Does Innovation Co-move with FDI? Evidence from OECD countries

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Abstract: In this study, the panel co-integration test combined with structural breaks was used to explore the long-term co-movement between FDI and patent and trademark applications， in accordance with 33 OECD countries from 1999 to 2018. The robust results demonstrate that both innovation variables including patent and trademark co-move with FDI in the OECD sample. Furthermore, this long-term co-movement of FDI and innovation experiences some structural breaks during the period 2003-2010. Finally, there is a long-term co-movement between FDI inflows and innovation activity in OECD countries.

Keywords: Innovation; FDI; Structural Breaks; DOLS.
JEL: C33; O34; F23.

Previous literature typically investigates the relationships between FDI and innovation from two directions separately, including uni-directional causality running from FDI to innovation, or the influence of innovation activities on attracting FDI. However, scant studies pay attention to the bi-directional relationship between FDI and innovation. Moreover, little research has attempted to expand attention onto the dynamic relationships between innovation and FDI. Since structural breaks are normal events in economics, ignoring them may contribute to misunderstanding the relationship between FDI and innovation. This research finds that the bi-directional co-movement between innovation and FDI is commonly neglected by previous wisdom. Therefore, the essential contribution of this study is that we examine the long-term dynamic co-movement between innovation and FDI in 33 OECD countries from 1999 to 2018, using a co-integration approach with breaks.

The rest of this paper runs follows. Section 1 is the existing literature review. Section 2 gives the theoretical background. Section 3 provides a description about the method and data, including the panel stationary test and the panel co-integration model. Section 4 exhibits the empirical results and Section 5 presents our main conclusion.

1. Literature Review

Plenty of studies have found that innovation activities are positively associated with foreign direct investment (FDI). From the theoretical aspects, the existing literature has explored the mechanism through which FDI affects national innovation performance in the host country (Cheung and Lin, 2004; Awokuse and Yin, 2010; Hsu and Tiao, 2015). Specifically, Cheung and Lin (2004) discuss four channels in greater details. First, local firms can obtain a technology spillover effect from advanced products from international firms. Second, more skilled workers trained by international firms enter local market, which encourage firms to formulate their own innovation program. Third, mature technologies brought by international firms lower the test cost of new technology. Fourth, technology spillover happens through vertical industrial linkages.

As is well recognized in the empirical literature, FDI has a positive effect on innovation activities (Javorcik, 2004; Awokuse and Yin, 2010). For example, using an ordinary least square (OLS) estimation and 138 industry sectors in 2004 as the sample, Wang and Kafouros (2009) explore the determinants of national innovation performance in emerging economies like China. The empirical evidence indicates that international trade and FDI are important determinants of national innovation performance. Additionally, Cheung and Lin (2004) examine the influence of FDI on provincial innovation output in China and note that FDI significantly promotes innovation development. Ascani et al. (2020) utilize data of manufacturing sectors in Italy to explore the impact of FDI on local innovation. They find that inward FDI indeed promotes local innovation, and this effect is stronger in science-based activities.

Numerous studies contrarily demonstrate that innovation exhibits considerable influence on FDI inflow, because international enterprises often bring advanced technologies to host countries. More commonly, Khoury and Peng (2011) indicate that innovation differences affect FDI, especially in developing countries. The authors state that strong intellectual property protection may lead to increased FDI. Aside from this, the other specific reforms are innovation-related, like patent laws that respect foreign intellectual property rights can actually attract more FDI.

Not only is the literature concerned about the determinants of innovation, but also the shocks from innovation to FDI (Wang and Kafouros, 2009; Khoury and Peng, 2011).[1] Studies have shown that intellectual property rights play an important role in attracting FDI. Improvements in intellectual property rights led to a sharp increase in foreign investment in China from 1992 to 2005 (Awokuse and Yin, 2010). Furthermore, the empirical results of Hsu and Tiao(2015) on the impact of property rights protection on FDI in 11 major Asian countries again show that improving patent protection helps to attract more FDI inflows.

2. Theoretical Background

One of the important reasons for attracting FDI is to gain advanced technology through access to products as well as services and hence improve innovation performance locally (Archigugi et al., 2011). The diffusion spillover effects of FDI are an objective existence. Konstandina et al. (2020) clearly show that FDI is able to promote technology transfer in the host country, as it can bring about a spillover effect

[1] There are few papers that explore the effect of innovation activities on attracting FDI (Khoury and Peng, 2011).

of technology, which stimulates independent innovation via technology imports and learning. Independent innovations helps promote feedback in attracting more FDI inflow (Hsu et al., 2015; Awokuse et al., 2010). Acs and Audretsch (2010) find a positive correlation between innovation activity and FDI growth rate in developed countries, but innovation activity and FDI show a negative association in most developing countries. Therefore, FDI may move and grow together with innovation in the long run, especially in OCED countries that exhibit greater economic development levels compared to developing countries.

It is also noted that the relationship between FDI and innovation is unable to remain constant and is likely to experience some structural changes. For instance, Sbia et al. (2014) show that the series of FDI follow a stationary process with some structural shifts. Solarina and Shahbaz (2015) also demonstrate that structural breaks exist in the series of FDI. In fact, FDI series tend to cointegrate with some macroeconomic variables with structural breaks. Umit and Alkan (2016) suggest that FDI has a long-term cointegrated correlation with employment under structural breaks. Therefore, structural breaks may be important in analyzing the long-term co-movement in FDI and innovation correlation activities and hence cannot be ignored in the model.

The need to consider structural breaks could be explained in the following ways. Structural breaks are a normal case in economics, as many political and economic incidents cause huge impact on FDI attractiveness or innovation performance. Structural breaks are an unneglectable problem in macroeconomic series since they cannot avoid common exogenous shocks like a global financial crisis (Chang et al., 2011).[2] For example, external factors (i.e., the 2008 global financial crisis) have brought a significant shock to FDI and innovation activities. In this case, there is a sharp decline in global FDI, and enterprises are also less likely to invest in innovation programs in order to survive during a crisis period. As a result, exogenous shocks including common ones and country-specific shifts will impact the long-term relationship between FDI and innovation, and as a result structural changes need to be accounted for in the estimation.

3. Methodology and Data

[2] Such a crisis presents a negative influence on innovation and research and development in all countries.

3.1 The panel stationary test with structural breaks

Because a structural break may disturb the stationarity of macroeconomic series, structural breaks need to be considered in studies concerning the relationships between FDI and innovation. The literature has demonstrated the importance of structural breakthroughs in examining the existence of unit roots (Chang and Lee, 2015). Zivot and Andrews (1992) develop the minimum test widely-used endogenous test. Lee and Strazicich (2001) as well as Jewell et al. (2003) investigate a model with endogenous structural breaks that brings about more significant result.

In this section we follow the models with the consideration of a structural break developed by Carrion-i-Silvestre et al. (2005), which are designed to test the null hypothesis of panel stationarity as follows:

$$y_{it} = \alpha_i + \sum_{k=1}^{m_i} \theta_{ik} DU_{ikt} + \beta_i t + \sum_{k=1}^{m_i} \gamma_{ik} DT_{ikt}^{*} + \varepsilon_{it}\,, \tag{1}$$

where y_{it} is the variable of interest in country i at time t, the dummy variable $DT_{ikt}^{*} = t - T_{bk}^{i}$ for $t > T_{bk}^{i}$, and T_{bk}^{i} denotes the k^th^ date of the break in country i, k={1,…, m_i}, $m_i \geq 1$. Implications of equation (1) mean each country may have a distinct number of structural breaks.

The test statistic for the null hypothesis as follow:

$$Z(\lambda) = \frac{\sqrt{N}(LM(\lambda) - \bar{\xi})}{\bar{\varsigma}} \rightarrow N(0,1) \tag{2}$$

We note that the limiting distribution of the test statistic is standard normal. To ensure robustness, we calculate the bootstrapped critical values.

3.2 Panel co-integration tests with structural breaks

According to the Westerlund (2006) panel co-integration test, the data generation process of dependent variables is as follows:

$$FDI_{it} = \gamma_{ij} SB_{it} + \beta_i X_{it} + e_{it}\,, \tag{3}$$

$$e_{it} = r_{it} + u_{it}\,, \tag{4}$$

$$r_{i,t} = r_{i,t-1} + \phi_i u_{i,t}\,, \tag{5}$$

X_{it} individually indicates the variables for innovation activities, patent and trademark; β_i is a country-specific slope; SB_{it} implies the deterministic components including structural breaks; and $j = 1, \dots, M_i$ refers to the break points. The locations of the structural breaks are given in the form of fixed fractions $\lambda_{ij} \in (0,1)$ of T such that $T_{ij} = [\lambda_{ij} T]$ and $\lambda_{ij-1} < \lambda_{ij}$.

To check for the existence of a long-term cointegrated relationship, the panel Lagrange multiplier (LM) test statistic is constructed as follows:

$$Z(M) \equiv \frac{1}{N} \sum_{i=1}^{N} \sum_{j=1}^{M_i+1} \sum_{t=T_{ij-1}+1}^{T_{ij}} \left(T_{ij} - T_{ij-1} \right)^{-2} \hat{\sigma}_i^{-2} S_{i,t}^2 \tag{6}$$

Here, $S_{i,t} = \sum_{k=T_{ij-1}+1}^{t} \hat{e}_{ik}^{*}$, and $\hat{e}_{i,t}^{*}$ is the regression residuals obtained using any valid estimate of the co-integration vector, such as traditional dynamic OLS (DOLS) estimates.

3.3 Panel dynamic OLS estimations with structural breaks

In order to examine the panel long-term relationships between innovation activities and FDI, we employ the panel dynamic OLS (DOLS) method, including leads and lags of the independent variables, as follows:

$$FDI_{it} = \alpha_i + \theta_i X_{it} + \varphi_i \left(X * SB_t \right)_{it} + \sum_{j=-q_i}^{q_i} c_{ij} \Delta X_{i,t+j} + \sum_{j=-q_i}^{q_i} d_{ij} \left(\Delta X * \Delta SB_t \right)_{i,t+j} + v_{it}, \tag{7}$$

where α_i indicates the country fixed effects; $X_{i,t}$ represents the innovation variable; $\left(X * SB_t \right)_{i,t}$ denotes the interaction term of innovation variable with the structural break variable; q_i indicates the leads and lags of the innovation variable; and $v_{i,t}$ refers to the error terms.

3.4 The data and variables

We gather the innovation variables, number of patent applications (*Patent*) and number of trademark applications (*Trademark*), from the World Intellectual Property Organization. Additionally, the variable *FDI* (measured by foreign direct investment, net inflow as % of GDP) is taken from the World Bank's World Development Indicators. Our final sample covers 33 OECD countries for the period 1999-2018.

Figures 1 and 2 show the time series of *Patent* and *Trademark* for 33 OECD countries respectively. These two figures indicate that the series of FDI and innovation experience structural breaks in the sample period. We find that *Patent* exhibits an overall growing trend, but with a fluctuation in most countries. It also appears that multiple structural changes occur around early 2000 and 2007. Similarly, we also plot *Trademark* for the sample, which shows the same trend as *Patent*. All most countries in our sample exhibit a fluctuation or slumping trend in 2007. This provides preliminary evidence that we should consider structural breaks when discussing the long-term linkage between FDI and innovation variables. Figure 3 and Figure 4 plot the mean scatters of *FDI-Patent* and *FDI-Trademark*, respectively. From Figure 3 and Figure 4, we roughly conclude that FDI and innovation have a long-term co-movement trend.

[Figures 1-4 are here]

4. Empirical Results

4.1 Results of panel co-integration test with multiple structural breaks

Preliminary analysis shows that when analyzing the long-term relationships between FDI and innovation activities, multiple structural breaks need to be considered in the model. We confirm the stationarity of FDI and innovation under the condition of considering structural breaks at first. Table 1 presents the results from the panel stationary test with structural breaks. The null hypothesis is that the sequence is stationary under the potential structural breaks. We observe that the statistics of the panel stationary test for *Patent* and *Trademark* are insignificant at any level of significance, irrespective of the homogenous case or heterogeneous case. We also find that the statistics for FDI do not show significance in the case of homogeneity. Overall, the panel stability test results with structural breaks support the stationarity of FDI, patent, and trademark. Once these series are stationary, we can go ahead to test the long-term co-movement between FDI and innovation.

[Table 1 is here]

Table 2 and Table 3 respectively list the panel co-integration test results of *FDI* vs. *Patent* and *FDI* vs. *Trademark*. In this process, the panel co-integration test can be a good explanation for structural breaks. Accordingly, the panel statistics are insignificant in Table 2 and Table 3, suggesting that we cannot reject the long-term cointegrated relationship in the null hypothesis. This confirms the long-term relationship between *FDI* with *Patents* and *Trademarks* at the significance level of 1%, respectively.

Our evidence does suggest that multiple structural changes in the long-term relationships of the panels need to be considered in the co-integration test. In other words, as Grossman and Helpman (1991), Aghion and Howitt (1998) suggestion that innovation is of great importance in the driving force of FDI inflow, and FDI inflow can promote national innovation development. It is therefore particularly relevant to understand the relationship between innovation and FDI in order to improve a country's international competitiveness.

Most of the anticipated structural breaks occurred in 1999-2001 and 2007-2008, respectively. The positive spillover effect of patents for advanced technology has been confirmed in the OECD countries. As is widely known, with the development of globalization in every field including, economies and cross-country investment, FDI plays an important part in domestic economic performances and technology progress. Looking back to the development of technology, both patent and trademark applications rose in almost all OECD countries between 1999 and 2004. This equates to a doubling of filings at the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO) and a 15% increase in filings at the Japanese Patent Office (JPO). The relative fluctuations in the growth rate of applications in OECD countries since 2001 are mainly due to the deterioration of the economic situation in OECD countries.

We also find that break points occur in the number of applications for patents and trademarks around 2008 from Table 2 and Table 3. The global financial tsunami broke out in 2008 and spread rapidly around the world. During the global financial crisis, R&D investment turned pro-cyclical, as seen in surveys of the 2008-2009 crisis on companies in several countries (Männasoo and Meriküll, 2011) and lead to the fell back of patent and trademark applications in OECD countries. As for companies' willingness to invest in the short term on innovation and R&D spending, the 2008 financial crisis had several negative effects in most OECD economies (OECD, 2009; Fernandes and Paunov, 2014; Archigugi et al., 2013).

Table 2 and Table 3 show that many sample countries, like Canada, Belgium, and Norway, had recovered somewhat from 2011. Innovation performance depends on macroeconomic conditions and maintaining policy priority. Although innovation indicators like patents and trademarks were affected by the 2008 financial crisis, they were able to recover with economic performance and policy stimulus. FDI also increased after financial crisis as there is large international investment demand (Archigugi et al., 2013).

[Tables 2-3 are here]

4.2 Panel causality test results

This paper uses the panel DOLS estimation proposed by Kao and Chiang (2001) to determine the relationship between innovation activities and FDI when these variables co-integrate in the long run. Table 4 presents the panel DOLS estimates with structural breaks in the estimated model. In each case, the panel estimates denoted as *Patent* and *Trademark* are significant at least at the 5% level, indicating that innovation development contributes positively to *FDI*. We also find that the panel parameter of variable *Patent* is (0.0005), which is slightly larger than variable *Trademark* (0.0002). Therefore, comparing with *Trademark*, *Patent* has played a more important role in attracting FDI into OECD countries. On a per country basis, in 17 of the 33 countries, *Patent* has a positive impact on FDI, all effects are positive. However, when the independent variable is *Trademark,* as shown in Table 4, NULL is found to be rejected at least at the 5% level in 18 of 33 cases. In summary, the country and panel parameters clearly indicate that a favorable innovation environment is conducive to attracting FDI into OECD countries.

[Table 4 is here]

Table 5 provides the results of whether or not higher FDI leads to higher innovation performance. First, both panel FDI parameters exhibit positive effects on *Patent* and *Trademark,* respectively; the influence of FDI on *Trademark* (6326) is more pronounced than that on *Patent* (89.5), providing clear evidence that FDI brings higher contributions to *Trademark* than to *Patent* in OECD countries. In the case of individual results, with *Patent* as the dependent variable, 11 of the 33 countries had significantly positive FDI coefficients at the 5% level, indicating that FDI promotes innovation output in these countries. FDI also presents positive impacts in 15 countries with statistical significant at least at the 5% level.

[Table 5 is here]

Through Table 4 and Table 5 we therefore confirm that in OECD countries, there is a long-term bidirectional positive causal relationship between FDI and innovation.

The empirical results show that the level of innovation activity and the level of FDI are mutually impactful. In other words, in the long run, high levels of innovation lead to high levels of FDI. This indicates that there is an endogenous relationship between innovation activities and FDI inflows, and any single equation forecast of one or the other could be misleading in the long run.

4.3 Robustness check: considering more factors

Given there are some important variables affecting innovation and FDI, the panel co-integration test with the consideration of two variables in our baseline estimation may ignore other important variables, leading to an unreliable conclusion.[3] As a consequence, we further include more variables in the co-integration test to enhance the robustness of our main findings. Specifically, we consider some variables affecting FDI inflow, including trade friction, technical barrier, and an innovation policy variable that impact national innovation performance. Following Zhao et al. (2020), we use the number of anti-dumping announcements obtained from the World Trade Organization to proxy trade friction (*AD*). Technical barrier (*TBT*) is measured by notifications of a technical barrier to trade.[4] Innovation policy is measured by the percent of R&D financed by the government and is obtained from the OECD database.

Table 6 shows the panel co-integration test results about other more important variables. We see that the statistics remain insignificant at the 10% level when trade friction (*AD*) and technical barrier (*TBT*) are included in the model, showing that the null of the co-integration relationship cannot be rejected, and hence the long-term co-movement between FDI and innovation remains. Similarly, when the innovation policy variable (*GOV*) is accounted for in the model, we also observe that the results do not show significance. Consequently, we confirm that our findings about the long-term cointegrated relationship are robust to the case of including other important factors affecting FDI and innovation.

We also account for the financial crisis in the test. As presented in a previous analysis, the 2008 financial crisis did affect FDI and hence innovation. Actually, this global event also has had a direct influence on countries' innovation performance, which may lead to biased results. Hence, we include the financial crisis variable in the

[3] We thank an anonymous reviewer for providing this valuable suggestion.
[4] The source is the WTO's TBT Annual Reviews of the Implementation and Operation of the Agreement.

model. In particular, the variable financial crisis (*FS*) is set to 1 when the year is lagged behind 2008 and 0 otherwise. The last column of Table 6 presents the corresponding results. It appears that the test cannot reject the ineffectiveness of long-term movements and argues that FDI and innovation in OECD countries are synchronized.

[Table 6 is here]

5. Conclusions

Using annual data from 33 OECD countries from 1999 to 2018, this research examines the long-term relationship between FDI and innovation activity. We aim to address the long-term co-movement between FDI and innovation and account for potential structural breaks. Our study compares studies that focus only on a one-way causal relationship from FDI to innovation or in the opposite direction. Different from the traditional uninterrupted co-integration studies, we consider both the panel stationarity test with multiple breaks proposed by Carrion-i-Silvestre et al. (2005) and the co-integration test with structural break proposed by Westerlund (2006). At the same time, we also use the DOLS model with multiple breakpoints to determine the long-term causality between the variables.

his paper has the following several findings. First, our results indicate that FDI and innovation follow I(1) processes, and when multiple structural mutations are considered, there is a significant co-integration relationship between *FDI-Patent* and *FDI-Trademark* in OECD countries.[5] Second, most of the estimated structural breakthroughs occurred around 2001-2008, when most OECD countries saw a large number of patent and trademark applications and rapid diffusion of technology. Moreover, the global financial crisis played a significant role in external influences as structural breaks around 2008-2010. Third, panel DOLS estimates provide evidence that levels of innovation activity and FDI influence each other, because in the long run, high levels of innovation lead to high levels of FDI, and vice versa. In OECD countries, *Patent* attracts more foreign direct investment than *Trademark*, but foreign direct investment contributes more to trademarks than patents.

We believe our empirical results provide more useful information to governments for formulating economic and trade policies. One policy implication in the long run is

[5] A more valuable issue is what are the specific path or mechanism supporting the long-term co-integrated relationship. We are grateful to anonymous reviewer for this precious suggestion.

that innovation must be based on sustained inflows of FDI inflows that can promote innovation activities. From the perspective of macro-economic policy, FDI affects domestic innovation activities and is one of the main influencing factors,[6] host governments must attract greater FDI inflows. Moreover, given that labor-intensive low-tech FDI contributes to less innovation in the host country compared to R&D-intensive high-tech FDI, governments should attach more importance on attracting the latter versus the former. In another sense, innovation can encourage developed countries FDI flows. Therefore, in accordance with our findings, the empirical implication is that governments of OECD countries should encourage the pursuit of more innovation, including original innovation and imitation innovation, in order to increase FDI flows.

We should mention that more specific paths or mechanisms may exist in the long-term co-movement between FDI and innovation. However, due to space limitations, we put such an important issue up to other scholars who are interested in this field.

[6] It should be noted that FDI is not the sole driver of innovation. There are other important drivers for innovation development.

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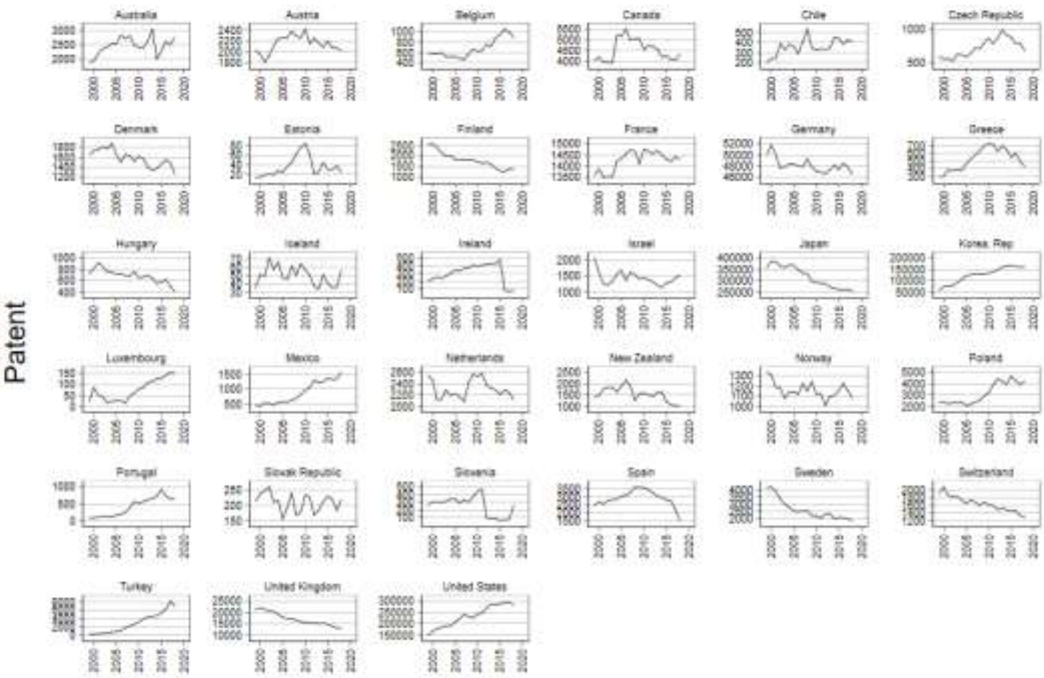

Figure 1 Plots of *Patent* by OECD country (1999-2018).

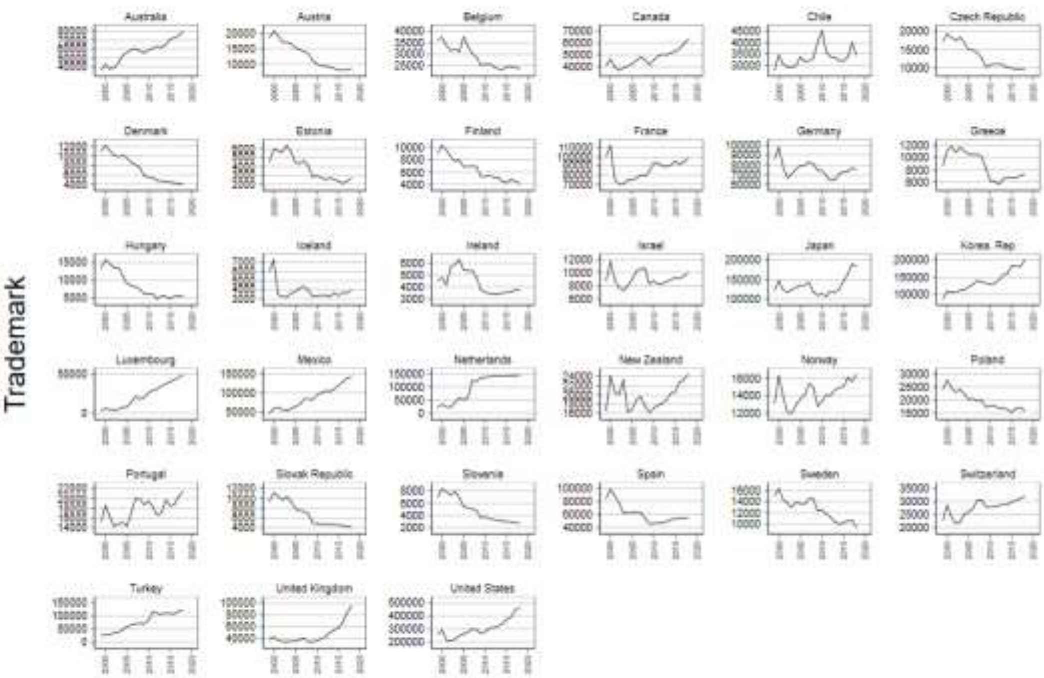

Figure 2 Plot of *Trademark* by OECD country (1999-2018).

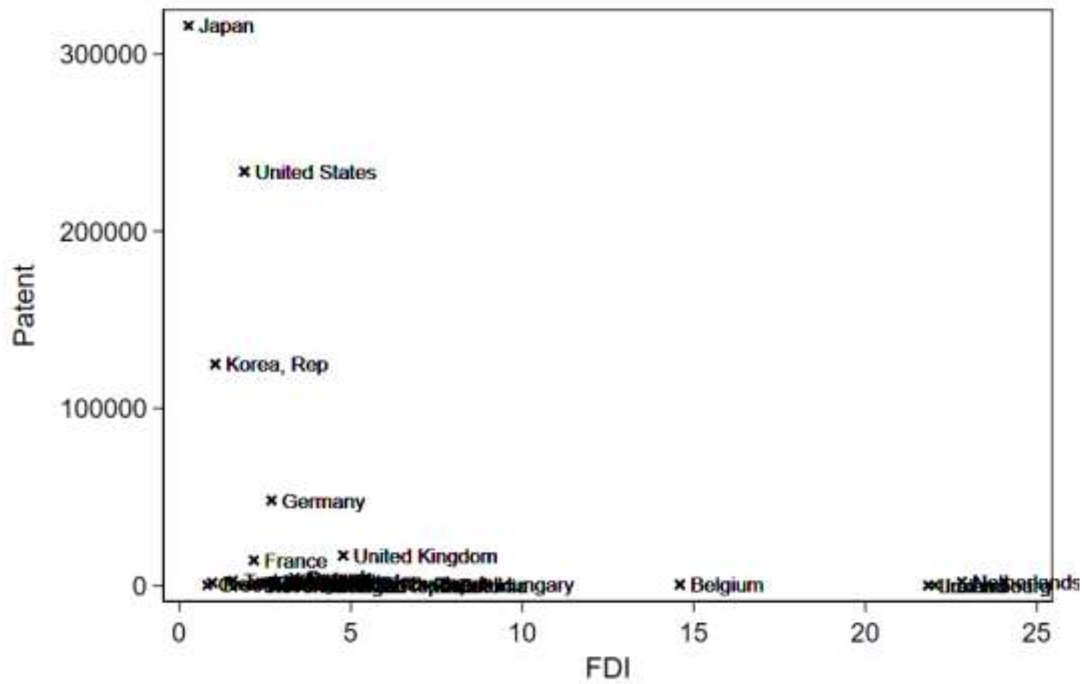

Figure 3 Mean scatter of *FDI* and *Patent* in OECD countries (1999-2018).

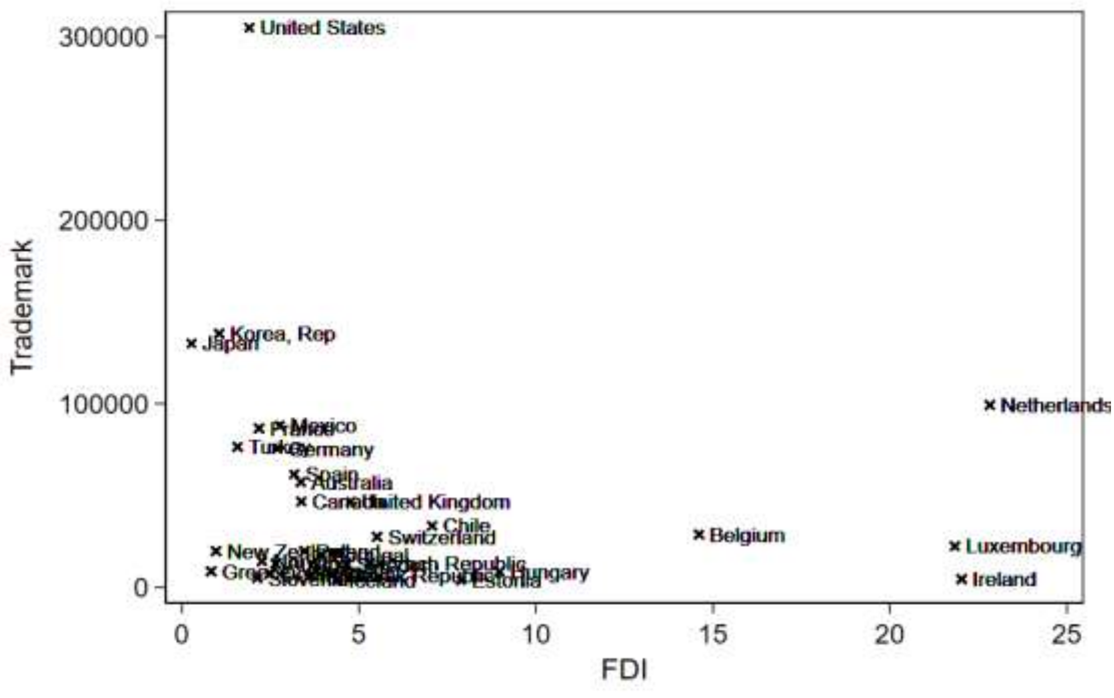

Figure 4 Mean scatter of *FDI* and *Trademark* in OECD countries (1999-2018).

Table 1. Panel Stationary Test with Structural Breaks for OECD Countries

Variable	Panel KPSS test	Test statistics	Bootstrap critical values			
			90%	95%	97.5%	99%
FDI	Homogeneity	6.232	16.266	19.748	23.164	27.631
	Heterogeneity	52.636**	40.659	47.340	54.457	64.089
Patent	Homogeneity	23.015	165.275	231.733	300.937	425.387
	Heterogeneity	23.841	166.709	198.599	221.839	261.585
Trademark	Homogeneity	12.051	17.160	22.844	29.724	39.261
	Heterogeneity	37.269	78.238	95.90	114.056	130.015

Notes: ** indicates statistical significance at the 5% level. The number of break points is estimated using the LWZ information criteria (or sequential sup-F test) allowing for a maximum of 5 breaks. The long-term variance is estimated using the Bartlett kernel with automatic spectral window bandwidth selection. In addition, all bootstrap critical values allow for cross-sectional dependence.

Table 2. Panel Co-integration Test with Structural Breaks: *FDI* vs. *Patent*

Country	M_i	Location of breaks				
Australia						
Austria	3	2000	2004	2007		
Belgium	3	2001	2006	2011		
Canada	3	2001	2005	2008		
Switzerland						
Chile	3	2000	2006	2015		
Czech Republic						
Germany						
Denmark	2	1999	2001			
Spain	2	1999	2002			
Estonia	2	1999	2007			
Finland						
France	2	1999	2008			
United Kingdom	3	2000	2004	2015		
Greece	3	2000	2002	2005		
Hungary						
Ireland	3	2000	2003	2014		
Iceland	4	2001	2004	2007	2015	
Israel						
Japan	2	1999	2015			
Korea, Rep.						
Luxembourg						
Mexico	2	1999	2012			
Netherlands						
Norway	2	1999	2012			
New Zealand						
Poland						
Portugal						
Slovak Republic	2	1999	2008			
Slovenia						
Sweden						
Turkey	3	2000	2004	2008		
United States						
Panel LM Test		0.921				

Notes: The null hypothesis is panel co-integration with breaks. The Panel LM Statistic is asymptotically distributed as normal. M_i is the number of estimated breaks. The breaks are estimated using the Bai and Perron (2003) procedure with a maximum number of five breaks for each state.

Table 3. Panel Co-integration Test with Structural Breaks: *FDI* vs. *Trademark*

Country	M_i	Location of break				
Australia						
Austria	2	1999	2004			
Belgium	4	2001	2001	2006	2011	
Canada	4	2001	2002	2009	2015	
Switzerland						
Chile	3	2000	2007	2015		
Czech Republic	3	2000	2002	2007		
Germany	3	2000	2003	2008		
Denmark						
Spain	3	2000	2001	2006		
Estonia	2	1999	2004			
Finland						
France	2	1999	2008			
United Kingdom	2	1999	2008			
Greece	3	2000	2005	2011		
Hungary	2	1999	2008			
Ireland						
Iceland	4	2001	2004	2007	2015	
Israel						
Japan						
Korea, Rep.	2	1999	2001			
Luxembourg	2	1999	2008			
Mexico	2	1999	2012			
Netherlands						
Norway	3	2000	2012	2015		
New Zealand						
Poland	2	1999	2003			
Portugal						
Slovak Republic						
Slovenia						
Sweden						
Turkey	3	2000	2004	2008		
United States	2	1999	2001			
Panel LM Test		0.789				

Notes: Same as Table 2.

Table 4. Panel DOLS Estimation with Time Breaks: *FDI*

Country	Independent variable: *FDI*			
	Patent	Patent*SB	Trademark	Trademark*SB
Australia	-0.002(-3.299) **	0.004(3.745) **	0.001 (0.399)	0.001 (0.736)
Austria	0.021(7.645) **	0.008(6.301) **	0.001 (4.42) **	0.003(3.449) **
Belgium	0.010(9.732) **	0.001 (0.422)	0.001(9.59) **	0.001 (1.281)
Canada	0.001(5.519) **	-0.001 (-0.982)	0.001 (2.329) **	0.001 (0.22)
Switzerland	-0.001(-4.432) **	-0.001(-1.45)	-0.004(-10.51) **	0.008(10.17) **
Chile	-0.004(-12.900) **	0.01(23.41) **	0.001 (0.428)	0.001 (0.086)
Czech Republic	0.002(2.735) **	0.002(1.601)	0.001 (7.95) **	-0.003(-5.489) **
Germany	-0.001(-3.374) **	-0.003(-2.849) **	-0.001 (-8.904) **	0.001 (7.987) **
Denmark	0.002(2.806) **	-0.001 (-0.571)	-0.001 (-8.275) **	-0.004(-10.22) **
Spain	-0.003(-4.263) **	0.003(5.1) **	0.001(14.29) **	-0.001(-12.59) **
Estonia	0.005(4.001) **	0.005(2.71) **	0.001(13.93) **	0.006(9.084) **
Finland	0.003(15.97) **	-0.003(-6.621) **	-0.001 (-1.234)	-0.001(-1.136)
France	0.002(9.038) **	-0.001(-9.803) **	0.001 (3.046) **	-0.001 (-9.293) **
United Kingdom	0.001(26.49) **	0.003(44.31) **	0.001(7.315) **	0.001 (0.196)
Greece	0.002(3.749) **	0.001(1.899)	-0.001 (-5.503) **	0.001(10.39) **
Hungary	0.013(8.838) **	0.013(4.865) **	0.001(13.12) **	0.028(37.68) **
Ireland	-0.024(-21.65) **	0.02(11.96) **	-0.003(-20.52) **	-0.008(-10.05) **
Iceland	0.004(3.652) **	-0.002(-1.054)	0.001(9.505) **	0.006(2.704) **
Israel	0.001(1.012) **	-0.002(-5.502) **	-0.001 (-2.48) **	0.001 (1.611)
Japan	0.001(3.68) **	0.004(8.975) **	-0.001(-0.876)	0.001(3.446) **
Korea, Rep.	-0.001(-9.225) **	-0.001 (-1.962) **	-0.001 (-2.548) **	0.001(3.72) **
Luxembourg	-0.051(-12.05) **	-0.052(-8.438) **	0.001(1.368)	-0.004(-2.372) **
Mexico	0.006(23.64) **	0.001 (1.005)	0.001 (6.377) **	-0.001 (-0.404)
Netherlands	-0.004(-1.472)	-0.004(-1.245)	0.001 (4.56) **	0.001 (0.023)
Norway	-0.001(-0.767)	0.006(22.09) **	0.001(13.24) **	0.001(13.81) **
New Zealand	-0.001(-1.189)	0.001(1.091)	0.001 (2.781) **	0.001(2.45) **
Poland	-0.006(-48.06) **	-0.002(-20.18) **	0.001 (14.1) **	-0.001(-12.12) **
Portugal	-0.004(-2.15) **	0.006(3.137) **	-0.001 (-0.371)	0.005(1.805)
Slovak Republic	0.004(21.47) **	-0.005(-14.37) **	0.001 (1.069)	-0.001(-3.521) **
Slovenia	0.003(52.91) **	-0.002(-16.41) **	-0.001 (-6.349) **	-0.001(-4.527) **
Sweden	0.004(45.69) **	0.003(15.4) **	0.001 (2.526) **	-0.003(-11.71) **
Turkey	-0.001(-8.476) **	-0.002(-17.9) **	0.001 (4.45) **	-0.001 (-5.485) **
United States	0.001(0.387)	0.001(0.185)	0.001 (3.358) **	0.001(1.881)
Panel	0.0005(20.13) **	0.0002 (8.507) **	0.0002(12.63) **	0.001(4.145) **

Notes: t-statistic is in parentheses. The asymptotic distribution of the t-statistic is standard normal as T and N go to infinity. ** denotes statistical significance at the 5% level. All results allow for up to five structural breaks for each country.

Table 5. Panel DOLS Estimation with Time Breaks: *Innovation*

Dependent variable	Patent		Trademark	
Country	FDI	FDI*SB	Trademark	FDI*SB
Australia	-116.3(-0.868)	-3125(-2.659) **	2100(0.269)	-5392(-0.19)
Austria	389.2(2.885) **	-453.7(-1.548)	2462(7.245) **	-738.3(-0.183)
Belgium	195.6(2.802) **	-692.9(-2.04) **	-1866(-1.825)	14810(2.649) **
Canada	-175.3(-3.117) **	1711(20.78) **	1995(1.241)	-847.1(-0.626)
Switzerland	-1962(-3.685) **	-4001(-8.453) **	4353(1.998) **	-9055(-5.102) **
Chile	-285.2(-7.375) **	-917.8(-6.798) **	-1210(-6.064) **	-3282(-4.951) **
Czech Republic	178.8(5.289) **	-6482(-10.07) **	-750.1(-0.822)	8215(3.527) **
Germany	-1004(-5.79) **	4912(2.709) **	-12970(-20.81) **	23363(13.59) **
Denmark	-544.3(-6.178) **	1782(4.66) **	-2429(-5.107) **	-4453(-2.11) **
Spain	-1941(-25.68) **	3783(15.54) **	-10686(-2.171) **	39888(2.301) **
Estonia	104.9(3.018) **	-27.15(-0.439)	1409(18.63) **	2970(13.23) **
Finland	-24.98(-0.802)	-7454(-14.91) **	1723(4.784) **	-9049(-2.779) **
France	537.9(4.641) **	4266(8.166) **	-1146(-3.835) **	22100(12.24) **
United Kingdom	477.2(12.28) **	3714(41.29) **	-316.7(-1.203)	-1452(-1.907)
Greece	260.8(4.004) **	-11112(-15.12) **	16226(14.42) **	-59412(-19.35) **
Hungary	-13.51(-5.304) **	-6371(-46.19) **	3831(13.07) **	-9379(-14.08) **
Ireland	59.62(1.483)	-138.8(-2.167) **	-276.9(-0.618)	-627.5(-0.063)
Iceland	-731.1(-13.34) **	1182(13.66) **	-2677(-8.256) **	4851(9.243) **
Israel	-1591(-7.232) **	-3733(-6.07) **	-17847(-3.25) **	3681(0.626)
Japan	6056(0.896)	-276378(-5.08) **	29523(4.033) **	-70099(-3.852) **
Korea, Rep.	-8950(-3.17) **	205580(9.773) **	-33835(-14.56) **	127375(18.16) **
Luxembourg	23.51(1.527)	-4775(-3.968) **	-564.9(-0.519)	7698(1.419) **
Mexico	-263.9(-4.991) **	2185(5.139) **	-7830(-5.275) **	46604(9.957) **
Netherlands	-19.03(-0.405)	-2842(-2.027) **	7917(57.23) **	74182(46.18) **
Norway	162.7(3.842) **	-1125(-24.61) **	8040(14.93) **	-7771(-8.692) **
New Zealand	-423.9(-1.497)	-3973(-3.139) **	23437(16.58) **	-47372(-19.23) **
Poland	-726.1(-1.653)	5201(2.093) **	16165(35.59) **	-2623(-3.289) **
Portugal	86.24(1.49)	-2913(-3.967) **	-1085(-2.476) **	-9796(-3.972) **
Slovak Republic	361.5(12.61) **	1464(14.49) **	2744(73.65) **	-7571(-31.2) **
Slovenia	-263.4(-2.83) **	-3528(-2.778) **	1999(4.541) **	-16201(-8.554) **
Sweden	371.6(10.59) **	1595(2.771) **	2206(20.65) **	3138(2.827) **
Turkey	1831(4.462) **	1348(0.817)	20492(6.965) **	109126(6.289) **
United States	10892(1.761)	104754(1.994) **	-259893(-5.658) **	812973(6.043) **
Panel	89.5(3.539) **	104.1(3.16) **	6326(37.14) **	31390(3.161) **

Notes: Same as Table 4.

Table 6. Robustness Test of Long-term Cointegrated Relationship

Dependent variable	*FDI*	*Patent*	*Trademark*
Patent+AD	1.538		
Patent+TBT	1.025		
Trademark+AD	1.036		
Trademark+TBT	0.918		
FDI+GOV		1.453	0.781
FDI+FS		1.318	1.476

Notes: This table presents the results of the panel co-integration test with breaks. AD is the trade friction variable measured by anti-dumping number. TBT is the technical barrier variable measure by technical barrier number. GOV is the innovation policy variable measure by government share in R&D expenditure. FS is a dummy variable that equals 1 if this year is larger than 2008. This table only presents the panel statistics. Other results are available upon request.