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Foreign Direct Investment and Research & Development Activity: The Role of Competition

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ABSTRACT

This paper investigates the relationship between foreign direct investment (FDI) and domestic research and development (R&D) activity, conditional on product market competition. The generalized Method of Moments (GMM) panel estimator is used to analyze the relationship using a sample of 61 countries over the 2000-2011 periods. The result reveals that FDI has little direct effect on R&D expenditure, but its effect manifests negatively conditional on competition. The finding contradicts with conventional wisdom regarding merits of competition as our evidence shows that competition undermines the effect of FDI on domestic R&D.

JEL Classification : F62, F21, L51, O32

Keywords: Foreign direct investment, competition, Research & Development, Generalized method of moments,

INTRODUCTION

Knowledge accumulation as proposed by Romer (1990, 1993) and Lucas (1988) is an endogenous determinant of long term growth. Since human capital accumulation has a vital role in creating and implementing new knowledge, it is important to invest in education and research and development (R&D) activities. Innovation is not limited to advancement in scientific technology but also in developing more efficient social and political systems. R&D expenditure, researches and infrastructure are inputs central to innovating activities which generate new knowledge as output. According to the Frascati manual published in 2002,

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"Research and experimental Development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge to devise new applications." Works by Madden *et al*. (2001) showed that domestic R&D stock has a relatively large effect on total factor productivity especially on a sample of Asian countries. Furthermore, in an analysis of 16 OECD countries Guellec *et al*. (2001) proposed that "doing R&D is important for productivity and economic growth". Therefore, R&D activity serves as an effective tool to accelerate growth by inducing productivity and growth on firms and national level.

To accelerate growth in developing countries, it is important to explore and identify the determinants of R&D activity so appropriate measures can be implemented to encourage R&D initiatives. Commonly used determinants include (but not limited to) tertiary education, number of scientific researchers and technicians (Wang, 2008), size of economy (Kathuria, 2008), intellectual property protections (Chen and Puttinan, 2005), foreign direct investment (FDI) and economic growth. The effect of growth on R&D is somewhat ambiguous in the literature. Wang (2008) discovered that income growth is not significant in explaining R&D expenditure in 26 OECD countries. FDI is highly associated with foreign knowledge diffusion in international technological transfer hypothesis. FDI inflow and outflow may be the transmission channel of technology across borders. Outward FDI can allow a developing country owned firm to learn new technology and skills from neighboring firms via geographical advantage in host country. On the other hand, inward FDI allows vertical transmission of technology through demonstration and linkages. However, this research focus on FDI inflows as it is more relevant in explaining domestic R&D activities.

The major players in the world R&D activity are concentrated in the OECD countries. In 2005, North America accounted for 35% and OECD accounted for 78% of R&D activities in the world (Gaillard, 2010). Understandably, most studies conducted on the effect of FDI on R&D took setting in OECD countries such as those by Wang (2008) and Coe and Helpman(1995). In high income countries most R&D effort is undertaken by business enterprise; however, in developing world, government and higher education institutions often has a more pronounced role in contributing to R&D activities (Gaillard). The underlying different characteristic between developed and developing countries proposes question on ability to extend findings in OECD countries to context of low and middle income countries. Wang (2008) states that his study on FDI and R&D was based on 26 OECD countries, thus "validity of application to other economies, particularly to developing economies, merits further investigation."(p.115) In addition, research interests have flourished in developing world especially over the past decade. Share of world R&D expenditure has risen over the years in developing countries from year 2002-2009 (UNESCO, 2010).Thus, it is important to have an inclusive study on effect of FDI on R&D activity.

The purpose of this study is therefore to evaluate the impact of FDI on R&D activity in both developed and developing countries. This study differs from the above-mentioned literature which focuses only on the direct impact of FDI on R&D activity. In this study, we argue that product market competition will make a difference to the way FDI affect R&D activity. The reason behind this prediction is that when MNCs enter a new market, they exert a competitive pressure on domestic firms, which eventually forces local firms to adopt new technology faster than they would without the pressure (Blomstrom *et al*., 1994). Degree of competition in market has a substantial effect on innovation as suggested in Aghion *et al*., (2005). Consequently, this will then affect firms' decision to invest in new technology in response to higher degree of competition. Thus, by interacting degree of competition with FDI we can test explicitly whether competition amplifies or diminishes the effect of FDI on R&D. Our finding reveals that competition reduces the impact of FDI on R&D activity in a sample of 61 developed and developing countries.

The rest of this paper is organized as follow, section 2 discusses literature which study FDI and R&D, section 3 shows theoretical framework of this model, section 4 presents methodology, section 5 presents results and finally section 6 concludes the findings of this paper.

LITERATURE REVIEW

FDI and international trade are two mechanisms that are generally agreed on in transmission of technology across borders. Specifically, international technological transfer hypothesis suggests that international technological spillover through FDI and trade can benefit host countries such as improving productivity. There are two opposite views on how transmission of foreign technology through FDI and trade can affect domestic R&Dactivities.

Competition argument highlights the advantages of competition introduced by trade, and in this research's context, FDI. Openness to foreign trade and capital will inevitably pressures domestic firms to improve and innovate, leading to an increase in local R&D activities. Coe and Helpman (1995) showthat the channel of trade flow transmits technology across countries. They discover the fact that foreign R&D has beneficial effects on domestic productivity and these positive spillovers are stronger in countries with higher openness. Since FDI is another major carrier of technology across border, its effect on R&D expenditure shows how foreign presence may alter domestic innovation initiatives. Correa and Ornaghi (2014) argue that there exists positive effect between competition and innovation. Their measure of innovation exceed beyond common measure of patents application, in which they include total factor productivity and labor productivity as additional or implicit productivity gain from innovation.

Eaton and Kortum (1999) discuss that there was significant technological diffusion in which Japan and United States together drove more than two-third of growth in United Kingdom, Germany and France. For example, 42% of productivity growth in Germany was due to research conducted in the United States.In addition, a study on Indian manufacturing firms suggests that "FDI inflow induces foreign-owned firms in high-tech industriesand firms in minority ownership to invest in R&D" (SasidharanandKathuria, 2011, p.126).Another study on Indian enterprises by Katrak (1989) argues that among firms that have R&D unit, firms that import technology have higher R&D expenditure than firms that do not import technology. Complementary effect between FDI and R&D can be due to the reason that domestic firms need to spend in R&D first to increase their absorptive capacity which is essential to benefit from FDI spillovers and foreign technological import.

On the other hand, there are many literatures that hold the opinion that FDI has a negative effect on R&D. The idea behind this argument is that FDI makes foreign technology accessible hence it makes imitation cheaper and plausible. Domestic firms that lack sufficient funding and research capability will simply imitate or import foreign technology rather than engaging in R&D themselves. Also, local enterprises may not devote their resources in R&D due to risks such as low profitability, gestation lag and so forth (Veugelers& van den Houte, 1990). Hence, these researchers assert that FDI or foreign technology will render local research effort as firms may find importing technology a favorable option. Wang (2008) present evidence on significant, robust, negative effect of FDI on R&D using data from 26 OECD countries. Bebczuk(2002) found that trade openness has a negative effect on R&D but the effect is mitigated as income (per capita GDP) and trade with more advance (OECD) countries increase. This suggests that openness may decrease R&D in developing countries but increase R&D in developed countries. Funk (2003) argued that increased import competition reduce R&D effort of domestic manufacturing firms in US.

It is to be acknowledged that despite the positive and negative effect contended above, there are some literatures that found inconclusive result between FDI and R&D.Kathuria (2008) found that effect of FDI on R&D in Indian firms is significant and negative inprobit and tobit estimations for year 1996 but is not significant for year 2001. However, the author suggests that firm size is an important determinant in which firms' decision to undertake R&D is increasing with its size.On the other hand, empirical analysis by Varsakelis (2001) concluded that degree of openness of an economy proxied by black market premium has no effect on R&D intensity in a cross-country regression.

One reason for this contending literature on the effect of FDI on R&D can be due to the fact that the business environment of host country is seldom included in the picture. So far, there have been very few studies which focus on conditional effect of FDI on R&D. FDI may accompany spillover effect such thatFDI spurs innovation through market competition and facilitate technological adoption through channels such as demonstration, labor turnover or vertical linkages (Saggi, 2002).Foreign presence in host country implies enhanced competition which will inevitably lead to change in R&D decision and expenditure in domestic firms (Sasidhaan and Kathuria, 2011). The effect of FDI on R&D can be negative when domestic firms decide to import technology in response to increased competition. So far, competition is only implied in FDI inflows and there are limited researches that explicitly incorporate competition in the FDI-R&D study.Thus, by investigating the effect of FDI on R&D in conjunction with product market competition level, our paper may be able to shed light on this issue.

THEORETICAL FRAMEWORK

Since there is limited theory that provides formal explanation on the effect of FDI on R&D conditional on competition, the theoretical model for this study is primarily derived from the product market competition and innovation theory in industrial setting. Prevailing view in Industrial Organization models of product differentiation and monopolistic competition suggested that competition reduces monopoly profit that incentivizes firms to innovate. Salop (1977) and Aghion & Howitt (1992) predicted that market competition reduces innovation by lowering post-entry rents. This is because a rise in market competition or rate in imitation, decreases monopoly rents that reward new innovation. Contemporary literature found evidences to support the idea that competition affects innovation positively, as firms under pressure will innovate to escape from competition (Correa and Ornaghi, 2014).

In 2005, Aghion and his colleagues developed a model that evaluates a situation where product market competition "discourages laggard firms from innovating but encourage neck-to-neck firms to innovate" (Aghion *et al*., 2005, p.701). They estimate the following equation:

$$E[y_{it|}c_{it},x_{it}]= e^{[g(c)+x'\beta]}Eq \quad (1)$$

Equation (1) shows that innovation is related to industry competition conditional on industry and time effect. Y denotes innovation measure, c denotes competition measure, x represents a complete set of time and industries dummies.Then they develop a model that can incorporate escape competition effect and Schumpeterian effect, and provided empirical evidence in their study.

From empirical analysis of an unbalanced panel consisting 17 industries in United Kingdom spanning from 1970-1994, Aghion and his colleagues discover an inverted-u shaped relationship between innovation (indicated by citation weighted patents) and competition (measured by Lerner's index) as shown in Figure 1. This inverted-u shaped relationship cannot be explained by previous industrial organization model of monopolistic competition.

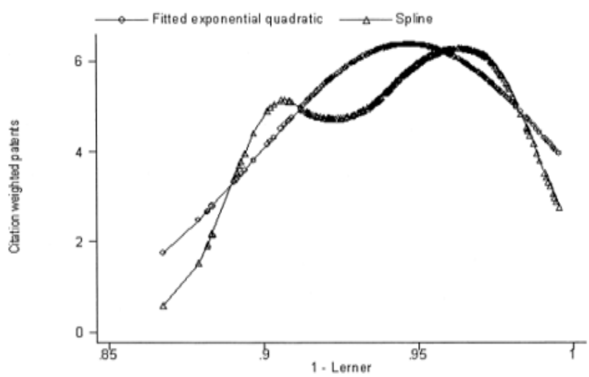

Figure 1: Innovation and Competition-Exponential Quadratic and the Semiparametric Specification with Year and Industry Effects;
Source: Aghion *et al*. (2005)

Aghion *et al*. (2005) assume there is an economy with two types of duopolies. There are firms with equal technology denoted the neck-and-neck (NN) industries and firms with unequal technology known as leader-laggard (LL) industries where the leader firm is one technological step ahead. The firms can devote resources to innovate so that they can compete with their rivals. As level competition rises, there are two opposite effect on firms' innovation decision. The first effect is known as the "escape competition effect", in which firms are eager to innovate to move on technological step ahead of their competitors to gain higher profit as a leader. The second effect is the "Schumpeterian effect", in which competition reduces incentives to innovate as competition reduces the monopoly profit.

The authors also argue that competition level changes fractions of level state which consists of more NN firms and unlevel state which consists more LL firms. In level state economies, "escape competition effect" dominates, versus the unlevel state, where "Schumpeterian effect" dominates. On one extreme where the competition is very low initially, neck-and-neck firms have less incentive to innovate until one of the firm innovate then cause the industry to be in unlevel state. The laggard firms will soon catch up (through imitation) thus innovation is higher in unlevel state and lower in level state. The industry will spend more time in level state, which has low innovation rate. In this industry that has low competition initially and more level state firms, higher competition can lead to increase in incremental profit from innovating, labeled "escape competition effect."

However, if competition is initially very high, laggard firms have lesser initiative to innovate. Neck-and-neck firms, meanwhile, has a relatively large incentive to innovate due to large incremental profit when they become monopoly. Thus, the industry will spend much time in unlevel state. Equilibrium research intensity of laggard firms is decreasing with level of competition (Aghion *et al*.). In short, if degree of competition is very high in the beginning, increased competition will have negative effect on innovation. This is illustrated as sloping downward section of the curve in Figure 1.Their econometric model is developed based on industrial organization framework and tested using a sample of industries in United Kingdom. The authors computed price cost margin to measure competition in industry. To adapt the theory into international setting, economic freedom index is used in this study. A component of economic freedom index - business regulation, is used as proxy for product market competition in our cross country analysis.

The model developed in Aghion *et al*. (2005) is further investigated by researchers such as Correa and Ornaghi (2014) and Hashmi (2013). Later studies show different results compared to Aghion's work and both authors provide explanations on reasons for such discrepancy. Correa and Ornaghi (2014) argue that using a larger United States industrial panel dataset, a robust positive relationship between competition and innovation is found. Their measure of innovation are patent application, total factor productivity and labor productivity, in which the latter two variables represent additional or implicit productivity gain from innovation. On the other hand, Hashmi (2013) found a mildly negative relationship between the two variables using a large U.S. dataset which comprises 7789 publicly traded firms in manufacturing industry compared to 311 firms used in Aghion *et al*. (2005). Hashmi (2013) suggests that characteristics of his data are accountable for such contradicting empirical results which do not support theoretical predictions in Aghion *et al*. (2005). It is possible to reconcile his study with Aghion *et al*. by using a partial equilibrium model with manipulated key parameter that measures average technological gap in the industry. In a simulation with various parameters of technological gap in industry, Hashmi(2013) suggests that his model can reconcile with findings from both Correa and Ornaghi (2014) and Aghion *et al*. (2005). A very low average technological gap is associated with positive linear relationship between competition and innovation. As the gap increases, the relationship becomes nonlinear such as the inverted-u relationship. When the gap is very high, the relationship between competition and innovation becomes negative.

Since there is no theoretical model that is formalized on FDI, competition and R&D, an adaptation of Aghion *et al*. (2005) model and FDI-growth model by Alfaro *et al*. (2004) is adopted in this study. The rationale behind this design is that effect of FDI on growth is conditional on absorptive capacity such as human capital and business environment. Hence, by using an interaction specification as presented in Alfaro *et al*. we can capture this contingent effect. In many other research findings, R&D investment leads to higher productivity and income growth (Coe and Helpman, 1995). In addition, the inverted-u model developed by Aghion *et al*. (2005) is derived at aggregate economy level in which "aggregate innovation rate" increases with degree of product market competition in level state and decreases in unlevel state (p.715). Thus, the model can capture effect of competition on R&D in our cross country setting. By reasonable speculation, FDI can affect R&D in conjunction with competition, in which competition manifests its role as absorptive capacity or business environment for FDI to exert its spillovers.

METHODOLOGY

Model Specification

The model used to test the impact of FDI on R&D is expressed as follows:

$$R\&D_{it} = \beta_1 R\&D_{(it-1)} + \beta_2\, FDI_{it} + \beta_3\, COM_{it} + \beta_4\, (FDI \times COM)_{\,it} + \beta_5\, X_{it} + \mu_i + \epsilon_{it} \qquad (2)$$

where, R&D= Gross R&D expenditure, FDI= FDI inflows, COM = Product market competition proxied with business regulation index, (1 for highly regulated, 10 for more competitive), X= control variables such as tertiary education and ratio of researchers to population, μ = unobserved country specific effect, and ε = error term

Equation (2) is adapted from equation (1) above by transformation. This model is adapted from Aghion *et al*. (2005) by making linear transformation. The dependent variable, R&D is a function of FDI, competition, interaction term between competition and FDI, and other variables. The benchmark variables in this study is R&D expenditure, FDI inflow and product market competition. Business regulation index is used as a proxy for competition. IFDI and COMPETITION terms are added in (2) so that the interaction term does not proxy for FDI inflow and competition. In this study, the coefficient of interest in equation (2) is $\beta3$. If $\beta3$ is significant, it shows that there FDI affect R&D expenditure depended on level of competition. To avoid the interaction term to proxy for FDI and R&D, both of the base variables are included in the equation as well.

Since equation (2) is a dynamic model, traditional panel estimation such as fixed and random effect model cannot remove the endogeneity problem. Generalized methods-of-moments (GMM) panel estimator is applied in this study to estimate the model above. Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998) develop this estimator that enhance the study of dynamic model. GMM panel estimation is applied to control for country specific characteristics that are time varying and time invariant. This is due to the fact that country specific dummy variables may not be able to fully capture the characteristic in this dynamic setting. Using country dummies will also create problems of losing degree of freedom and it violates the principle of parsimonious. Arellano-Bond estimators remove country specific effects by taking first differences and then use instruments to form moment conditions. Equation (3) below shows the transformation proposed by Arellano and Bond (1991) to remove country specific effects μ.

$$R\&D_{it} - R\&D_{(it-1)} = \beta_1(R\&D_{(it-1)} - R\&D_{(it-2)}) + \beta_2(FDI_{it} - FDI_{(it-1)}) + \beta_3 (COM_{it} - COM_{(it-1)}) + \beta_4 [(FDI \times COM)_{it} - (FDI \times COM)_{(it-1)} + \beta_5 (X_{it} - X_{(it-1)}) + (\epsilon_{it} - \epsilon_{(it-1)}) \quad (3)$$

If the autoregressive process is too persistent, Blundell and Bond (1998) show that the lagged-level instruments in the First Difference GMM estimator become weak. Thus, the authors proposed a system GMM estimator that uses moment conditions such that lagged differences are used as instruments for the level equation in addition to the moment conditions of lagged levels as instruments for the differenced equation. GMM can also tackle simultaneity problem as the error term is correlated with lagged difference of lagged dependent variable. For example, higher R&D may attract higher FDI inflow as the foreign investors seek to benefit from technological spillovers from host country. The causality relationship between IFDI and R&D may be reversed (Wang, 2008). By using instrumental variable technique, GMM estimation can counter the endogeneity problem. The application of GMM in estimating dynamic panel is popular in recent studies such as in the study on FDI and growth conditional on economic freedom by Azman-Saini *et al*. (2010).

Data and Description

The sample data used in this study consists of 61 countries selected based on data availability. The countries in our sample are listed in Appendix A. The sample covers from year 2000 to 2011, which is a total of 12 years. The key variables in the model is gross expenditure on R&D, net FDI inflow (IFDI) and product market competition which is proxied by business regulation index (COMPETITION). Data on GERD are obtained from UNESCO statistics database [1] while data on FDI inflow are obtained from United Nations Conference on Trade and Development (UNCTAD) database.

To measure competition, economic freedom index is used in this study. Business regulation index is one subcomponent of economic freedom index reported by Fraser Institute. This index serves as proxy for product market competition and can be viewed as measure of competition, with higher index close to 10 indicates higher competition [2]. In Aghion's framework, Lerner index is used to measure competition in industries. Economic freedom index published by Fraser institute has been used to measure competition. In De Haan *et al*. (2006) paper, he suggested that "economic freedom implies competition" (p.15). Later papers by Azman-Saini *et al*. use EF index to show its crucial role in promoting growth and development as it provide settings that can multiply benefits from MNC presence. There is another country level competitiveness index such as the economic freedom index by Heritage Foundation but the data span is shorter than Fraser Institutes' so it is not used in this study.

Human capital is an essential determinant of R&D capacity. Controls used in the model comprise two variables that Wang (2008) found significant across various models in his study of FDI and R&D using extreme bound analysis technique. The two variables are tertiary education

[1] Some of the missing GERD data are interpolated using Gross Domestic Product (GDP) and Gross Fixed Capital Formation data acquired from World Bank database (Coe and Helpman, 1995). This is performed using linear regression of GERD on GDP and Gross Fixed Capital Formation in available dataset for each individual country. The estimated coefficients obtained from regression are then used to interpolate missing GERD for specific years

[2] There are six criteria used to measure business regulation index, which are administrative cost, bureaucracy cost, business startup cost, extra payments, licensing restrictions and tax compliance's cost. Detailed explanation of the indicator can be found in "Economic freedom of the world: 2013 annual report" (Gwartney, Lawson and Hall, 2013, page 254).

ratio in working age population and ratio of researchers to total population. Tertiary education ratio are obtained from World Bank's World Development indicator. Due to data availability, number of researchers and technicians are used and the data is obtained from UNESCO dataset. Both indicators are popular choices in measuring human capital stock.

EMPIRICAL RESULTS

Table 1 provides a summary statistic of variables used in this analysis The main variables used are natural log of gross R&D expenditure (R&D), natural log of net FDI inflow (FDI) and product market competition (COM). There are a total of 61 countries over the span of 12 years. The control variables are tertiary education(TERTIARY EDUCATION) and number of researchers and technicians (RESEARCHERS TECHNICIANS).

Table 1: Summary Statistics

Variables	Mean	Std. Dev.	Min	Max	Obs
			Main Variables		
R&D	22.465	2.938	16.240	31.412	724
FDI	23.736	2.538	13.911	30.853	701
COM	6.237	1.076	3.032	9.037	709
FDI*COM	147.881	29.775	67.215	231.015	682
			Controls		
TERTIARY EDUCATION	24.278	9.226	3.400	54	558
RESEARCHERS TECHNICIANS	94542.87	203443.50	276	1400000	595

Table 2 reports results from two-step system GMM estimations with robust standard error. The dependent variable is natural log of gross R&D expenditure (R&D). System GMM can improve estimation when autoregressive process is persistent. Column 1 shows the main estimated result while column 2, 3 and 4 are models to test for robustness with removal of potential outliers. Column 2 shows estimation after removing United States (USA), column 3 shows estimation after removing United States and Ireland (IRL) and column 4 shows estimation after removing United States, Ireland and Japan (JPN). In the first row of column 1, the coefficient of lagged R&D expenditure is very high and significant. This shows that previous R&D expenditure has a large effect on current R&D expenditure, and there exist dynamic in the model. Since the variance–covariance matrix of the two-step GMM estimators are biased, WC robust standard error is used (Windmeijer, 2005). FDI inflow is positive and significant in Column 1. This suggests that the direct effect of FDI on R&D exist with positive effect. For each percent increase in net FDI inflow, R&D expenditure increases 0.037%. Although FDI increases R&D directly, its effect seems to be diminished by competition level as the interaction term is found to be negative and significant at 5% level.

Table 2: GMM estimation of Gross R&D Expenditure

	1 Main model	2 Remove USA	3 Remove USA, IRL	4 Remove USA, IRL, JPN
	Main Variables			
$R\&D_{t-1}$	0.9329***	0.9341***	0.9342***	0.9414***
	(0.0275)	(0.0280)	(0.0275)	(0.0300)
FDI	0.0368**	0.0351**	0.0345**	0.0324**
	(0.0145)	(0.0144)	(0.0146)	(0.0145)
COM	-0.0183	-0.0163	-0.0182	-0.0194
	(0.0145)	(0.0143)	(0.0145)	(0.0156)
FDI*COM	-0.0182**	-0.0180**	-0.0181**	-0.0172**
	(0.0072)	(0.0073)	(0.0072)	(0.0073)
CONSTANT	0.8587**	0.8533**	0.8790**	0.7597*
	(0.3946)	(0.4021)	(0.3920)	(0.4500)
	Controls			
TERTIARY EDUCATION	-0.0026 (0.0025)	-0.0027 (0.0026)	-0.0029 (0.0026)	-0.0028 (0.0029)
RESEARCHERS TECHNICIANS	6.11e-7** (3.04e-7)	6.98e-7 (3.96e-7)	7.04e-7* (3.99e-7)	9.69e-7 (6.24e-7)
	Tests			
Sargan	0.2623	0.3038	0.3188	0.3996
AR(2)	0.2522	0.2513	0.2485	0.2524
No. of Obs	424	423	419	413
No. of instruments	35	35	35	35
No. of country	60	59	58	57

Note: Windmeijer bias-corrected (WC) standard errors are reported in bracket under coefficients. P-values are reported for Sargan and AR(2) test. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level respectively. Number of instruments is limited to maximum two lags of dependent variables to reduce bias. Such operation is suggested inBaltagi, Demetriades and Law (2008).

It is worth to note that there may be multicollinearity problem when interaction specification is used (Woolridge, 2009). Therefore, a two-step procedure is performed in this case to alleviate the problem. First, the interaction term is regressed on FDI and competition. Then, the residuals from the regression are saved and used to represent the interaction term. This method to remove multicollinearity in model with interaction specification is also applied in recent literature such as in the study by Azman-Saini *et al*. (2010).

Column 1, row 4 from Table 2 shows the coefficients of the interaction term. The interaction terms are negative and significant at 5% level. This provides evidence that marginal effect of FDI on R&D is dependent on level of competition. However, the relationship is negative. This suggests that higher competition countervails the positive effect of FDI on R&D. High domestic competition induces by FDI inflow cause R&D to fall. This negative impact on R&D brought by competition coincides with a study by Hashmi (2013) who finds negative relationship between competition and innovation. The author shows that there is a mildly negative relationship between competition and innovation in a large United States industrial dataset.

Compared to the inverted-U relationship suggested by Aghion *et al*. (2005) using a United Kingdom data, Hashmi (2013) argues that the average technological gap in the industries in his U.S. dataset is larger than in U.K. data. In his partial equilibrium industry model, he shows that the higher the technological gap, the more negative the relationship between competition and R&D. Since technological gap in cross country setting should be considerable larger than in industrial setting, this may explain the diminishing effect of competition which counteract with FDI found in this study. Bringing in the inverted-u relationship explanation, it appears that our dynamics coincide with the nonlinear shape. In the first part, FDI increases R&D, but its effect is diminishing in competition level. As competition level rises, the net effect of FDI on R&D will be negative when competition level is high.

Despite literature such as Wang (2008) who finds postive relationship between tertiary education ratio and R&D expenditure, this study finds insignificant result. The possible reason is that education level which is often measure of human capital cannot always translate into innovation. As suggested by Hu and Mathews (2005), "the returns of education investment are reflected in the promotion of overall productivity of labor, rather than directly contributing to international patenting activitiy" (p.1338). Hence, education which measure human capital and R&D which measure innovation do not always have positive and significant relationship in literature as effect of education mainly translate into higher labor productivity but not innovation, which relies more on inputs such as number of researchers and technicians. As shown in column 1 in Table 4.2, number of researchers and technicians are positive and significant in our analysis, which conforms with literature such as Hu and Mathews (2005) and Wang (2008).

There are two diagnostic tests conducted, which are Sargan test and serial correlation test. Sargan test is used to determine whether the overidentifying moment conditions are valid. The p-values for Sargan tests are reported in Table 2 under subsection Tests. This shows that the instruments for all models are generally valid at 5% significance level. Also, the moment conditions in system GMM model are valid only if there is no serial correlation in the idiosyncratic errors (Arellano and Bond, 1991).Arellano–Bond test for serial correlation is shown below Sargan tests. Only p-values for tests of serial correlation of order 2 is reported as rejecting the null hypothesis at higher orders implies that the moment conditions are not valid. Our empirical results show that all models pass the second order serial correlation test.

Outliers test is also performed using DFITS statistics to analyze the sensitivity of our model. In the Figure below, United States, Ireland and Japan are top three possible outliers as they are located at the upper right corner.

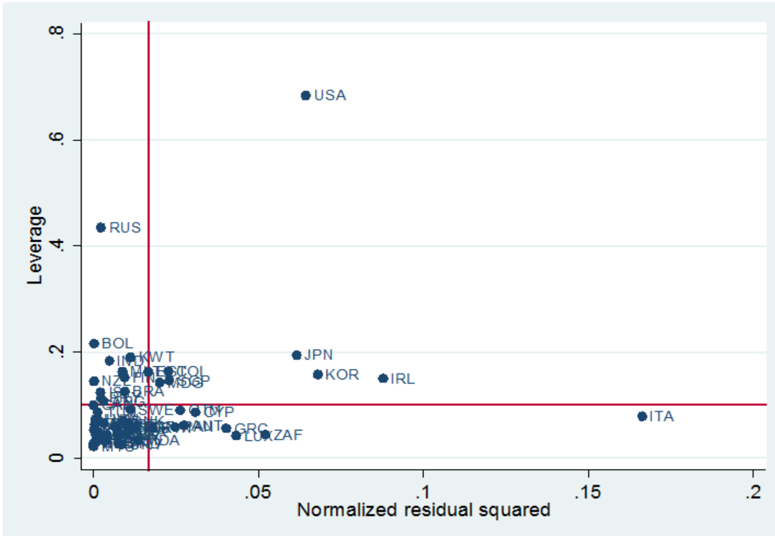

Figure 2: Outlier test

United States, Ireland and Japan are removed one by one to see if this affects the significance of GMM result. However, the results of our main variables do not change much after removing these potential outliers, suggesting that the model is not sensitive to this problem.

CONCLUSIONS

This paper has contributed in providing fresh result on the study of conditional effect in the relationship between FDI and R&D. Using a panel data consisting of 61 countries and spanning from 2000 to 2011 (12 years), this paper draws one important conclusion from the empirical analysis. FDI has no direct effect on domestic R&D expenditure, but it affects R&D negatively conditional on competition. This suggests that competition hinders the effect of FDI on R&D as higher competition lower domestic R&D.

The negative result from the effect of FDI on R&D conditional on competition may be due to the fact that under competitive pressure, firms resort to import technology rather than conduct domestic R&D activities. In face of increased competition, importing technologies is a favorable alternative to investing in R&D that is both time consuming and uncertain for local firms. This is not surprising as international R&D specialization is more common in this era of globalization. As in evidence, in a study by Blomstrom *et al*. (1994), there is a significant positive relationship between technology imports by foreign affiliates in host country and local competition measured by change in capital stock and change in output. Technological diffusion to local firms may occur conveniently in this case through MNC, thus hampering domestic R&D investment initiatives.

Policymakers may be interested to see how level of competition can undermine the effect of FDI on domestic R&D. Strategies that are aimed to attract FDI may inevitably lead to changes in competition level that may eventually lower domestic R&D investment. For example, after the reform in India in 1991 which liberalize foreign investment, domestic investment in technology was reduced by local firms (Sasidharan&Kathuria, 2011). As shown in our analysis, competition diminishes the positive effect of FDI on domestic innovative effort. The tradeoffs between these key economic variables need to be weighted to achieve best outcome for society. It is also important to note that the result should be consider with care as R&D expenditure is an imperfect indicator of innovation as it measures input but not output. The use of R&D spending to proxy for innovation is due to its advantage of being quantifiable. Even though indicators for innovation output such as patent applications may be considered regardless of its data constraint problem, it also poses the same problem of not being able to capture effect of technological diffusion, particularly innovation process in organizational change. The high possibility that actual diffusion of innovation arises from foreign presence may be larger should be acknowledged.

The limitations of this study are a few. First, data limitation on the control variables can be a caveat in this paper. Better quality data can improve the estimation and probably making the variables significant. For example, firm level data can possibly provide more insight than country level analysis but most of the firm level data are scarce to find. Second, this paper uses business regulation index to proxy for product market competition in the country level setting. Better measure of competition can be used in this model to capture the dynamic of competition more efficiently. For example, in firm level analysis, Herfindahl-Hirschman Index could possibly measure market concentration more accurately. The model in this paper can be fitted to firm-level analysis for a specific country as difference in data and individual characteristics may provide new contribution to this area. This paper can be extended into future research by studying more conditional effects such as regulation on the effect of FDI on domestic R&D.

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APPENDIX A: LIST OF COUNTRIES

1	Argentina	22	Hungary	43	Panama
2	Australia	23	Iceland	44	Paraguay
3	Austria	24	India	45	Poland
4	Belgium	25	Ireland	46	Portugal
5	Bolivia	26	Italy	47	Romania
6	Brazil	27	Japan	48	Russia
7	Bulgaria	28	Republic of Korea	49	Singapore
8	Canada	29	Kuwait	50	Slovakia
9	Colombia	30	Latvia	51	Slovenia
10	Costa Rica	31	Lithuania	52	South Africa
11	Croatia	32	Luxembourg	53	Spain
12	Cyprus	33	Republic of Macedonia	54	Sweden
13	Czech Republic	34	Madagascar	55	Thailand
14	Denmark	35	Malaysia	56	Tunisia
15	Egypt	36	Malta	57	Turkey
16	Estonia	37	Mexico	58	Ukraine
17	Finland	38	Moldova	59	United Kingdom
18	France	39	Morocco	60	United States
19	Germany	40	Netherlands	61	Uruguay
20	Greece	41	New Zealand		
21	Guatemala	42	Norway		