R&D, FDI, and Innovation:  
Examination of the Patent Applications in the OECD Countries

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ABSTRACT
This paper analyzes the effect of research and development expenditure (R&D) on innovation in the Organization for Economic Cooperation and Development (OECD) member countries over the period 1996-2015. Innovation, the dependent variable, is measured using two different proxies: patent applications by residents (PAR) and the patent applications by non-residents (PANR) in the host countries. R&D is the main variable of interest which is also interacted with foreign direct investment (FDI) to see how the entry of foreign competitors influence the role of R&D on innovation in the host country. The findings show that R&D alone promotes innovation by residents but impedes innovation by non-residents. However, when FDI interacts with the R&D in the host country, it produces opposite results. Specifically, increasing FDI in the presence of a certain level of R&D in host countries impacts PAR negatively and the PANR positively. These results have important policy implications.

JEL Classification: F21, O30
Key Words: R&D, FDI, OECD, Innovation, Patents

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1. Introduction

Joseph Schumpeter in 1942 commented that the “creative destruction refers to the incessant product and process of innovation mechanism by which new production units replace outdated ones” (Schumpeter, 1942). By innovation, he means the changes in the methods of production and transportation, production of a new product, change in the industrial organization, opening up of a new market, etc. In that sense, innovation refers to the applications of new technology, new material, new methods and new sources of energy. But, identifying the determinants of innovation is important from policy perspectives and for their economic significance. In that regard, this paper focuses on two sources that make technological expertise more prominent -- research and development expenditure (R&D) and foreign direct investment (FDI) -- and analyzes how they promote innovation, and, thus, help with the creative destruction.

To accomplish this objective, we use two different measures of innovation. A widely used proxy of innovation in the literature is the number of patents, or one of its variants, filed in the entity of interest (Katila, 2000; McAleer & Slottje, 2005; Gallini, 2002). Utilizing this proxy, we disaggregate the patent applications in to two categories: patent applications by residents (PAR) and those by non-residents (PANR) across the member countries of the Organization for Economic Cooperation and Development (OECD). This allows us to examine, first, how innovations by the two different groups of firms and individuals are associated with the individual country’s domestic R&D expenditure. Second, it also allows us to analyze if the impact of such domestic investment in research and development is altered by external influence, mainly the FDI.

To boost innovation and to enhance their economic performance, many OECD member countries have implemented national strategic plans. According to the OECD (2019) data, the gross domestic spending on R&D in OECD countries was $1.42 trillion or about 2.37% of the close to $60 trillion GDP. This figure for the OECD countries alone is much higher compared to the global R&D expenditures, which was about $1.961 trillion in 2017. The OECD countries have generally refrained from active industrial policy in recent years and rather sought new ways to improve the environment for innovation in order to boost productivity and growth (OECD, 2007). An OECD report suggests that as global competition intensifies and innovation becomes riskier and more costly, the business sector internationalizes knowledge-intensive corporate functions, including R&D (Guinet & De Backer, 2008). The report shows more recent patterns of firms’ increasing practice of offshore R&D activities to other countries to tap the benefits of new market and technology trends worldwide.

The statistics presented above reflect only one side of the story. FDI has been traditionally considered to be a vital source in the dissemination of technology. It tends to involve establishing more of a substantial, long-term impact in the host country’s economic performance. FDI is usually undertaken by multinational companies, large institutions, or venture capital firms for their R&D activity. And, such FDI is considered to have played an important role in the economic growth of OECD countries (Borensztain, et al., 1998; Liu, 2008). The main reason for such case is because the internationalization of production helps exploit the advantages of enterprises and countries, increase competitive pressures in OECD markets and stimulate technology transfer and innovative activity (OECD, 2002). So, there is an incentive for the member countries to promote FDI inflow in their respective economies. As a result, global FDI reached $1.76 trillion in 2015 and OECD countries were the major recipients (UNCTAD, 2016).
Given the background, it is appealing to analyze whether R&D impacts innovation and if FDI influences such impact. In that context, this paper specifically analyzes what happens to the innovation (as measured by patent applications) due to domestic R&D vis-a-vis FDI, and effect of their interactions using a panel data for the OECD member countries for the period 1996-2015. The findings show that R&D alone promotes innovation by residents but impedes the innovation by non-residents. However, when FDI interacts with the R&D in the host country, it produces opposite results. Specifically, increasing FDI in the presence of certain level of R&D impacts PAR negatively and the PANR positively. That is, R&D and FDI have a substitution effect on innovation by residents whereas they have a complementary effect on innovation by non-residents.

The remainder of the paper is structured as follows. Section 2 provides a summary of the representative literature in the FDI-innovation nexus. Section 3 sets up the empirical model; Section 4 presents the data source and the summary statistics of the variables used in the estimation. Section 5 discusses the results with respect to patent applications of residence and that patent of non-residents. Section 6 concludes the paper.

2. Literature Review

It is a widely held view that research and development (R&D) and innovative activities are difficult to finance in a freely competitive marketplace. R&D investment has a number of characteristics that make it different from ordinary investment. First and most importantly, 50% or more of R&D spending goes towards the wages and salaries of highly educated scientists and engineers (Hall & Lerner, 2010). Labor creates an intangible asset, the firm’s knowledge base, from which profits are generated. If workers leave or get fired before accomplishing a project, this is a loss to the firm’s output. Because of that, firms want to smooth their R&D spending over time, in order to avoid having to lay off knowledge workers. A second important feature of R&D investment is the degree of uncertainty associated with its output. R&D investment through venture capital does not always guarantee innovation in the early state. However, it promotes innovation in the development stage, and restrains innovation in the expansion stage (Lin et al., 2019). Thus, the impact of R&D on innovation may depend on the labor markets.

FDI, on the other hand, has been a major area of research for a long time, especially focused on its impacts on a country’s macro economy. However, the question of whether it impacts innovation is relatively scant. Erdal and Gocer (2015) find that China has been the largest FDI recipient among developing countries since the 1990s. Similarly, India, Malaysia, Singapore, South Korea provided tax incentives, monopoly rights, and cost advantages to multinational companies in order to increase FDI inflows to their countries. They have also internalized technical knowledge and technology brought in by foreign investors to produce high-tech and high value-added products and finally they have managed to export them. Chen (2007) studied about the impact of FDI on regional innovation capability in China. The analysis indicates that the spillover effect of FDI are not significant and the impact of FDI on innovation capability is weak. The FDI alone has no use for enhancing indigenous innovation capability. Rather, inward FDI might have the crowding out effect on innovation as well as domestic research and development activities.

Research also shows that FDI inflow contributes to speed up R&D and innovation activities that enable host counties to produce value-added products and help increase the national income via export revenues from high-tech products (Erdal & Gocer, 2015). Inward FDI brings knowledge spillovers and new technologies and products into the host country and promotes domestic firms’
innovation capability (Sivalogathasan & Wu, 2014). FDI enables the less advanced economy to learn from the production activities in that country. Efficiency in the research labs in the country is thereby increased and innovation becomes profitable (Walz, 1997). Existing research also shows a positive and significant effect of FDI in the productivity growth in service sectors Fernandes and Paunov (2008). Similarly, Gorodnichenko et al. (2014) find that well established (old) firms and firms operating in a sector where methods and skills of production are relatively visible (i.e. services) benefit from the presence of foreign competitors and from supplying to foreign firms. The authors argue that FDI contributes to growth in the countries with strong financial system. A strong financial mechanism contributes positively to the process of technological diffusion associated with FDI (Hermes & Lensink, 2003). Thus, the impact of FDI depends on many domestic characteristics. Our goal in this paper is to see if FDI impacts innovation any differently in the presence of a certain level of R&D in the host country.

Huang et al. (2012) use a data set on twenty-nine Chinese provinces for the period 1985–2008, to analyze a threshold model and show the relationship between spillover effects of foreign direct investment (FDI) and regional innovation in China. They show that the level of regional innovation reaches the minimum innovation threshold then FDI will begin to produce positive regional productivity spillovers. Furthermore, positive productivity spillovers from FDI are substantial only when the level of regional innovation attains a higher threshold. In a related paper, AlAzzawi, (2012) investigates how the flows of knowledge transmitted through FDI affect the production of knowledge in both source and recipient countries, as well as how these flows affect productivity. The paper finds that there are large differences in the way FDI affects innovation and productivity between countries that are technological leaders, and technological followers. The paper concludes that technological followers have much to gain from FDI-induced R&D spillovers, and therefore governments in these countries will find it worthwhile to attract foreign multinationals, while those in the more technologically advanced economies need to consider the costs and benefits of FDI carefully. In sum, most of the studies find a positive and significant effect of FDI on innovation. Very few studies show an insignificant result of FDI on innovation.

This research is different from the existing literature in two ways. First, it focuses on the impact of R&D activity on the innovation by residents and non-residents, which provides us an insight that has not been explored in the literature. Second, very few studies exist in the literature investigate the interaction between FDI inflows and the research and development expenditure in the host country. This aspect is important from policy perspective. Additionally, we focus on the OECD countries that are considered to be the leading economies in terms of innovation. And the use 20 years of data immediately after the establishment of WTO to evaluate the impact of FDI inflows on innovation allows us to study how the innovation environment has changed since the shift in the policy that has resulted in a higher international capital flows across the globe.

3. Model and Estimation Technique

To find the determinants of innovation, we specify an econometric model where patent application is a function of research and development expenditure (R&D), the inflow of foreign direct investment (FDI), and the gross domestic product (GDP) per capita. Doing so allows us to isolate the effect of R&D and FDI separately, controlling for the macroeconomic performance of a country largely represented by its GDP. Following model represents the relationship among these variables.
Innovation = f(GDP, R&D, FDI)  

(1)

Estimating the above specification using a contemporaneous panel regression model exhibits potential endogeneity issues. Given the nature of the economic variables used in the model, there may exist a situation that the direction of causality runs both ways from R&D and FDI to innovation, and vice versa, i.e. there could be a reverse causality. There could also be a simultaneity bias if other macroeconomic variables impact R&D, FDI, and innovation in the same period. To address the potential endogeneity issues, we use two different approaches: lagged explanatory variables and an instrumental variable generalized method of moments, or the system-GMM.

First, to subdue this problem, we use the lagged values of all the explanatory variables and explore their association with the current innovation. Since we have two different measures for the dependent variables (i.e., innovation = PAR and PANR), it produces two panel regression equations expressed as follows:

\[ \ln(Inv_{it}^k) = \alpha_0 + \beta_1 \ln(R&D_{it-1}) + \beta_2 \ln(FDI_{it-1}) + \beta_3 \ln(GDP_{it-1}) + \beta_4 \ln(R&D * FDI)_{it-1} + \epsilon_{it} \]  

(2)

Where, \( \ln \) represents the natural logarithms of the variables, \( Inv \) is the innovation measure, \( R&D \) is the dollar value of domestic expenditure in research and development, \( FDI \) is the dollar value of FDI in the balance of payments accounts, \( GDP \) is the gross domestic product per capita, and \( \epsilon \) is the error term; \( i = 1, 2, \ldots, 35 \) representing the OECD member countries; \( t = 1995, 1996, \ldots, 2015 \), the twenty years since the establishment of WTO. The key focus here is to test whether the marginal impact of R&D on innovation \( (\beta_1) \) and the interaction between FDI and the R&D measure \( (\beta_4) \) are statistically significant in the above model.

In analyzing the data using the standard panel data model, we use the Hausman test to choose between the fixed effects (FE) versus the random effects (RE) model for the panel data. FE regression is an estimation technique employed in a panel data setting that allows one to control for time-invariant unobserved individual characteristics that can be correlated with the observed independent variables. Whereas, in the RE model, the individual-specific effects are uncorrelated with the independent variables. The Hausman test suggests random effect model being the more appropriate for the data used in this paper. Random effect models assist in controlling for unobserved heterogeneity when the heterogeneity is constant over time and not correlated with independent variables (Wooldridge, 2016).

Next, we use a dynamic estimation technique - system generalized method of moments or the system-GMM. This technique uses internal instruments in producing consistent estimators. The system GMM not only produces consistent but also more efficient estimators (Ghimire et al., 2016). Thus, the results from the system GMM estimation allow us to check the robustness of the results obtained from the random effects model. The econometric model is expressed as below:

\[ \ln(Inv_{it}^k) = \beta_0 \ln(Inv_{it-1}) + \beta_1 \ln(R&D_{it}) + \beta_2 \ln(FDI_{it}) + \beta_3 \ln(GDP_{it}) + \beta_4 \ln(R&D * FDI)_{it} + \alpha_i + \nu_{it} \]  

(3)

where, we use country-specific fixed-effects \( (\alpha_i) \) to account for an unobserved country-specific fixed effect. The last term \( (\nu_{it}) \) in the model (4) indicates an independent and \( \nu_{it} \) identically distributed error term. Again, the key focus is on testing whether the marginal impact of R&D on innovation \( (\beta_1) \) and the interaction between FDI and the measure of R&D \( (\beta_4) \) are statistically significant in the above model.
4. Data

To accomplish the main objective of this paper in isolating the effect of domestic R&D and FDI inflows on innovation in OECD countries, we use a panel of 35 countries for the period from 1996-2015. The annual data of patent applications are used in the model as a proxy for innovation. We use patent application of residents (PAR) and patent of non-residents (PANR) as dependent variables. Patent has some features that makes it the most popular way of measuring innovations despite its critique (Smith, 2005). Similarly, FDI inflows, research and development expenditure percentage of GDP (R&D), and nominal gross domestic product per capita (GDPPC) are the independent variables.

All the data for both the dependent and independent variables are obtained from World Development Indicators database maintained by the World Bank (2016). Moreover, FDI is interacted with research and development expenditure (R&D*FDI). The summary statistics of all the variable used in the model is presented in Table 1.

Table 1. Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Var</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln_PAR</td>
<td>654</td>
<td>7.38</td>
<td>4.82</td>
<td>2.195</td>
<td>2.485</td>
<td>12.859</td>
</tr>
<tr>
<td>ln_PANR</td>
<td>654</td>
<td>6.779</td>
<td>6.26</td>
<td>2.501</td>
<td>1.099</td>
<td>12.59</td>
</tr>
<tr>
<td>ln_R&amp;D Exp</td>
<td>549</td>
<td>.538</td>
<td>0.22</td>
<td>0.466</td>
<td>0</td>
<td>1.386</td>
</tr>
<tr>
<td>ln_GDPPC</td>
<td>700</td>
<td>10.074</td>
<td>0.61</td>
<td>0.781</td>
<td>7.796</td>
<td>11.667</td>
</tr>
<tr>
<td>ln_FDIBOP</td>
<td>646</td>
<td>22.86</td>
<td>3.20</td>
<td>1.789</td>
<td>14.509</td>
<td>27.322</td>
</tr>
</tbody>
</table>

5. Empirical Results

5.1 Baseline Results: Random Effect Results

This section presents the econometric results obtained by estimating the random effect model shown in Equation 2 as suggested by the Hausman test. Two alternative specifications are reported in Table 2: first column shows the results for the resident patent applications and the second column shows the results for the non-resident patent applications.

As seen on Table 2, the first row shows that R&D alone has a positive association with the patent applications by resident but a negative association with the patents by non-residents. In particular, a 1% increase in R&D increases PAR by 2.9% but reduces PANR by 4.16%. From the second row, FDI alone has a positive significant association with PAR but a negative insignificant result on PANR. In particular, a 10% increase in FDI increases PAR by 9.7%. Based on the coefficients on the interaction term, we see opposite results. Especially, there is negative coefficient when we estimate the PAR but a positive coefficient when we estimate the PANR. The findings show that R&D and FDI alone have a positive association with PAR but a negative association with PANR. However, if FDI interacts with certain level of R&D in the host country, it produces opposite results.
Table 2. Estimating the impact of R&D and FDI on PAR and PANR.

<table>
<thead>
<tr>
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<th>(1)</th>
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<tr>
<td></td>
<td>ln_PAR</td>
<td>ln_PANR</td>
</tr>
<tr>
<td>ln_R&amp;D</td>
<td>2.906***</td>
<td>-4.161***</td>
</tr>
<tr>
<td></td>
<td>(6.27)</td>
<td>(-4.10)</td>
</tr>
<tr>
<td>ln_FDI</td>
<td>0.0972***</td>
<td>-0.0369</td>
</tr>
<tr>
<td></td>
<td>(5.53)</td>
<td>(-0.96)</td>
</tr>
<tr>
<td>ln_R&amp;D*FDI</td>
<td>-0.0863***</td>
<td>0.201***</td>
</tr>
<tr>
<td></td>
<td>(-4.19)</td>
<td>(4.47)</td>
</tr>
<tr>
<td>ln_GDP</td>
<td>-0.0283</td>
<td>-1.557***</td>
</tr>
<tr>
<td></td>
<td>(-0.56)</td>
<td>(-14.10)</td>
</tr>
<tr>
<td>_cons</td>
<td>5.159***</td>
<td>23.12***</td>
</tr>
<tr>
<td></td>
<td>(9.56)</td>
<td>(21.58)</td>
</tr>
<tr>
<td>N</td>
<td>548</td>
<td>548</td>
</tr>
</tbody>
</table>


5.2 System-GMM Results

Below, we present the results obtained from the system-GMM estimation expressed in Equation 3. While the results are not as strong as observed in the random effects estimation in terms of the size of the coefficients and the statistical significance, they are consistent in terms of the direction of the association.

Table 3. System-GMM dynamic panel data estimation.

<table>
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<tr>
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<tbody>
<tr>
<td></td>
<td>ln_PAR</td>
<td>ln_PANR</td>
</tr>
<tr>
<td>Inv_Lag</td>
<td>0.974***</td>
<td>0.927***</td>
</tr>
<tr>
<td></td>
<td>(82.44)</td>
<td>(39.97)</td>
</tr>
<tr>
<td>ln_R&amp;D</td>
<td>0.489</td>
<td>-1.767*</td>
</tr>
<tr>
<td></td>
<td>(1.30)</td>
<td>(-2.10)</td>
</tr>
<tr>
<td>ln_FDI</td>
<td>0.0150</td>
<td>-0.0674*</td>
</tr>
<tr>
<td></td>
<td>(1.19)</td>
<td>(-2.37)</td>
</tr>
<tr>
<td>ln_R&amp;D*FDI</td>
<td>-0.0269</td>
<td>0.0948*</td>
</tr>
<tr>
<td></td>
<td>(-1.59)</td>
<td>(2.54)</td>
</tr>
<tr>
<td>ln_GDP</td>
<td>0.0687</td>
<td>-0.0562</td>
</tr>
<tr>
<td></td>
<td>(1.73)</td>
<td>(-0.68)</td>
</tr>
<tr>
<td>_cons</td>
<td>-0.756*</td>
<td>2.391**</td>
</tr>
<tr>
<td></td>
<td>(-2.13)</td>
<td>(2.91)</td>
</tr>
<tr>
<td>N</td>
<td>520</td>
<td>520</td>
</tr>
</tbody>
</table>


$t$ statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
As seen on Table 3, the first row shows that innovation in the past periods have a positive association with the current level of innovation. This is true for both PAR and PANR as expected. From the second row, we see that R&D alone has a positive insignificant association with the patent applications by resident but a negative significant association with the patents by non-residents. From the third row, FDI alone has a positive insignificant association with PAR but a negative significant result on PANR. Based on the coefficients on the interaction term, we see opposite results. Especially, there is negative insignificant coefficient when we estimate the PAR but a positive significant coefficient when we estimate the PANR. The findings show that R&D and FDI alone have a positive association with PAR but a negative association with PANR. However, if FDI interacts with certain level of R&D in the host country, it produces positive results.

5.3 Discussion of the Results

We see that the results from both the random effects model and the system GMM estimation are consistent. This makes sense because residents would always try to invest in innovation when they are left alone, but when FDI comes foreign firms want to take advantage of a favorable environment in the host country and file more patent applications. This would crowd out the role of R&D on host country firms. Regardless, it’s good for the host country to increase total patent applications and help with overall innovation. In particular, it is the non-residents who are helping the country innovate.

Our results are consistent with existing research. Research shows that FDI can benefit innovation activity in the host country via spillover channels such as reverse engineering, skilled labor turnovers, demonstration effects, and supplier–customer relationships (Cheung & Ping, 2004). Similarly, Papaioannou (2004) claims that there is a positive innovation effects on productivity growth, generated by the adoption of FDI. The findings are also consistent with Kuemmerle (1999) who suggest that firms seek different types of spillovers from the national and local environment in which they invest that would influence other sectors in the economy. Foreign firms also create spillovers for the local environment because R&D sites provide employment and learning opportunities for local researchers. Liu and Buck (2007) show that foreign R&D activities by multinational enterprises in a host country significantly affect the innovation performance of domestic firms only when absorptive ability is considered. Chen (2007) also found that the FDI can be an important channel for technology diffusion, however, the correlation between FDI and regional innovational capabilities (RIC) is statistically insignificant. Only when the volume of FDI matches the stock of human capital (researchers) and technological capabilities then the regional innovational capabilities be developed and enhanced.

Similarly, Fu and Gong (2011) find that the collective indigenous R&D activities at the industry level are the major driver of technology upgrading of indigenous firms that push out the technology frontier. However, foreign investment appears to contribute to static industry capabilities, R&D activities of foreign-invested firms have exercised a significant negative effect on the technical change of local firms. Liu et al. (2010) also shows that FDI intensity in an industry has a negative impact on local innovation.
6. Conclusions

The main objective of this study is to analyze how research and development expenditure (R&D) and foreign direct investment (FDI) impact innovation in a country. The paper analyzes data from the Organization for Economic Cooperation and Development (OECD) member countries employing the random effect panel data model and the dynamic system GMM technique. The empirical study considers two different measures of the dependent variable: patent applications by residents (PAR) and the patent applications by non-residents (PANR) in the host countries. R&D is the main variable of interest which is also interacted with foreign direct investment (FDI) to see how the entry of foreign competitors influence the role of R&D on innovation in the host country. Overall, the analysis produces the following results: R&D alone promotes innovation by residents but impedes the innovation by non-residents. However, when FDI interacts with the R&D in the host country, it produces opposite results. Specifically, increasing FDI in the presence of certain level of R&D in host countries impacts PAR negatively and the PANR positively. That is, R&D and FDI have a substitution effect on innovation by residents whereas they have a complementary effect on innovation by non-residents. In other words, in a globally competitive environment, it is the FDI that leads to a higher level of innovation. It is an interesting result in the context of FDI being used in the literature as a proxy for imitation (for example, Ghimire et al., 2018). In that sense, the increase in PANR may be a result of imitation of the technology carried into the country by the foreign firms and not necessarily an invention of a new idea or technology. It raises an important policy debate in the host countries. The foreign firms that bring in FDI are potentially more competitive than the domestic firms and this crowds out the role of R&D on host countries firms to innovate. Hence, to rescue the firms from crowding out effect, government may have to implement necessary policies to strengthen domestic firms.
References


