago, but the current COVID-19 pandemic has sped up this process for many businesses and individuals.

Another instance of using ICT in the primary sector is the vertical farming where it is vital in meeting the need for food security and reducing the greenhouse gases emissions. ICT expansion and its feasibility in the *manufacturing sector* can be judged by the fact that it helps facilitate business operations through automatic production. In the presence of a well-developed ICT sector, there is no need for human presence, supervision, and lighting; hence, it may lead to high efficiency and productivity. The presence of ICT allows economies of scales for the firms in the *services sector* and their competitive structure explained by both increased fragmentation as well as concentration. Our findings are similar to Gholami et al. (2006).

On the other hand, Panel B reports the results when we use ICT as the dependent variable and it is evident that aggregate as well as sectoral FDI positively affects the ICT sector of China. The effect of FDIs on ICT is such that if aggregate FDI is achieved by one percent, there will be an increase of 0.16 - 0.47 percent in ICT ($^{p} < 0.01$). A one percent increase in the agricultural, manufacturing and services sector FDI can increase ICT by 0.08 - 0.19 percent ($^{0.1 < p < 0.05}$), 0.29 - 0.88 percent ($^{0.05 < p < 0.01}$), and 0.09 - 0.28 percent ($^{p < 0.01 \text{ and } p < 0.1}$), respectively. The results are in line with Song et al., (2020). In this regard, the primary sector may provide raw materials for the expansion of the silicon-valley; the manufacturing sector transforms the raw materials into finished goods, while the service sector supports the ICT industry by providing needed capital and labour. Table 6. Results on Long Run Effect (See at end of article).

Similarly, the coefficients of control variables are according to our expectations and economic theories. The diagnostic results show that the inclusion of additional variables improves the overall goodness of fit. GDP is an important determinant of FDI and ICT. GDP has a significant and positive impact on the aggregate as well sectoral distribution of FDI, i.e., a one percent increase in GDP may increase the aggregate, agricultural, manufacturing, and services sectors FDI up to 1.34, 1.54, 0.58, and 3.80 percent, respectively. Similarly, HC has a significant and positive impact on the aggregate as well sectoral distribution of FDI, i.e., a one percent increase in HC may increase the aggregate, agricultural, manufacturing, and services sectors FDI up to 7.13, 10.03, 4.16, and 19.73 percent, respectively. The reverse effect also holds which employs that GDP and HC positively and significantly impact the ICT sector.

Sensitivity analysis and diagnostics results are shown in Table 7 (See at end of article). The Lagrange Multiplier (LM) test shows that our models are not suffering from the autocorrelation. The autoregressive conditional heteroskedasticity (ARCH) test reveals that we have no heteroskedasticity problem. The Ramsey reset test indicates that our models is correctly specified. Similarly, the Jarque-Bera test shows that the residuals of the models are normally distributed.

The establishment of cointegration is a necessary condition of the long-term relationships among variables (Narayan and Smyth, 2005). For a sufficient condition to be fulfilled, there should be at least unidirectional causality among the underlying variables (Morley, 2006). Table 8 reports the results of short- and long-term causalities. Short and long-term causalities are determined by the significance of lagged levels of independent variables through the application of the Wald test (Ali and Wang, 2018; Lee, 2010; Zhang, 2001). The results imply that there is bidirectional causal relationship between ICT and all levels of FDI. The values of ECTs are significant and negative.

Table 8. Granger causality results.

Panel A. ICT to FDI

	Short-run causality (F-statistics)	*Long-run causality (F-statistics)*					
	ΔICT	*ΔGDP*	*ΔHC*	*ΔICT*	*ΔGDP*	*ΔHC*	*ECT*
ΔFDI	5.2**			17.1***			-0.17***
	-	0.08		0.53	0.11		-0.18*
	7.8**	9.6***	15.8***	49.7***	16.8***	43.9***	-0.47***
ΔPRI	9.6***			9.7***			-0.45***
	9.6***	3.56*		0.12	3.11*		-0.93***
	11.8***	0.74	4.44*	4.28**	3.62*	13.1***	-0.34
ΔSEC	2.70*			14.3***			-0.41***
	-	0.07		8.8***	0.05		-0.64***

	3.77*	4.13*	10.1***	3.46*	2.44	10.9***	-0.34***
ΔTER				3.19*			-0.09*
		1.49		0.02	0.17		-0.02
	10.0**	1.20	14.8***	17.1***	35.7***	56.8***	-0.02
Panel B. FDI to ICT							
	Short-run causality	*Long-run causality*					
	Δ FDI	*ΔGDP*	*ΔHC*	*Δ FDI*	*ΔGDP*	*ΔHC*	*ECT*
ΔICT w.r.t FDI	4.22*			16.4***			-.29***
	12.9***	7.6***		19.4***	42.5***		-.74***
	54.2***	8.34**	14.1***	48.2***	31.3***	36.5***	-1.01
ΔICT w.r.t PRI	10.2***			1.2			-.18***
	6.9***	1.36		1.02	5.60**		-.28***
	3.90*	1.4	1.15	0.75	0.76	1.10	-.21*
ΔICT w.r.t SEC				5.82**			-.24***
				5.71**	6.58***		-.37***
	12.4***	4.64*	11.3***	0.25	0.24	0.26	-0.07
ΔICT w.r.t TER	0.01			0.01			-.23***
	4.18*	2.10		11.4***	27.2***		-.58***
	10.4***	2.32	21.1***	35.3***	36.4***	40.3***	-1.43***

Note. * *p<0.10,* ** *p<0.05,* *** *p<0.01.* w.r.t = with respect to.

The aim of our study was to examine the causal nexus between sectoral FDI and the ICT sector of China. The above discussion shows that that there exist bidirectional long- and short-term causal relationships between ICT infrastructure and FDIs. Our study confirms the hypothesis that ICT positively attract foreign investors; the reverse impact also holds. The presence of foreign investment boosts ICT performance in China. Sectoral distribution of FDI also played a key role in promoting ICT infrastructure. The possible explanations of the results are that the Chinese internet, as well as other companies, are growing enormously and becoming more influential because the private sector and state are financing them with needed capital both inside and outside of the country.

Additionally, the ICT infrastructure became an integral part of daily life in China since the entrepreneurs create new business applications and technologies that support and bring innovation into the day to day activities and routine work. The usage of smartphones and other IT (information technology) types of equipment resulted in less investment in fixed-line telephones and other advanced technologies, thus the introduction of these technologies enabled Chinese people to do many smart things like e-commerce, shop online etc.

Moreover, the domestic players in the *telecom and hardware sector,* i.e., China Unicom, China Telecom, China Mobiles, Lenovo, Huawei, Founder, Haier, Xiaomi, etc. play a key role in attracting foreign investment in China. The presence of foreign companies, i.e., IBM, HP, Dell, Apple, Cisco, and ARM, contribute positively to the ICT sector. Similarly, the domestic player in the software industry (e.g., Kingdee, Huawei, and Neusoft) performs well in attracting FDI (Microsoft, Apple, SAP, Cisco, and Oracle). In a nutshell, MNEs invested 16% of the total FDI in the ICT sector of China. And the presence of domestic players in the ICT sector paves the way for further investments.

The recent literature on China shows that HC is a crucial factor in developing the ICT sector (Pick et al., 2013) and attracting FDI in various sectors (Salike, 2016). Our results also support the hypothesis that the education sector (secondary school enrolment) has a positive correlation with the sectoral distribution of FDI and ICT expansion. The results are line with Pick et al., (2013) and (Salike) 2016). Similarly, market size increases productivity and sales of the MNEs thereby attracting them to the host economies. Chakrabarti (2001) provided strong evidence by arguing that the GDP of host economies can determine FDI inflows to the host economies. With large market size and GDP, the residents of the host may have a higher propensity to consume ICT development (Nishida et al., 2014; Song et al., 2020).

The summary results of the short and long-termcausality between the ICT infrastructure and foreign direct investments (aggregate and sectoral) are shown in Table 9. The summary indicates that there is bidirectional causality between ICT and sectoral FDI.

Table 9. Long- & short-run causality

Specifications	Short-run causality	Long-run causality
Aggregate as well as sectoral FDI and ICT		
Model 1.	Bidirectional	Bidirectional
Model 2.	Bidirectional	Bidirectional causality
Model 3.	No causality	Bidirectional causality

Conclusion

The massive inflow of foreign direct investment (FDI) in China is a marvellous phenomenon the world has seen over the last three decades. The opening up policy made China the second-largest destination for FDI. In the meantime, the Chinese ICT sector also improved. Hence, this study is an endeavour to examine the sectoral FDI-ICT nexus.

Previous studies focus on the impact of ICT on FDI in a cross-country analysis or concentrate on a single aspect of ICT like the internet, mobile phone subscriptions, and vice versa. For the first time, we contribute to the existing literature by investigating the relationship between sectoral FDI and ICT on a country level to give in-depth insight. We investigate the relationship in a broader set of ICT indicators and multilevel specifications framework. The indicators are composed of a number of internet users, personal computers, mobile cellular telephone subscriptions, fixed telephone lines, ISDN subscriptions, and faults per 100 fixed telephone lines per year.

Using the ARDL and VECM approaches, we find a long-term relationship between ICT and sectoral distribution of FDI. The estimated coefficients of ICT reveal that it positively and significantly affects FDI. The Johansen's multivariate cointegration verifies the robustness of the results. The Granger causality in the VECM framework shows that a bidirectional short- and long-term causal relationship exists among the variables in our study.

Based on our findings, we put forward several policy recommendations, such as investment promotion policies, Silicon Valley development, tax and tariff reduction, and the like. China needs more investments in its ICT sector to be at par with the developed economies and encourage more; therefore, the government should focus on this issue. This study is the limited explanation of sectoral FDI-ICT nexus, and it can be extended by exploring the mechanism at the firm and sub-sectoral level, e.g., telecom, real estate, pharmaceuticals, and vice versa. Rich and comprehensive datasets of the control and independent variables are needed to produce robust results that are free from omitted variable biases.

Disclosure statement

No potential conflicts of interest were reported by the authors.

Appendix A

Figure A1. ICT and non-ICT intensive sectors in the US and China. 0=NA, 1=No, 2=Yes, and 3=Yes/No.

Appendix B

Table B1. ICT sector's scope comparison.

NBS classification	OECD definition
Manufacturing	
396-7/399. electronic tubes, valves 395. Equipment and apparatuses related to communication, televisions, and radios. 394. Radars as well as its apparatuses 393. Line telegraphy as well as its apparatuses, such as radios and televisions transmitters 392. Communications equipment 391. Peripheral equipment and computers A390. Machinery related to electronic, telecommunication, and computing	2680. Optical as well as magnetic media 2640. Consumer electronics 2630. Equipment about communication 2620. Peripheral equipment and computers 2610. Electronic boards and components
Services	
I65. Computer services I64. Web portals, hosting, and data processing	9512. Repairing of equipment related to communication

I63. Telecommunication activities such as satellite, wireless, and wired	9511. Repairing of equipment related to peripheral and computers 6312. Web portals 6311. Data hosting and processing 6209. computer and IT services 6202. activities related to computer's facility management as well as consultancy 6201. activities related to computer programming 6190. activities related to telecommunication 6130. Satellite telecommunication 6120. Wireless telecommunication 6110. Wired telecommunication 5820. Software publishing

Source: China National Bureau Statistics (2011) and (OECD Guid. to Meas. Inf. Soc. 2011, 2011) OECD (2011) .

Note: The classification of the ICT scope and sectors is based on the ISIC Rev.4 industries classifications' code.

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Table 6

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Panel A. Effect of ICT on FDI												
	Aggregate FDI	Primary FDI	Manufacturing FDI	Service FDI								
ICT	0.71***	0.66*	2.07**	1.00***	0.76*	1.36*	0.61***	0.80***	0.57*	0.34*	0.80*	1.67***
	(0.197)	(0.334)	(0.695)	(0.262)	(0.431)	(0.750)	(0.213)	(0.249)	(0.298)	(0.202)	(0.450)	(0.451)
GDP		0.39*	1.34**		0.71*	1.54*		0.24**	0.58*		0.88**	3.80**
		(0.207)	(0.407)		(0.380)	(0.798)		(0.117)	(0.324)		(0.404)	(1.094)
HC			7.13**			10.03**			4.16*			19.73**
			(2.263)			(3.437)			(1.983)			(4.965)
_cons	2.93***	1.48	8.41**	5.50***	2.63	16.67**	6.31***	9.18***	21.88***	1.52*	1.14	26.85***
	(1.033)	(2.580)	(3.041)	(1.742)	(5.163)	(6.070)	(2.159)	(2.311)	(6.087)	(0.753)	(5.318)	(9.362)
Adj. Rqrd	0.30	0.57	0.80	0.40	0.45	0.65	0.24	0.45	0.57	0.22	0.54	0.74
F-stat.	4.41***	5.59***	6.84***	4.23***	2.66**	3.84**	3.53**	4.98***	3.64**	2.32*	5.09***	4.53**
Panel B. Effect of FDI on ICT												
FDI	0.16***	0.26***	0.47***	0.08*	0.19*	0.15**	0.88***	0.29**	0.84**	0.10***	0.09*	0.28***
	(0.019)	(0.085)	(0.078)	(0.035)	(0.107)	(0.061)	(0.042)	(0.149)	(0.250)	(0.012)	(0.042)	(0.051)
GDP		0.67***	0.53***		0.08*	0.20*		0.09*	0.65**		0.42**	0.55***
		(0.182)	(0.114)		(0.031)	(0.101)		(0.042)	(0.257)		(0.159)	(0.122)
HC			1.78***			0.76			3.77**			2.54***
			(0.355)			(0.869)			(1.086)			(0.519)
_cons	0.92***	4.40***	2.78***	0.01	1.11	1.49	1.16*	2.47***	13.10**	0.04	3.92**	7.75***
	(0.313)	(1.057)	(0.671)	(0.282)	(0.645)	(1.948)	(0.642)	(0.704)	(4.356)	(0.187)	(1.393)	(1.428)
Adj. Rqrd	0.78	0.86	0.96	0.85	0.86	0.86	0.77	0.77	0.85	0.78	0.80	0.94
F-stat.	28.63***	14.31***	33.54***	20.94***	19.03***	10.08***	20.73***	27.84***	9.31***	11.69***	13.17***	24.55***

Note. * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Values in parenthesis represent standard errors.

Table 7. Sensitivity analysis.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
AC	2.126 (0.16)	2.475 (0.13)	0.521 (0.49)	0.002 (0.96)	0.017 (0.90)	3.121 (0.12)	1.058 (0.31)	0.902 (0.35)	0.720 (0.41)	0.115 (0.73)	0.016 (0.90)	6.016 (0.07)
ARCH	1.94 (0.16)	1.981 (0.15)	0.131 (0.71)	0.598 (0.43)	0.625 (0.42)	1.002 (0.31)	0.471 (0.49)	0.941 (0.33)	0.018 (0.89)	1.739 (0.18)	1.672 (0.19)	0.015 (0.90)
Functional specification	1.50 (0.24)	1.54 (0.24)	4.80 (0.06)	0.08 (0.96)	2.01 (0.18)	0.14 (0.93)	2.16 (0.12)	0.31 (0.81)	0.97 (0.44)	1.49 (0.25)	2.14 (0.14)	0.73 (0.62)
Normality	4.51 (0.11)	4.981 (0.08)	0.389 (0.82)	3.15 (0.21)	0.19 (0.90)	0.31 (0.85)	5.15 (0.08)	0.54 (0.76)	3.21 (0.20)	0.246 (0.88)	0.12 (0.94)	5.72 (0.06)
Stability	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*
	Aggregate FDI	Primary FDI	Manufacturing FDI	Service FDI								
AC	1.253 (0.27)	0.785 (0.39)	4.016 (0.09)	1.382 (0.25)	1.122 (0.30)	0.964 (0.35)	0.222 (0.64)	0.286 (0.59)	2.872 (0.14)	0.007 (0.93)	0.041 (0.84)	3.016 (0.12)

ARCH	1.130 (0.28)	1.269 (0.25)	2.467 (0.11)	1.151 (0.28)	0.031 (0.86)	0.011 (0.91)	1.809 (0.17)	0.625 (0.42)	0.004 (0.94)	1.360 (0.24)	0.003 (0.95)	1.177 (0.27)
Functional specification	3.31 (0.19)	0.034 (0.98)	0.860 (0.65)	0.778 (0.67)	4.231 (0.12)	0.324 (0.85)	3.231 (0.20)	5.20 (0.07)	3.53 (0.17)	1.982 (0.37)	1.361 (0.50)	0.360 (0.83)
Normality	0.48 (0.70)	2.02 (0.18)	3.88 (0.09)	1.11 (0.37)	1.73 (0.20)	0.25 (0.85)	0.99 (0.42)	0.42 (0.73)	5.10 (0.08)	0.57 (0.64)	1.11 (0.37)	3.78 (0.10)
Stability	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*	*Stable*