The Impact of International Trade and Foreign Direct Investment on a Nation's Domestic Innovation: An Empirical Study

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Abstract:

This project is an empirical investigation of the role of international trade in determining the rate of innovation in leading innovative and emerging innovative countries. Previous research has revealed strong and positive relation between trade and innovation rates. This project focuses on measuring the impact of imports of goods and services, impacts of imports of high-technology goods as well as the impact of foreign direct investment(FDI) on a country domestic innovation level. This project is also trying to find out the heterogenous effects of international trade and capital flows on leading innovative and emerging innovative countries. The analysis is conducted on a panel data of 20 countries from 2000 to 2016, which are compiled from sources including World Intellectual Property(WIPO), World Development Indicators(WDI), The Organization for Economic Co-operation and Development Indicators(OECD) and so on. Patents granted by each country is used as a proxy variables of a nation's domestic innovation capability. The results show that (i) imports of goods and services in general have a strong negative impact on a nation's innovation level; however, (ii) imports of high-technology goods, which is measured as ICT goods (Information, Communication, Technology goods) have a significant positive influence. Besides, (iii) FDI might have a negative impact in country FE model and a positive impact in time FE model and no significant effect in RE model. Fixed effects and random effects

regression effect are applied. Principal Component Analysis and Extremely Randomized Trees algorithms are used to find out most relevant control variables.

Introduction

Trade have been an unneglectable force in fostering a country's economic growth and innovation level. Imports provide more choices for consumers and boost consumption and exports provide opportunities for domestic firms to compete with firms abroad and benefit from international consumers. It also enhances a country's absolute and comparative advantages in production through reallocating a country's capital and resources to the most productive sectors. 'Creative destruction' is a term raised by Joseph Schumpeter to describe the process of 'industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one.' Paul Krugman emphasized the importance of trade in accelerating this process and technological growth in his book Pop Internationalism. For developing countries, foreign investment also makes it possible to develop advantages in capital-intensive industries combined with their existing advantages in labor-intensive industries.

On the other hand, trade could bring competition that shocks domestic firms in a negative way. Research theory shows that there is general negative relationship between product diversification and innovation (Hitt, Hoskisson, Ireland (1994)). Some model shows that competition only encourages neck-and-neck firms to innovate and discourages laggard firms (Aghion, Bloom, Blundell, Griffith, Howitt (2005)).

In this research, I am interested in finding out whether negative or positive effects of international trade dominates the other in explaining a country's innovation activities. I am interested in finding out if trades of various goods and services types would exert different influences by comparing the effects of importing ICT goods and the effects of overall level of imports. Also, it is question worth pursing in terms of whether the impact of FDI and trade flows reveal similar patterns for both leading innovative countries who already have had much knowledge capital and emerging innovative capital who are catching up in their innovation levels. The hypothesis is that international trade would have strong impact on national innovation level and the impact scales would differ by trading types as well as by countries with various innovative power.

Literature Review

Economists have long been interested in the models of innovation and economic growth in open economies. Study by Eaton and Kortum (1996) focused on a sample of developed countries and showed that the major of growth in the countries in their sample come from innovation in United Sates, Germany and Japan. Eaton and Kortum also found the positive spillover effects of trade in spreading benefits of advanced technology and the importance of geographical proximity in enjoying the benefits (Eaton and Kortum (1997)). Interestingly, research has provided evidence on how emerging or lagging innovative countries can take advantage of the technologies developed by leading innovative countries and surpass them by developing institutions that can deal with challenges more efficiently than their competitors (Giuliani, Gorgoni, & Rabellotti, 2014; Luo & Tung, 2007). These studies reveal interesting dynamics of technological diffusion through trade between leading and emerging innovative countries.

Other research papers also study the impacts of international trade on innovation and knowledge diffusion in one individual country. A paper named 'Do Firms learn from

International Trade' by Megan MacGarvie validates the positive impact of international trade on firm-level inventions in France by showing that firms with more patents tend to make citations and be cited by foreign patents. Other papers study the negative impacts of international knowledge flows in preventing domestic innovative activities. The paper 'Foreign Competition and Domestic Innovation: Evidence from U.S. Patents' showed that Chinese competition led to fall in innovation on firm levels by studying the changes of main patents concentration across sectors. These papers provide evidence that impacts of trade vary from country to country and also from industry to industry. How to study the impacts in stratified groups of countries and industries will be crucial to accurate estimation.

A paper of particular interest to me studies the impact of international trade activities and intellectual property rights (IPR) on national innovation in leading innovator countries and emerging innovator countries using a dataset covering 80 countries in the time period from 1981 to 2010(Wu, Ma, Zhuo(2017)). The main model in this paper builds upon the framework developed by Furman and Hayes which states that a nation's innovation level is mainly determined by three factors: common innovation infrastructure, cluster-specific environment for innovation and quality of linkages. Wu, Ma and Zhuo modify this framework to let it fit in an open economy by incorporating international trade activities, foreign direct investment, index of a country's legal system and other control variables. Their results reveal that imports of high technology goods and FDI have a significant impact on boosting innovation activities in emerging innovator countries while have no impacts on those in leading innovator countries. Also, IPR protections are beneficial for innovation in leading innovator countries and harmful for innovation in emerging innovator countries.

Methodology

Model:

The model in this project is inspired by the paper 'Enhancing national innovative capacity: The impact of high-tech international trade and inward foreign direct investment'(Wu, Ma, Zhuo(2017)) and is an adaption to a close-economy model by Furman & Hayes in 2004. The model by Furman & Hayes builds a relationship between flows of innovations and observable contributors to national innovative capacity.

$$I_{i,t} = (X_{i,t}^{INF}, Y_{i,t}^{CLUS}, Z_{i,t}^{LINK}) H_{i,t} A_{i,t} \tag{1}$$

In this model, $X_{i,t}^{INF}$ is a nation's innovation infrastructure; $Y_{i,t}^{CLUS}$ is the environment for innovation in a country's industrial cluster; $Z_{i,t}^{LINK}$ is the strength of linkage between common infrastructure and a nation's industrial clusters; $H_{i,t}$ is human capital stock in a nation; $A_{i,t}$ is stock of knowledge in a nation.

To change this model to an open-economy model, I incorporated the theoretical constructs of interest representing international trade flows and foreign direct investment into the model, which is $M_{i,j}$(international trade flow) and $F_{i,j}$ (foreign direct investment). Besides control variable are also included to solve omitted variable bias issue, which is $C_{i,j}$(other relevant control variables). The open economy model is the following:

$$I_{i,t} = (X_{i,t}^{INF}, Y_{i,t}^{CLUS}, Z_{i,t}^{LINK}) H_{i,t} A_{i,t} M_{i,t} F_{i,t} C_{i,t} \tag{2}$$

After taking natural log transformation on both sides, it becomes a linear regression model and can better interpreted in terms of elasticity. Besides, it is less sensitive to outliers before log transformation.

$$lnI_{i,\,t} = \beta_0\, lnC_{i,t} + \beta_1 lnX_{i,\,t}^{INF} + \beta_2 lnY_{i,\,t}^{CLUS} + \beta_3 lnZ_{i,t}^{LINK} + \beta_4 lnH_{i,t} + \beta_5 lnA_{i,\,t} + \beta_6 lnM_{i,\,t} + \beta_7 lnF_{i,\,t} \qquad (3)$$

Data:

The panel data of 20 countries ranging from 2000 to 2016 come from sources World Intellectual Property(WIPO), World Development Indicators(WDI), The Organization for Economic Co-operation and Development Indicators(OECD) and so on. Patents granted in each country has been widely adopted by economists to measure a country's innovation level. After checking for multicollinearity using Variance Inflation Factors among all potential proxy variables for the model, I choose to use **education expenditure as a percentage of total GDP**, **secondary school enrollment gross percentage** to measure common innovation infrastructure; **percentage of R&D expenditure by business sector** to measure cluster-specific innovation environment; **percentage of R&D expenditure by government** to measure the quality of linkage between common innovation infrastructure and cluster-specific innovation environment; **imports of services and goods as percentage of total GDP** and **ICT goods imports as percentage of total goods imports as trade flows**; **foreign direct net inflows in U.S. billions dollars** to measure as FDI.

To find control variables, I run PCA and Extremely Randomized Tree models to pick the two most relevant variables from ten potential control variables including female percentage in labor force, urban population as percentage of total population, access to electricity as percentage of population and so on. Using PCA method, I choose control variables by selecting the ones with highest values of sum of multiplication of explained variance ratio and feature score for component. In Extremely Randomized Tree method, I choose the ones with highest feature importance scores. The PCA method selects **domestic credit to private sector as percentage of GDP** and **mobile phone subscription per 100 people** as control variables. The randomized tree method selects **population ages 65 and above as percentage of total population** and **urban population as percentage of total population**.

The panel data are divided into leading innovative countries and emerging innovative countries based on their patents stock. Leading innovative countries include **Canada, Finland, Germany, Israel, United States, Japan** and **Sweden**. Emerging innovative countries include **Argentina, Austria, Belgium, China, Czech Republic, Denmark, Greece, Ireland, Italy, Mexico, New Zealand, Singapore** and **Turkey**.

	VIF Factor	features
0	177.3	Intercept
1	3.5	rd_p
2	3.3	rd_g
3	1.7	ict
4	1.8	edu
5	1.1	fdi
6	2.0	im
7	3.0	sec_enroll
8	2.0	dom_credit
9	1.6	cellphone

Table 1: VIF Factor for model including control variables selected by PCA

(factors < 5 indicating no strong correlation among exogenous variables)

	VIF Factor	features
0	237.9	Intercept
1	4.4	rd_p
2	3.3	rd_g
3	1.8	ict
4	1.7	edu
5	1.0	fdi
6	2.5	im
7	3.7	sec_enroll
8	2.2	pop_65
9	2.1	urban_pop

Table 2: VIF Factor for model including control variables selected by Randomized Tree

(factors < 5 indicating no strong correlation among exogenous variables)

	edu	rd_p	rd_g	ict	fdi	im	sec_enroll	dom_credit	cellphone	pop_65	urban_pop
edu	1.000000	0.126317	-0.303193	-0.321987	-0.056282	-0.210041	0.599684	0.287437	0.222695	0.195262	0.198987
rd_p	0.126317	1.000000	-0.784450	0.203418	0.328822	0.027985	0.260337	0.597161	0.050872	0.358855	-0.016813
rd_g	-0.303193	-0.784450	1.000000	0.007508	-0.203367	-0.022962	-0.368030	-0.538538	-0.201134	-0.346396	-0.064278
ict	-0.321987	0.203418	0.007508	1.000000	0.212372	0.459598	-0.376430	0.134480	-0.249032	-0.462458	-0.106997
fdi	-0.056282	0.328822	-0.203367	0.212372	1.000000	-0.091301	-0.122250	0.372663	-0.134774	-0.134299	-0.198044
im	-0.210041	0.027985	-0.022962	0.459598	-0.091301	1.000000	0.499392	-0.034895	0.251227	-0.151001	0.312309
sec_enroll	0.599684	0.260337	-0.368030	-0.376430	-0.122250	0.499392	1.000000	0.121664	0.327124	0.417081	0.553578
dom_credit	0.287437	0.597161	-0.538538	0.134480	0.372663	-0.034895	0.121664	1.000000	0.043353	0.330870	0.011944
cellphone	0.222695	0.050872	-0.201134	-0.249032	-0.134774	0.251227	0.327124	0.043353	1.000000	0.474324	0.265368
pop_65	0.195262	0.358855	-0.346396	-0.462458	-0.134299	-0.151001	0.417081	0.330870	0.474324	1.000000	0.146332
urban_pop	0.198987	-0.016813	-0.064278	-0.106997	-0.198044	0.312309	0.553578	0.011944	0.265368	0.146332	1.000000

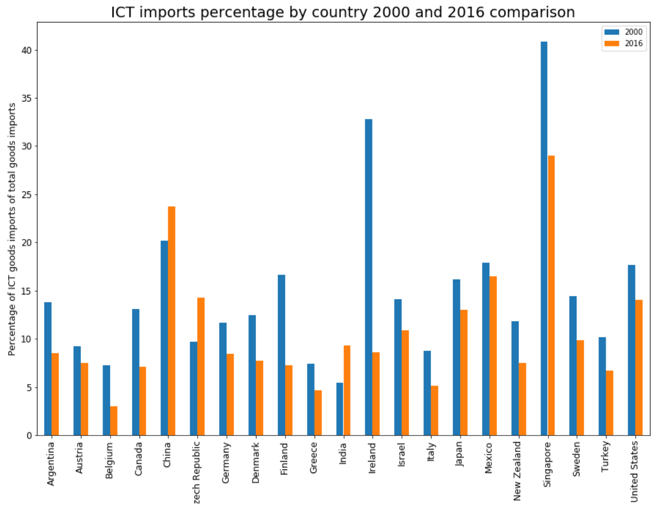
Table 3: Correlation between each variable

	count	mean	std	min	25%	50%	75%	max
edu	82.0	5.453508	1.180042	3.319150	4.819010	5.553995	6.387885	7.717740
rd_p	107.0	60.984384	11.173612	34.263929	53.051998	63.523296	68.161230	78.172487
rd_g	106.0	24.905388	6.637841	12.181295	18.525667	26.281771	30.383377	34.883262
ict	119.0	10.853075	2.577123	5.769329	8.809738	10.876453	12.825693	17.655702
fdi	119.0	59.229243	99.217035	-20.444719	6.982027	18.217810	62.054477	506.000000
im	119.0	29.745480	10.239378	9.195168	17.369192	32.892596	38.190866	43.546034
sec_enroll	111.0	106.706454	14.026718	93.033859	99.623047	102.092537	107.531620	152.168426
dom_credit	108.0	122.243737	45.710095	52.718727	80.215104	110.193229	165.392423	212.268799
cellphone	119.0	97.702962	29.318804	28.393625	77.400874	98.466525	121.845123	172.178726
pop_65	119.0	16.252764	3.976178	10.012237	12.819154	16.544534	19.107058	26.564563
urban_pop	119.0	83.270353	5.631181	73.067000	80.072000	82.905000	85.889500	93.928000

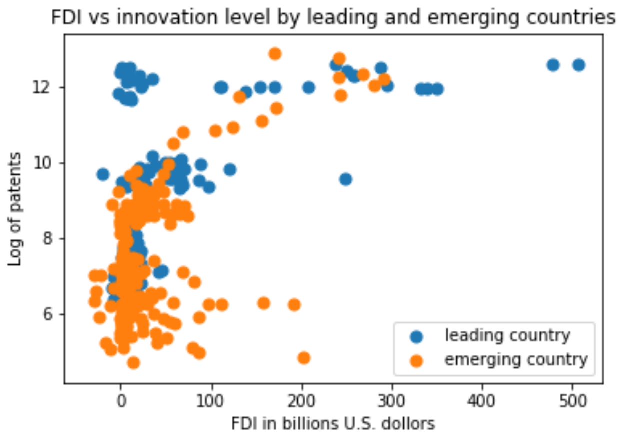
Table 4: Summary statistics for leading innovative country panel data

	count	mean	std	min	25%	50%	75%	max
edu	162.0	5.054183	1.421172	2.529080	4.091150	4.839075	5.847600	8.559550
rd_p	179.0	47.464804	13.214955	17.219706	38.725639	47.279813	58.577297	76.058786
rd_g	179.0	39.912143	13.900720	20.034815	28.215242	37.979418	47.431999	76.385317
ict	221.0	11.940404	8.162549	2.753965	6.058860	8.668268	16.452883	40.805818
fdi	219.0	29.685718	53.168352	-29.948414	2.880601	11.809449	33.374304	291.000000
im	221.0	51.079696	41.752693	10.273291	26.549505	33.351225	64.810112	210.409316
sec_enroll	191.0	105.136905	21.476980	59.654881	93.931030	99.479202	117.104042	163.930527
dom_credit	207.0	81.042544	47.195151	9.682518	44.952417	84.762195	111.719450	201.258664
cellphone	221.0	97.132633	36.466955	6.644332	77.893213	100.507295	121.355752	163.794486
pop_65	221.0	13.047296	4.695079	5.042874	8.791407	13.052744	17.294789	22.709319
urban_pop	221.0	76.765801	14.757530	35.877000	67.180000	75.045000	87.142000	100.000000

Table 5: Summary statistics for emerging innovative country panel data



Graph1



Graph 2

Method:

Principal Component Analysis and Extremely Randomized Tree methods are applied to find out control variables. Time and individual fixed effects method are both applied on panel data as well as leading and emerging samples. Random effects method is also applied for comparison.

Results and Discussion

	FE on country (all)	FE on country (leading)	FE on country (emerging)	FE on year (all)	FE on year (leading)	FE on year (emerging)	RE (all)	RE (leading)	RE (emergin g)
Import of goods and services (% of GDP)	-0.033*** (0.0071)	-0.0386** (0.0148)	-0.02** (0.01)	-0.0685*** (0.0027)	-0.0403** (0.0163)	-0.0505*** (0.0048)	-0.0189** (0.007)	-0.0189** (0.007)	-0.0165** (0.0068)
% of R&D expenditure by government	-0.0035 (0.0102)	-0.0062 (0.0172)	0.0201* (0.0116)	-0.0185** (0.0074)	-0.0388* (0.0218)	-0.03 (0.0213)	0.0299*** (0.0065)	0.0299*** (0.0065)	0.0305*** (0.0061)
% of R&D expenditure by private	0.0063 (0.0093)	0.0055 (0.0073)	0.0315** (0.0118)	0.0157** (0.0057)	0.0297** (0.0113)	-0.0341* (0.0199)	0.0411*** (0.0059)	0.0411*** (0.0059)	0.042*** (0.0068)
ICT import	0.0177* (0.0093)	0.0355 (0.0269)	0.0378*** (0.0065)	0.0761*** (0.0162)	-0.1325** (0.031)	0.0823*** (0.0133)	0.052*** (0.0112)	0.052*** (0.0112)	0.046*** (0.0099)
Education expenditure (% of GDP)	-0.0762 (0.0692)	-0.3364** (0.1044)	0.0729 (0.0654)	-0.5071*** (0.1043)	-0.8709*** (0.1336)	0.2336* (0.1224)	0.0617 (0.0836)	0.0617 (0.0836)	0.1015 (0.082)
FDI	-0.0013** (0.0006)	-0.0012 (0.0013)	-0.0018** (0.0008)	0.0091*** (0.001)	0.0109*** (0.0015)	0.0061** (0.0019_	-0.0001 (0.0014)	-0.0001 (0.0044)	-0.0018 (0.0012)
School enrollment percentage (secondary)	0.0108** (0.0036)	0.0104** (0.0046)	0.0254** (0.0105)	0.0089** (0.0044)	-0.0017 (0.0067)	0.0022 (0.0058)	0.0278*** (0.0044)	0.0278*** (0.0044)	0.0326*** (0.0068)
Domestic credit to private (% of GDP)	-0.008** (0.0032)	-0.0118** (0.0038)	-0.0032 (0.0039)	0.0031** (0.001)	0.0048** (0.0016)	-0.0148*** (0.0024)	-0.0021 (0.0021)	-0.0021 (0.0021)	-0.0023 (0.0023)
Cellphone subscription (per 100 people)	-0.0056** (0.0019)	0.0091* (0.005)	0.0021 (0.0013)	-0.0022 (0.0023)	-0.0135* (0.0068)	0.016*** (0.003)	0.006** (0.0016)	0.006** (0.0016)	0.0014 (0.0016)

(* p<0.1, ** p< 0.05, *** p<0.01)

Table 6: Regression Results using control variables by PCA

From the regression results using control variables by PCA, we can see that regardless of the regression methods we use (different assumptions we make on the data), imports of goods and goods and services have a significant negative impact on domestic innovation in both leading and emerging innovative countries. Besides, compared with R&D expenditure by the government, R&D expenditure by the private sector has a more important role in boosting innovation as the coefficients results for the latter tend to be more significant and positive. Different from imports of all kind of services and goods, the imports of ICT (information, communication and technology) goods tend to have more positive impacts. Also, if we focus on the fixed effects models, we can see that the impact of ICT goods in emerging innovative countries are more significant while its impact in leading innovative countries are either insignificant or negative. Likewise, education expenditure as percentage of GDP plays a much more important role in emerging countries with their impacts being negative in leading countries. Secondary school enrollment and cellphone subscription also shows great importance. The impacts of FDI is hard to tell as they show contrary results in time fixed model and country fixed model and not significant in random effect models.

	FE on country (all)	FE on country (leading)	FE on country (emerging)	FE on year (all)	FE on year (leading)	FE on year (emerging)	RE (all)	RE (leading)	RE (emergin g)
Import of goods and services (% of GDP)	-0.0209** (0.009)	-0.0567** (0.0181)	-0.0051 (0.0071)	-0.0642*** (0.0057)	-0.063*** (0.009)	-0.0432*** (0.0086)	-0.026*** (0.0059)	-0.0465** (0.011)	-0.0071 (0.0074)
% of R&D expen by government	0.0024 (0.0116)	-0.0384*** (0.0072)	0.0253** (0.0097)	-0.0205** (0.008)	0.0414* (0.0217)	0.0108 (0.0171)	0.0045 (0.0059)	0.0948*** (0.0132)	0.0271** (0.0075)
% of R&D expenditure by private	0.0048 (0.0129)	0.0064 (0.006)	0.0407*** (0.0061)	0.0059 (0.0073)	-0.0054 (0.0147)	-0.0083 (0.0183)	0.0095 (0.0058)	-0.0061 (0.0111)	0.0402*** (0.0094)
ICT import	0.0401*** (0.0092)	0.0416** (0.0139)	0.0504*** (0.0091)	0.0994*** (0.013)	-0.1264 (0.0275)	0.0661*** (0.017)	0.0417*** (0.0086)	0.0016** (0.0357)	0.0502*** (0.0099)
Education expenditure (% of GDP)	-0.1491 (0.0925)	-0.2511** (0.117)	0.0766 (0.0822)	-0.4566*** (0.0917)	-1.146*** (0.0752)	-0.079 (0.1093)	-0.1376** (0.0436)	-1.303*** (0.1099)	0.0666 (0.0853)
FDI	-0.0016** (0.0007)	-0.0003 (0.0008)	-0.0023** (0.0008)	0.0106*** (0.0009)	0.0125*** (0.0014)	0.0086** (0.0025)	-0.0005 (0.0011)	0.0119*** (0.0133)	-0.0021* (0.0013)
School enrollment percentage (secondary)	0.009** (0.0026)	0.0052** (0.0025)	0.0285** (0.0131)	-0.002 (0.0073)	0.0007 (0.0061	0.003 (0.0114)	0.0087** (0.0035)	0.0133** (0.0064)	0.0259** (0.0093)

Population age 65 or above (% of total)	-0.0526 (0.0537)	0.0595 (0.0998)	-0.0798* (0.0442)	0.071** (0.0187)	0.0844* (0.045)	0.0369**	-0.008 (0.0315)	0.0872** (0.0312)	-0.0649 (0.0495)
Urban population (% of total)	0.1099** (0.0359)	0.0759 (0.0521)	0.0072 (0.0615)	0.0188* (0.0108)	0.077*** (0.0149)	-0.0085 (0.0112)	0.0973*** (0.0117)	0.147*** (0.0062)	0.0225 (0.0221)

(* p<0.1, ** p< 0.05, *** p<0.01)

Table 7: Regression Results using control variables by Randomized Tree

Quite similar to the results using control variables chosen by PCA, the regression results using control variables by Randomized Tree Method shows significant negative impacts of imports of goods and services on innovation for both leading and emerging countries. Also, strong evidence is shown in the result in terms of the positive effects of ICT goods imports and its more significant impact in emerging countries. Besides, education expenditure also seems to have more impact in emerging countries. The FDI impact cannot be determined as they appear in different patterns for different models; unless one model is chosen, we cannot make any conclusions about FDI impact so far. In addition, secondary school enrollment and urban population also shows great importance in explaining innovation levels.

Conclusions:

After comparing the fixed effects and random effects models incorporating control variables using two machine learning methods, we can get some general conclusions. Generally, imports of goods and services would have negative impacts on a nation's innovation level. However, imports of high technology goods would have significant positive impacts on a nation's innovation level for emerging countries and potentially bad for leading innovative countries. The empirical results support the idea that competition from other countries would likely to drive local firms out of markets instead of boosting the innovative potentials in local firms. Also, for leading innovative countries, foreign ICT goods pose a threat to compete with local high-technology goods while foreign ICT goods can be a new technology to study for firms in emerging countries. This conclusion accords with some theories stating that emerging countries can take advantage of technologies by leading countries and surpass them(Giuliani, Gorgoni, & Rabellotti, 2014; Luo & Tung, 2007).

Surprisingly, the FDI coefficients results are not consistent across various models and its impacts could be ambiguous on leading and innovative countries. Their impacts are all negative in country fixed effect model and positive in time fixed effects model. Based on graph 2, we should expect a positive relation between FDI and patents granted for each country and the impact is stronger for leading countries. In this case, we are inclined to choose time fixed effects model as it better fits our assumption.

Other findings include that R&D investment by private sector plays more important role than R&D investment by the government. This might be good evidence of policy implementations in helping domestic firms to invest in technological innovations instead of by the government. Besides, the significance of secondary school enrollment suggests the importance of implementing compulsory education and strong relation between human capital accumulation and innovation. The significance of urban population points to the importance of urbanization as a foundation for clustering effects in boosting innovation.

Limitations and future research

The results of this research provide us with some insights to understand how international trade flows and foreign investment could impact a nation’s innovation level. However, there are still limitations in this research which hinder the external validity of this research. Firstly, there could be better proxy variables to measure the theoretical constructs in the model. For instance, R&D invested by private sector and R&D invested by the government measure cluster-specific innovation environment and quality of linkage respectively. They still have relatively strong correlation with each other even though VIF factors are low. This could be potentially harmful for the accuracy of independent variables in the model. More candidate proxy variables should be included to choose the best ones.

The second limitation is concerned with the data size. Some data are missing and they are balanced. It is quite difficult to get a large size of panel data with few missing values. How to balance the data becomes a crucial problem. Besides, more candidate control variables should be included to reduce omitted variable bias.

In addition, rigorous model selection criteria should be set up. In this research, we cannot tell whether the control variables selected by PCA or by randomized tree are more valid. Assumptions are not tested on the data to fit the best regression model. In the future research, more work will be focusing on establishing the criteria to choose the best model that fits the data.

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