What Fosters Innovation?

A Cross-Sectional Panel Approach to Assessing the Impact of Cross Border Investment and Globalization on Patenting Across Global Economies

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Abstract

This study considers the impact of foreign direct investment (FDI) on innovation in high income, upper-middle income and lower-middle income countries. Innovation matters because it is a critical factor for economic growth. In a panel setting, this study assesses the degree to which FDI functions as a vehicle for innovation as proxied by scaled local resident patent applications. This study considers research and development (R&D), domestic savings, imports and exports, and quality of governance as factors which could also impact the effectiveness of FDI on innovation. Our results suggest FDI is most effective as inward direct investment in countries outside the technological frontier possessing adequate existing domestic investment capital and R&D spending to convert foreign investment capital and technological spillover into innovation. Nonetheless, FDI was not a consistent indicator for innovation; rather, the most consistent indicators across this study were R&D and domestic savings. Differences amongst income groups are highlighted as well as their varying responses to our array of causal factors.

Keywords: Foreign Direct Investment (FDI); Innovation; Patents; Patent Applications; Scaled Local Patent Applications; Institutions; Research and Development (R&D); Gross Domestic Savings

JEL Codes: A10, B22, C82, E00, E02, O10, O11, O30, O31, O32, O33, O34, O43

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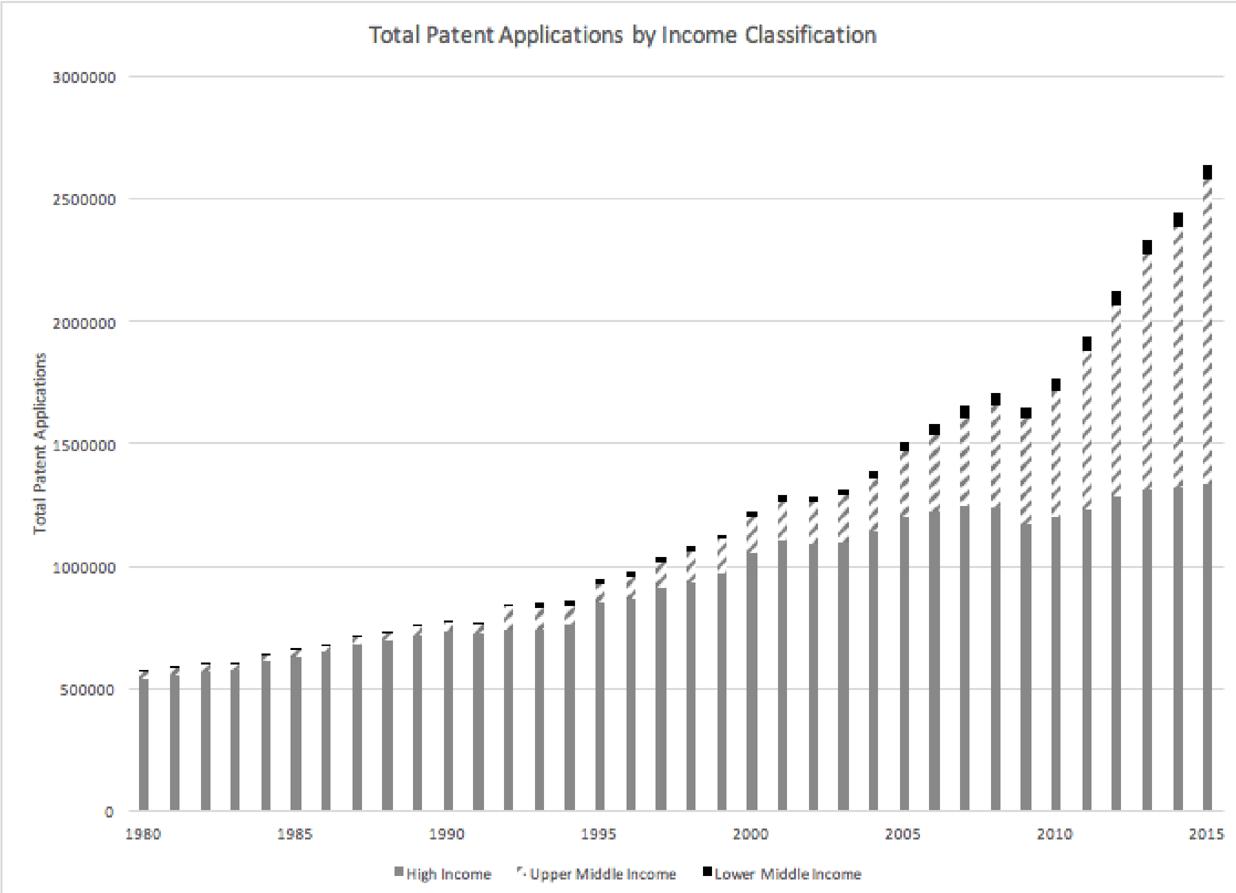
1. Introduction

Increasingly, knowledge and technology have been diffusing across companies, industries, and global borders. Since the early 1980s, the increase in trade openness and global capital flows has been fueled by a multitude of factors including cross-border trade organizations, the rise of Asian manufacturing, the fall of the Soviet Union, and the advent of the internet and other technologies. Such trends have led to a period of rapid modern globalization in which trade, investment and technical diffusion are rapidly exchanged across borders. In such an environment, it has become more important than ever for firms and governments to incorporate innovation to remain competitive in the modern world economic landscape.

Technological progress and innovation foster increases in productivity growth and are thus paramount to fostering long-term economic growth and prosperity. Hence, it is imperative to understand the underlying processes of innovation and technological progress to equip economies with an understanding of how to best support long-run growth. While previous studies have linked FDI and growth or FDI and innovation within individual economies, limited precedent literature has employed a panel regression to study the impact of FDI across global economies of differing institutional quality and income. Here, we study the interaction of globalization and technological progress on innovation, specifically the impact of foreign direct investment (FDI) flows on scaled local resident patent applications across 92 high-income, upper-middle income, and lower-middle income economies.

While innovation can take many forms, this study will focus on patent applications as a proxy for innovative activities. It should be noted that this measure is representative primarily of technological hardware advancement. Increased emphasis on innovative activities across global economies is reflected in the rise of total patent applications as seen in *Figure 1*. Total patent applications across the countries included in this study have increased significantly from 1980 to present, signaling the increased global focus on, and rate of, innovation.

Figure 1. Total Patent Applications by Income Classification



As can be seen in *Figure 1*, patent application growth has not been evenly distributed amongst the representative high income, upper-middle income and lower-middle income countries studied. This suggests that differences exist with respect to innovation across income groups. As a result, we classify the countries examined here into the three categories listed above.[1] In *Figure 1*, the upper-middle income countries account for the majority of the net growth. Between 1980 and 2015, total patent applications across high income, upper-middle income and lower-middle income countries grew 147%, 4,315% and 1,057%, respectively (World Intellectual Property Organization). Relatively low high income patent growth reflects the Law of Diminishing Returns, with countries that have surpassed the technological frontier exhibiting slower patent growth. Such disparities capture inherent differences amongst these countries, and illustrate the need to further investigate the underlying factors facilitating new innovation across all income thresholds.

Before continuing further with the discussion of innovation, it is important to explicitly define the independent variable under study: FDI. Critical to the definition is the distinction between inward flowing FDI (IFDI), and outward flowing FDI (OFDI). According to the World Bank, IFDI is the value of inward direct investment by non-resident investors in the reporting

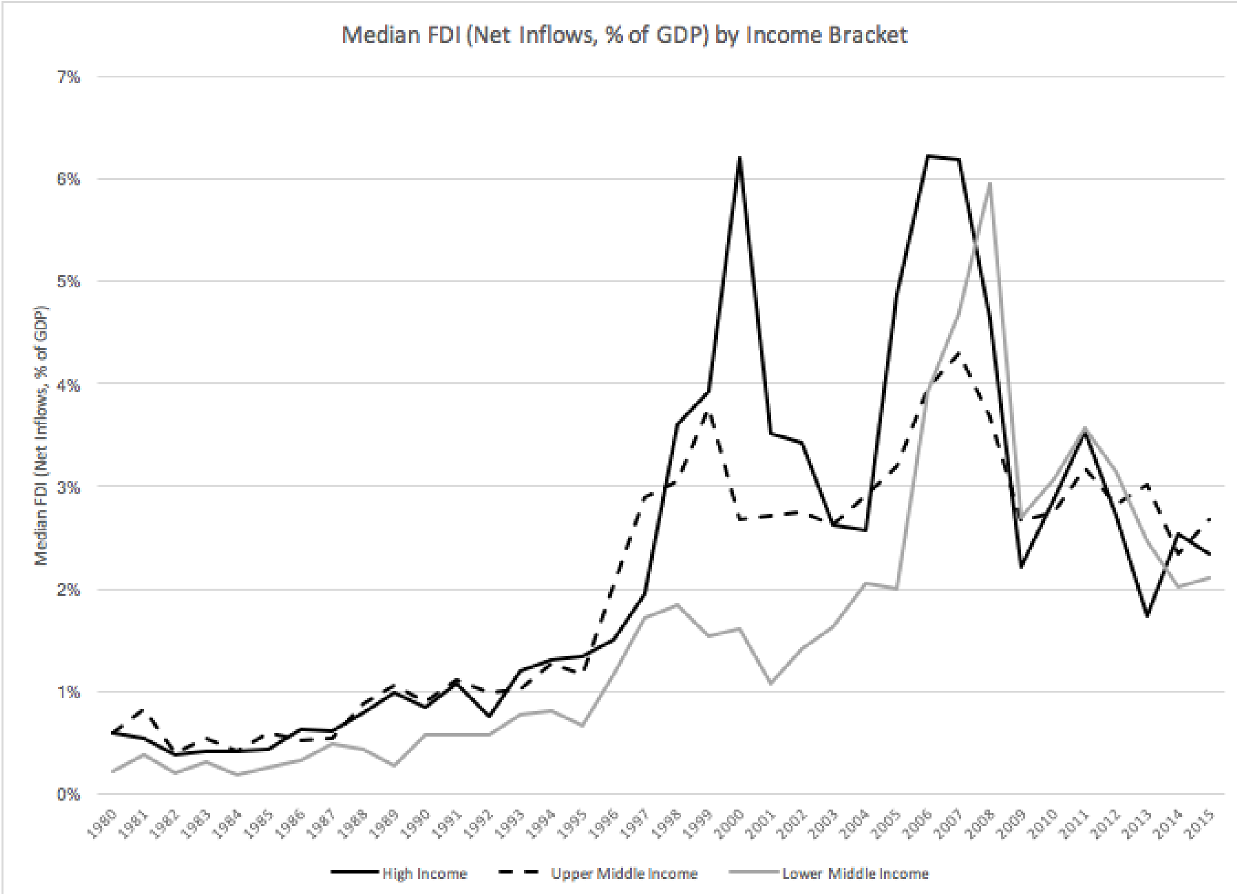
[1] Countries classified as high income had a 2015 GNI per capita in excess of $12,236 per capita; 56 countries fall in the high income range. Income per capita between $3,956 and $12,235 are defined as upper-middle income countries, of which there are 55 in this study. Lower-middle income countries, with GNI per capita ranging between $1,006 and $3,955, included 46 countries. An in-depth breakdown of income categories is presented in section 5.4.

economy. Inward direct investment is representative of the flows of investments, including all liabilities and assets, between resident direct investment enterprises and their direct investors. This definition includes assets and liabilities between resident and nonresident fellow enterprises regardless of whether the the ultimate controlling parent is nonresident. OFDI (also known as direct investment abroad) is the value of outward direct investment made by residents of the reporting economy to external economies. OFDI includes assets and liabilities distributed between resident direct investors and their direct investment enterprises as well as the transfers of assets and liabilities between resident and nonresident entreprises (World Bank).

Existing literature such as Borensztein, Gregorio and Lee (1998), Alfaro, Chanda, Kalemli-Ozcan and Sayek (2006), Lin and Lin (2010) and Mahembe and Odhiambo (2015) have considered imports, exports, IFDI, and OFDI as primary drivers for innovation, particularly in countries outside the technological frontier. In these countries, many innovations are a result of both technological and knowledge-based spillover. In other words, the distribution of foreign advanced products, manufacturing techniques and managerial techniques breed innovation amongst domestic firms through a diffusive process as a result of contact with these factors. Previous literature indicates IFDI will have a larger impact on innovative activities than OFDI as it combines inward investment capital with technological and managerial spillover.

Figure 2 shows that median IFDI (% of GDP) across high income, upper-middle income, and lower-middle income countries has grown significantly since 1980, coinciding with the increase in total patent applications. The large uptick and subsequent downturn occurring in the late 1990s across the high and upper-middle income countries coincides with the dot-com bubble and burst. The second uptick and subsequent downturn through the mid to late 2000s coincides with economic optimism corresponding to the era of securitization and loose regulation preceding the Great Recession. Borensztein, et al. (1998), Alfaro, et al. (2006), and Lin and Lin (2010) suggest that growth in FDI is a result of increased cross-border investment due to technology, trade organizations, and monetary unions.

Figure 2. Median FDI (net inflows, % of GDP) by Income Bracket



Thus, the aim of this paper is to determine the role of FDI as an economic driver for innovation in high income, upper-middle income and lower-middle income global economies. Intuitively, IFDI can serve as a vehicle for innovation by providing monetary capital for research and development (R&D), reduce selection bias in capital allocation, and increase intellectual capital via industry expertise, managerial expertise, and existing patents. Further, OFDI stimulates innovation through increased competition and product variety, and through technological and managerial spillover abroad. Given the positive externalities resulting from both inward and outward FDI, we expect it to have a positive and significant impact on our metrics for innovation.

Conventional wisdom suggests that capital and labor are complementary. Thus, the result of increased productivity in physical capital may be a positive boost to the efficiency of labor and vice versa. Moreover, all of these aspects may vary across countries and regions due to such things as the nature of institutions and the development of the state. Hence, this study intends to control for differing levels of income and institutional quality to isolate the role that FDI plays in fostering innovation. By outlining the implications of this relationship, results presented here can guide future international and national policy decisions that best promote innovation and economic prosperity. Similarly, by delineating between income thresholds, we better identify the different factors that best fuel innovation depending on a country's income profile.

Across all sets of regressions in the study, there are mixed results capturing the relationship between FDI and innovation. Results indicate that IFDI does have a significant and positive impact on innovation in certain situations. However, negative coefficients for OFDI were confounding, indicating the need for additional economic work. It should be noted that our explanatory power may be impacted by two way causality between FDI and innovation, as greater resident innovative activities within an economy can prompt greater FDI. Amongst other variables, R&D and gross domestic savings proved to be the two most robust indicators across all samples. These indicators were most potent in upper-middle income countries, suggesting their importance to the innovative process. The array of results presented here capture inherent differences in the innovative processes for different income brackets.

The paper is organized as follows. Section 2 reviews literature on FDI, reviewing theoretical and empirical evidence linking FDI and other factors to economic growth and innovation growth. Throughout this section, an integrated summary of the literature will be provided in terms of important themes, findings, and contributions. Section 3 will cite the existing theoretical framework guiding the empirical work of this study. Section 4 will identify the empirical specification employed. Section 5 provides an overview of the data including sources and summary statistics. Section 6 will present the study's empirical results, including a discussion on the implications of the results. Section 7 concludes.

2. Literature Review

Precedent literature such as Borensztein, et al. (1998), Connolly (1998), Sanchez-Robles and Calvo (2003), Subash (2006), Basu (2007), Alfaro and Sayek (2009), Lin and Lin (2010), and Tiwari and Mutascu (2014) have demonstrated the role of both IFDI and OFDI to the importance of accelerating growth across global economies. Important to note is that many papers study the link between FDI and growth, but few study the link between FDI and innovation on a macroeconomic global scale.[2] The substitution of innovation for growth is based on the notion that innovation is a major factor for growth, consistent with the work of Lin and Shampine (2016) and Qian (2017). As such, we outline a number of variables below that drive economic growth, per precedent literature, and seek to establish their relationship with innovation.

2.1 Foreign Direct Investment

Research including the works of Choe (2003), Sanchez-Robles and Calvo (2003), Rosenberg (2004), Alfaro, et al. (2006), Subash (2006), Tiwari and Mihai (2014) and Suliman, Elian and Ali (2018) highlight the impact of FDI from multinational corporations (MNCs) to developing countries on economic growth. Borensztein, et al. (1998) expounded upon this theory and studied the impact of FDI flows on economic growth across 69 countries. After empirically determining a positive correlation between FDI and economic growth, Borensztein, et al. (1998) hypothesized that the link between economic growth and FDI is the diffusion of advanced knowledge, primarily new technology and managerial techniques. However, the effect of FDI on

[2] Precedent literature has explored the link between FDI and innovation within small communities or within individual countries. Behera (2016) explored the impact of regional FDI as a method for technological spillover across firms in clusters across India, Hafner and Borras (2017) linked technological spillovers from FDI to innovation in Spanish speaking communities, and Olabisi (2017) studied the effects of exports and FDI on product innovation amongst Chinese firms. However, few researchers have performed macroeconomic studies on global impacts of FDI on innovation across economies of differing levels of institutional quality and income.

economic growth is most pronounced when pre-existing levels of human capital are sufficient.[3] Such a result is indicative of the need for an adequately educated labor force to absorb and utilize the knowledge spillover. The study also notes that FDI likely exhibits a non-linear relationship with economic growth, indicating FDI is most effective in countries experiencing the catch-up effect.

Borensztein, et al. (1998) also determines that FDI has a crowding-in effect for domestic investment. Intuitively, one might believe increased FDI would result in less direct domestic investment due to greater competition and limited quality investment opportunities. However, the authors observe the contrary: "FDI may support the expansion of domestic firms by complementarity in production or by increasing productivity through the spillover of advanced technology."[4] It is important to note that the period Borensztein studies terminates in 1989, and since then, globalization, cross-border trade, and cross-border investment flows have grown. Nonetheless, Borensztein, et al.'s (1998) primary takeaway supports the notion that FDI serves as a mechanism for technology transfer through either physical technology transfer or knowledge transfer (via management skills and techniques).

This theory has been supported by more recent work performed in transitioning economies. Wei, Xie and Zhang (2017) determined that firms in China between 2005 and 2007 most effectively transformed R&D spending into patents when supported with FDI. This idea is similarly supported in research by Feng (2014) and Boeing (2016).

The concepts developed in Borensztein et al. (1998) and Connolly (1998) are further explored in Lin and Lin, (2010). Lin and Lin perform an empirical study on the impact of IFDI, OFDI, imports, and exports on the manufacturing and service industries in Taiwan based on the 2003 First Taiwan Technological Survey (TTIS-I). The authors base their study on the theoretical framework developed by Bertscheck (1995) which predicts IFDI, OFDI, imports and exports have positive influences on firm innovative activities. The authors further hypothesize that the impact of FDI would be greater than either imports or exports, as FDI generates competition amongst local companies, driving down profits, and is a more time intensive endeavor, requiring greater certainty of profit. The specific methods which the authors mention that may serve as vehicles for FDI to generate innovation are as follows: reverse engineering of products, flow of technical workers in the labor market (providing local firms with foreign know-how), the demonstration effect from IFDI (which can inspire local firms and help them shorten the trial-and-error process of R&D), and vertical spillover of foreign firms to their local suppliers (leading to transfer of know-how, and employee training). Lin and Lin (2010) note that the product-related spillover effects mentioned above can also be applied to imports.

Similar to the approach applied here, Lin and Lin (2010) proxied innovation through the "number of valid patents (granted to a firm during the 1998-2000 period) held by the firm at the end of the year 2000."[5] The authors hypothesized that IFDI, OFDI, imports and exports should exhibit positive impacts on manufacturing and service based firms. However, across the entire sample only IFDI, OFDI, and imports were statistically significant regardless of the measurement of innovative activities. In total, FDI was found to have greater impact on innovation than either imports and exports. The findings demonstrate the need to control for imports and exports, and provides context regarding industry-specific effects of IFDI and OFDI.

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[3] In Borensztein, et al. (1998), human capital is proxied by years of male average secondary schooling.

[4] Pg. 117

[5] Pg. 444

The empirical work of Borensztein et al. (1998) is further developed in Connolly (1998). Connolly empirically quantifies the impact of high-technology imports separately to domestic imitation and innovation in both developed and less-developed countries. Connolly furthermore considers the impact of overall trade openness, quality-adjusted research per capita, transportation and communication infrastructure, population (as a proxy for domestic market size), a time varying intellectual property rights (IPR) protection index, and IFDI (as a percent of GDP). In line with the work of Borensztein et al. (1998), IFDI (as a percent of GDP) had positive coefficients across the entire study, and was statistically significant in all regressions.

These findings were further corroborated in Wei et al. (2017), as the authors found that Chinese firms with foreign investment, across most size deciles, reported higher patent counts per million RMB investment in R&D than either state owned firms or domestically invested firms.

In total, many precedent papers have demonstrated a positive correlation between IFDI, OFDI and economic growth. Nonetheless, economic growth can be impacted by a number of other factors. In order to best isolate the effect of FDI, it is important to understand the underlying additional factors which drive and could be affecting economic growth and innovation.

2.2 Other Factors

A wide array of literature explores other underlying factors which contribute to innovation in global economies. Rosenberg (2004), (2007) offers a holistic perspective regarding the many factors which impact innovative activities within an economy via studies performed by the OECD. Rosenberg determines the major factors to the innovation formula include trade openness, investment capital, "aggregate measures of human capital, R&D and capacity to conduct it, patent valuations as well as intangible assets such as brand value or firm-specific knowledge."[6] These factors are supported by the works of Mahmood and Mitchell (2004), McKelvie, Brattström and Wennberg (2017), and Chiu, Meh and Wright (2017).

2.2.1 R&D

The work of Connolly (1998) empirically demonstrated over 75 developed and less-developed countries via fixed effects regressions the importance of R&D to the innovative process. Across regressions run with one, two and three year lags, quality adjusted research per capita had a positive and significant coefficient, demonstrating the importance of the research process to innovative activities regardless of timing. Nonetheless, innovations take time to research and develop, which is supported by the increasing magnitude of research's coefficient with increasing lag. Interestingly, the imitative process[7] did not exhibit positive coefficients, suggesting other processes to developing imitative patents.

The results of Connolly (1998) are further supported by the work of Stam and Wennberg (2009) who empirically demonstrate the importance of R&D activity to high-technology new-firm growth. The authors study the impact of R&D in high-technology and low-technology firms on "new product development, interfirm alliances and employment growth".[8] The authors

[6] Pg. 1

[7] Defined as the number of applications for domestic patents by home residents minus U.S. patent applications by residents of that same country

[8] Pg. 1

find that R&D enables firms to exploit external knowledge and stimulates new product development, both of which contribute to overall innovative activities within individual firms.

The results of Wei, et al. (2017) further buttress the findings of Connolly (1998) and Stam and Wennberg (2009). The authors hypothesize that not only does R&D spending have a positive impact on overall innovative and economic growth, but that more specific metrics such as researchers per capita and spending per researcher are both positively correlated with economic growth. These concepts are directly supported by the results of Lin and Lin (2010). The authors utilize a logit regression to determine the impact of FDI on innovative activities amongst firms in Taiwan. The results indicate that R&D intensity and and R&D cooperation between firms both have positive and significant impacts on firm innovative activities. Furthermore, the authors find that the presence of an internal R&D facility within a firm is positively and significantly correlated with firm innovative activities, especially relative to firms which outsource R&D processes to the government or other firms.

2.2.2 Gross Domestic Savings

Precedent empirical studies have concluded that available capital for investment exerts a major influence on economic growth. In particular, Gross Capital Formation (% of GDP) is elemental to economic growth. As our dataset lacks consistent data for Gross Capital Formation, we proxy capital formation using available local investment capital. The use of Gross Domestic Savings is consistent with the work of Choe (2003) and Suliman, et al. (2018).

The work of Suliman, et al. (2018) utilizes panel data for Western Asian countries from 1980-2011 and tests for the association between FDI and economic growth, controlling for "FDI-growth deriving factors, namely Gross Domestic Savings."[9] According to traditional economic development theory, greater gross domestic saving rates would lead to greater economic growth by influencing domestic investment and attracting FDI. The empirical results of the experiments find that there is a positive coefficient for Gross Domestic Savings at the 5% significance level, indicating that savings has a clear effect on economic growth.

In a similar light, Choe (2003) attempts to outline the causal relationships between economic growth and FDI and gross domestic investment (GDI) across eighty countries from 1971-1995. While precedent empirical studies have outlined high positive correlations between GDI and economic growth, Choe's findings suggests that statistically positive correlations do not necessarily prove a causal relationship.

2.2.3 Trade Openness

The work of Lin and Lin (2010) highlights the importance of imports and exports to economic growth and innovation. Consistent with the work of Bertscheck (1995), Lin and Lin (2010) determine that imports and exports both have a positive and significant effect on innovative activities of firms as proxied by number of patents. The authors hypothesize that the underlying method through which imports increase innovation is via availability of foreign products for reverse engineering and increased competition in local markets. The authors further hypothesize that the underlying method through which exports increase innovation is via increased firm competitive pressures in foreign markets. However, the authors note that the effect of imports is less than the effect of IFDI, and that the effect of exports is less than that of

[9] Pg. 94

OFDI, as consistent with Bertscheck (1995). The authors' results suggest firms are more likely to benefit from OFDI than from exports, as OFDI enables firms to also capture foreign techniques relating to R&D, management and technological development. Likewise, the authors' results suggest firms are more likely to benefit from IFDI than imports, as IFDI also includes the effects of the following: technological and managerial spillover, the diffusion of knowledge in addition to increased local capital, and availability of reverse engineering foreign products.

Connolly (1998) develops these concepts further by isolating the effect of high-technology imports on innovative and imitative activities. Across imitative regressions, regardless of lag, Connolly finds a positive and significant correlation suggesting the importance of imports to imitative activities. Within regressions studying innovation, high-technology imports is only positive and significant for a 1-year lag, suggesting an importance of initial exposure of researchers to foreign high-technology products.

2.2.4 Measures of Institutional Quality

Alfaro, et. al. (2006) also demonstrated that high quality institutions attract higher levels of FDI and enable FDI to effectively increase economic activity through various forms of investment.

Chiu, et al. (2017) delves deeper into the theoretical framework for developing innovation optimally in an economy. The authors develop a model suggesting there are significant frictions present in transactions of technology from innovators to entrepreneurs in the absence of financial institutions. This leads to less innovation and is attributable to uncertainty surrounding the ability to bring ideas to market. The study determines that "search, bargaining, and commitment frictions impede the idea market, reducing efficiency and growth."[10] The theoretical framework developed in the study finds that these frictions are mediated by the presence of financial and other institutions, which ease the transfer of technologies by providing such things as liquidity, and better evaluation techniques, enabling the "financing of more transactions with fewer assets and, more subtly, by ameliorating holdup problems"[11].

The results of Chiu, et al. (2017) were further supported by the findings of Alfaro, et al. (2006), who similarly studied the role of positive productivity externalities, particularly local financial markets, in enabling FDI to foster growth. It is also important to note that the health of non-financial institutions within an economy can impact the diffusion of technology. When the primary diffusion of technology to a country is being driven by FDI, institutional health often impacts the country's ability to receive and retain FDI.

3. Theoretical Framework

The framework we employ in our regression is adapted from Borensztein, et al. (1998), which is based on a theoretical framework initially developed by Romer (1990), Grossman and Helpman (1990), and Barro and Sala-i-Martin (1995). Their findings explore the effect of FDI on economic growth using data from a number of different countries. Based on this model, the economy is assumed to be producing a single good using technology, labor (human capital) and capital (physical capital) in the following form:

[10] Pg. 95
[11] Pg. 95

$$Y_{it} = AH_{it}^{\alpha}K_{it}^{1-\alpha} \quad (1)$$

A represents the current state of the economy, H denotes human capital, and K represents physical capital. Y is output or gross domestic product (GDP). This is the standard Cobb-Douglas specification of the Solow Growth model with constant returns to scale. In empirical testing, A is the Solow residual. Embodied in A are such things as quality of governance, additional features of institutional quality, and the state of technology. In other words, A will capture the broader environment in which businesses operate and innovate. Variables are measured either across country (*i*), across time (*t*), or across both.

Across time, the stock of domestic capital is represented by:

$$K_{it} = \left\{\int_0^n x_{it}(j)^{1-\alpha}dj\right\}^{\frac{1}{(1-\alpha)}} \quad (2)$$

Thus, the stock of capital, K, is the integration of capital goods, each one being denoted by [x(j)]. Both domestic and foreign firms produce capital goods such that $N = n + n_i^*$. N is the total number of varieties of capital goods, n is the domestic production of capital variety, and n* is foreign production of capital goods. These goods earn a rental rate M(j) given by

$$M_{it}(j) = A_{it}(1-\alpha)H^{\alpha}X_{it}(j)^{-\alpha} \quad (3)$$

Where the rental rate is equal to the marginal productivity of the capital good.

Generally speaking, the process of technology adaptation is costly, hence we assume some fixed setup costs, F:

$$F = f\left(\frac{n_{it}^*}{N}, \frac{N_{it}}{N}\right) \quad (4)$$

$$\text{Where } \frac{\delta F}{\delta(\frac{n^*}{N})} < 0, \frac{\delta F}{\delta(\frac{N_{it}}{N})} > 0$$

This cost depends negatively on the ratio of the number of foreign firms to domestic firms in the home market since foreign firms bring more knowledge to the production of new capital -- that is, foreign firms are a source of technology transfer. In addition, the fixed set up costs also depend positively on the number of capital products produced in the home market relative to the foreign market due to adoption and catch up effects associated with technological progress.

Further assume that due to free entry and exit, the rate of return, r, will be such that economic profit equals zero. This condition leads to:

$$r = A^{\frac{1}{2}}\varphi F\left(\frac{n^*}{N}, \frac{N}{N^*}\right)^{-1}H, \quad (5)$$

$$\varphi = \alpha(1-\alpha)^{\frac{(2-\alpha)}{\alpha}}$$

Since the process of capital accumulation is funded through the pool of savings, we need to include the utility function (u_{it}). We assume individuals maximize their intertemporal utility function:

$$u_{it} = \int_t^{\infty} \frac{C_i^{1-\sigma}}{1-\sigma} e^{-\varrho(s-t)} ds \quad (6)$$

$$Y_{it} - C_{it} = S_{it} \quad (7)$$

Where C denotes consumption and S equals savings. Given a rate of return r, the optimal consumption path is given by:

$$\frac{\hat{C}_{it}}{C_{it}} = \frac{1}{\sigma}(r_{it} - \rho) \quad (8)$$

The growth rate of consumption must be equal to the rate of growth of output g, in the steady state. So substituting equation (5) into (8) produces the following specification for the rate of economic growth:

$$g_{it} = \frac{1}{\sigma}[A_{it}^{\frac{1}{\alpha}} \varphi F(\frac{n^*}{N}, \frac{N}{N^*})^{-1} H_{it} - \rho] \quad (9)$$

Equation (9) indicates that FDI reduces the cost of introducing new varieties of capital goods and increases the rate of their introduction. Moreover, the cost of new capital goods is lower for countries with fewer varieties; i.e. more backward economies with lower N/N*. Hence, these economies may grow faster. Finally, the effect of FDI on an economy's growth rate is positively related to human capital H such that higher human capital in the host country will enhance the effect of FDI on growth.

4. Empirical Specification

The basic empirical proxy for growth therefore becomes:

$$g_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 H_{it} + \beta_4 Y_{it_0} \quad (10)$$

where,

$FDI_{it} = \textit{foreign direct investment, net inflows in country } i\textit{, which captures foreign investment}$

$HC_{it} = \textit{tertiary school enrollment, \% gross in country } i\textit{, which captures human capital per country}$

$Y_{it_0} = \textit{initial GDP per capita in country } i\textit{, which captures the catch up effect for poorer countries}$

Extending the model of Borensztein, et al. (1998), we include the summation of imports and exports (% of GDP) and OFDI (% of GDP) as consistent with the work of Lin and Lin (2010) and Connolly (1998). These determinants capture the potential for technology transfer embedded in imports through trade openness, and present firms with international competition through exports and OFDI. In addition, we incorporate gross domestic savings (% of GDP) as a measure of domestic investment levels consistent with the work of Rodrick (1995). We also include population as a proxy of market size consistent with the work of Connolly (1998). In addition, included in our extended model are metrics capturing the quality of governance. Finally, the model includes a variable for the year in which the observations are studied. The inclusion of the year variable is consistent with the models in Borensztein, et al. (1998), capturing the general effect of time on the dependent variable. These inclusions result in a more comprehensive empirical specification given by:

$$
\begin{aligned}
g_{it} = \beta_0 &+ \beta_1 IFDI_{it} + \beta_2 OFDI_{it} + \beta_3 H_{it} + \beta_4 POP_{it} \\
&+ \beta_5 Y_{it_0} + \beta_6 Overall\ Score_{it} + \beta_7 Property\ Rights_{it} + \beta_8 Government\ Integrity_{it} \\
&+ \beta_9 Business\ Freedom_{it} + \beta_{10} Monetary\ Freedom_{it} + \beta_{11} Investment\ Freedom_{it} \\
&+ \beta_{12} Financial\ Freedom_{it} + \beta_{13} Judicial\ Effectiveness_{it} + \beta_{14} \frac{X+M}{GDP}_{it} \\
&+ \beta_{15} Gross\ Domestics\ Savings_{it} + \beta_{16} Infrastructure_{it} + \beta_{17} Year + \beta_{18} D_{1_{it}} + \beta_{19} D_{2_{it}} \quad (11)
\end{aligned}
$$

D_1 and D_2 are dummy variables for upper-middle income and lower-middle income countries, respectively. We are benchmarking to high income countries; nonetheless, the coefficients for D_1 and D_2 are expected to be ambiguous due to catch up effects. As consistent with the work of Connolly (1998), we add R&D expenditures (% of GDP) and an infrastructure index (1-5 scale) to account for the impact of R&D spending on innovative activities and the impact of internal ability to communicate and trade. Finally, since technological advancement is the mechanism for long term growth, we substitute innovation, I, for growth producing:

$$
\begin{aligned}
I_{it} = \beta_0 &+ \beta_1 IFDI_{it} + \beta_2 OFDI_{it} + \beta_3 H_{it} + \beta_4 POP_{it} \\
&+ \beta_5 Y_{it_0} + \beta_6 Overall\ Score_{it} + \beta_7 Property\ Rights_{it} + \beta_8 Government\ Integrity_{it} \\
&+ \beta_9 Business\ Freedom_{it} + \beta_{10} Monetary\ Freedom_{it} + \beta_{11} Investment\ Freedom_{it} \\
&+ \beta_{12} Financial\ Freedom_{it} + \beta_{13} Judicial\ Effectiveness_{it} + \beta_{14} \frac{X+M}{GDP}_{it} \\
&+ \beta_{15} Gross\ Domestics\ Savings_{it} + \beta_{16} Infrastructure_{it} + \beta_{17} Year + \beta_{18} D_{1_{it}} + \beta_{19} D_{2_{it}} \quad (12)
\end{aligned}
$$

where I is innovation as proxied by number of scaled resident patent applications[12]. FDI is measured as a ratio of gross FDI/GDP, net of credits minus debits and corresponds to the fraction of goods produced by foreign firms in the theoretical framework (n*/N).
Our final empirical specification (13) is an adaption of (12):

$$
\begin{aligned}
I_{it} = \beta_0 &+ \beta_1 IFDI_{it} + \beta_2 OFDI_{it} + \beta_3 R\&D_{it} + \beta_4 \frac{X+M}{GDP}_{it} \\
&+ \beta_5 Gross\ Domestics\ Savings_{it} + \beta_6 Overall\ Score_{it} + \beta_7 Property\ Rights_{it} \\
&+ \beta_8 Year + \beta_9 D_{1_{it}} + \beta_{10} D_{2_{it}} \quad (13)
\end{aligned}
$$

While an ideal model would isolate the impact of each of the above variables on innovation, there are inevitable interaction effects between these variables. As such, these variables may be causing changes in each other, leading to a potential diminishment of our explanatory power.

[12] We initially used Total Patent Applications as the dependent variable. Due to theoretical considerations we use only Resident Patent Applications per Million to isolate resident innovative activities from the impact of multinational corporations partaking in defensive patenting to protect market share in targeted markets. Regressions with Total Patent Applications as the dependent variable are available from the authors upon request.

4.1 Omitted Variables

Population is omitted from the final specification because the dependent variable is scaled per million population and therefore accounts for the effect of population on both market size and on availability of human capital for innovative activities.

Furthermore, we drop the human capital term. While we recognize the theoretical importance of human capital to growth as demonstrated in Borensztein, et al. (1998) and Connolly (1998), there were limited available variables which adequately capture the technical skills needed to drive innovative processes[13].

Judicial Effectiveness is omitted in the final empirical specification due to lack of available data from the Freedom Index. Through iteration, we also drop all other Freedom Index metrics other than Property Rights and Overall Score due to collinearity, and run each in separate regressions. Property Rights is most closely linked to propensity to innovate, as it predicts a firm's protection for its profits on new innovations. Overall Score is a complete indicator inclusive of all Freedom Index sub-scores, and is a proxy for quality of governance and thus enforcement. See *Table 1* for a complete correlation matrix of the Freedom Index Indicators. Of note is the relative high correlation across all variables, further supporting the omission of certain metrics. Due to limited availability of data, we similarly drop the Infrastructure Index to maintain sufficient observations. We thus arrive at our final empirical specification given by equation (13).

The time period studied is 1995-2015, in part due to data limitations. Initial regressions included a full sample set from 1980-2015; however, the 15 year period from 1980-1995 included fewer than 200 observations. As such, the regressions reported here study only 1995-2015. Regressions encompassing the full 1980-2015 dataset are available from the authors upon request.

5. Data

In this section, we review the various data sources and variables used. We further provide a statistical overview (e.g. summary statistics) and outline our empirical technique used. As noted in the introduction, this study employs time series, cross-sectional data. The datasets are sourced from a compilation of publicly-available sources: *World Intellectual Property Office* (WIPO), the *World Bank Group*, and the *Index of Economic Freedom*. There are varying time spans across the different datasets, which are detailed in the subsections below.

As noted in Section 4.1, there were numerous cases of discontinuous data, which led to the omission of the following variables: human capital, judicial effectiveness, and the Infrastructure Index. This is not due to the quality of the sources being used; rather, many developing countries lack reliable data.

[13] The measures for human capital that were considered included: percentages of school enrollment across primary, secondary, and tertiary schools, educational attainment levels across the population aged 25+, and labor force educational attainment levels across the labor force aged 25+. Many of these indicators lacked continuous data, particularly across upper-middle and lower-middle income countries. Those with sufficient data measured school enrollment at a point in time rather than a human capital stock making them poor indicators for total human capital within an economy.

5.1 World Intellectual Property Organization (WIPO) Data

Innovation is proxied using patent data from WIPO's Annual IP Data Survey. The WIPO data provide counts of patents based on where the patent provides legal protection, as well as the residence of the patent holder. Hence, the data can be used to estimate the flow of intellectual property between countries. The data are available annually from 1980 to 2015 for all countries considered here, and this is the full period for the data. We initially considered both Total Patent Applications and Resident Patent Applications per Million. Total Patent Applications reflects the total number of patents applied for from the filing office of the selected country, whereas Resident Patent Applications per Million consists of only patents applied for by local residents of a given country, scaled by the country's population. Total Patent Applications accounts for the impact of multinational corporations patenting in countries in which they hope to sell product. Such patenting is a defensive strategy to protect market share in targeted markets, and is not reflective of innovation or technological progress occurring in the given country. As this study aims to determine the true impact to innovation, we drop the Total Patent Applications as a dependent variable focusing instead on Resident Patent Applications per Million which is a superior measure of the level of innovative activities in a given country.

5.2 World Bank WDI Data

Our measures for FDI, and data on several controlling macroeconomic factors, is derived from *The World Bank World Development Indicators* (WDI). IFDI is represented by the indicator FDI Net Inflows (% of GDP), and OFDI is represented by FDI Net Outflows (% of GDP), which refers to direct investment net equity flows (credit - debit) across borders. Both these measures are representative of gross FDI flows.[14] To control for trade openness, we use Imports of Goods and Services (% of GDP) plus Exports of Goods and Services (% of GDP). Gross domestic savings (% of GDP) provides a measure of the available local investment funds for supporting innovation within each country. Consistent with Connolly (1998), we further include R&D Expenditure (% of GDP) to account for relative spending on processes crucial to the innovative process. Because we lack an adequate human capital indicator, R&D (% of GDP) serves to capture some degree to which an economy can absorb and convert investment flows into innovations. The data are available annually from 1960 to 2017 for all countries considered here.

5.3 Index of Economic Freedom Data

To control for institutional quality we use data collected from the *Index of Economic Freedom*, which is published by the Institute for Economic Freedom and Opportunity. The index investigates recent human history, exploring the factors that have both facilitated and impeded economic progress. We include these measures as existing literature, such as Chiu et al. (2017), demonstrate the importance of high-quality institutions in fostering business, investment, and, ultimately, innovation. The index covers twelve total freedoms, of which we utilize two in our final regression. The full set of indicators included in the initial empirical specification were dropped due to high collinearity, as indicated in Table 1. As a result, we run separate regressions

[14] The use of "Net" within the titles of the World Bank FDI measures is representative of net equity flows, and does not equate to inflows minus outflows. These measure are representative of gross FDI.

including the Overall Freedom Index score, which encompasses all sub-scores, and a second regression with Property Rights, chosen for its crucial role in motivating innovative activity. The dataset begins in 1995 and data are available annually for each country from 1995-2015.

Table 1. Correlation Matrix Across Governance Indicators

VARIABLES	Overall Score	Property Rights	Gov Integrity	Tax Burden	Government Spending	Business Freedom	Labor Freedom	Monetary Freedom	Trade Freedom	Investment Freedom	Financial Freedom
Overall Score	1.000										
Property Rights	0.847	1.000									
Gov Integrity	0.818	0.919	1.000								
Tax Burden	-0.100	-0.388	-0.403	1.000							
Government Spending	-0.069	-0.347	-0.390	0.485	1.000						
Business Freedom	0.761	0.698	0.712	-0.257	-0.318	1.000					
Labor Freedom	0.437	0.301	0.307	0.054	-0.103	0.377	1.000				
Monetary Freedom	0.604	0.540	0.528	-0.263	-0.187	0.445	0.172	1.000			
Trade Freedom	0.560	0.388	0.440	-0.100	-0.216	0.382	0.087	0.277	1.000		
Investment Freedom	0.814	0.700	0.646	-0.269	-0.237	0.608	0.149	0.533	0.540	1.000	
Financial Freedom	0.807	0.672	0.612	-0.196	-0.199	0.560	.181	0.561	0.493	0.753	1.000

The Freedom Index seeks to define the relationship between individuals and governments and measures the degree to which policies promote or constrain economic liberty. Countries in the high income bracket demonstrate relative stability, with all indicators remaining relatively high and stable throughout the period measured. Upper-middle and lower-middle income countries were less consistent than high income countries across all indicators. Nonetheless, most indicators changed very little over the time period studied.

Useful to the discussion of the data is the potential limitation of the Index of Economic Freedom Data. This index is subject to a degree of error because, in some cases, the twelve sub-score that make up the Overall Score rely on survey data and independent assessments, which inherently limits the explanatory power of the index. Further, it is possible that our measure of property rights, which includes factors such as quality of land protection, doesn't properly measure the true impact to innovation, intellectual property and patents.

5.4 Country Income Classification

The income brackets used in this study are based on the World Bank Country and Lending groups for the 2015 fiscal year. GNI per capita is the dollar value of a country's final income in a year divided by its population. The following table displays the number of countries studied per income group and outlines the income classifications based on *GNI per Capita, Atlas Method (Current USD) in 2015*, as sorted by the World Bank income brackets*:*

Table 2. Country Income Classification Based on GNI per Capita, Atlas Method (Current USD) in 2015

	High Income	Upper-Middle Income	Lower-Middle Income	Low Income	No Data
Income Range	> $12,236	$12,235 - $3,956	$3,955 - $1,006	< $1,005	N/A
Number of Countries	56	55	46	27	33
Mean GNI per Capita	$26,700	$4,380	$1,400	$390	N/A

Low income countries were excluded due to their low level of patenting; as of 2017, these countries collectively account for 0.3% of global patent application filings. Countries lacking continuous and consistent GNI data were also omitted.[15] It should be noted that not all countries classified here are in the final regressions as some countries dropped due to lack of data across other variables. The total number of countries in the final regression specification in the high-income bracket is 44, in the upper-middle income bracket is 30, and in the lower-middle income bracket is 18. This country selection enables us to compare the impact of FDI on innovation across income brackets with a representative global sample. These income brackets are employed due to the fact there are clear differences across income groups in patenting rates.

5.5 Summary Statistics

Summary statistics for the final data set utilized is presented below in Table 3. The values presented are generally consistent with expected levels based on precedent research.

Table 3. Summary Statistics of all variables studied

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max	(6) Expected Direction
Resident Patent Applications per Million (First Dif)	1,661	4.757	38.31	-373	673	N/A
Inward FDI (% GDP)	3,154	5.751	16.62	-58.32	451.7	(+)
Outward FDI (% GDP)	2,795	2.291	11.77	-89.71	219.8	(+)
Research & Development (% GDP)	1,524	0.940	0.886	0.00544	4.277	(+)
Imports + Exports (% GDP, First Dif)	3,115	94.99	54.87	0.0210	531.7	(+)
Gross Domestic Savings (% GDP)	2,864	20.83	18.87	-167.6	83.72	(+)
Overall Freedom Index Score	2,726	61.39	10.66	15.60	90.50	(+)
Property Rights	2,729	51.80	24.00	5	95	(+)
High Income Dummy	3,297	0.357	0.479	0	1	(=)
Upper-Middle Income Dummy	3,297	0.350	0.477	0	1	(-)
Lower-Middle Income Dummy	3,297	0.293	0.455	0	1	(-)

We expect IFDI and OFDI to have a positive impact on Resident Patent Applications per Million due to technological and managerial knowledge transfer, reverse engineering, and increased competitive pressure respectively. This is consistent with the work of Borensztein et. al

[15] See Appendix A for figures and more in-depth discussion.

(1998), Connolly (1998), and Lin and Lin (2010). Furthermore, we expect R&D (% of GDP) to have a positive impact on both dependent variables as increased R&D spending increases firm and government resource allocation toward developing new innovation. Both imports + exports (% of GDP) and Gross Domestic Savings are also expected to be positive due to increased competitive pressure and ability to reverse engineer products, and increased capital availability. Particularly in upper-middle and lower-middle income countries without access to global capital markets, local innovative activities need local available savings pools to serve as sources of capital. These expectations are consistent with the work of Lin and Lin (2010). Finally, as consistent with the work of Borensztein et. al (1998), the governance indicators Overall Freedom Score and Property Rights are both expected to have a positive coefficient. The Overall Freedom Score is expected to be positive as higher quality governance enables firms to capture more profits generated by new investments, by providing strong property rights, functioning courts to protect property rights, diminished likelihood of extortion and diminished costs of doing business. Of these factors, Property Rights is the most likely to enable firms to capture the majority of their profits from innovation.

5.6 Data Gathering / Cleaning Process

All datasets gathered required cleaning, reshaping and merging. Our initial attempts to gather data were performed in Microsoft Excel. However, this process was slow and inefficient, especially when adding or removing potential variables. Our subsequent attempts were almost completely performed within StataSE 15.0. Each data set needed to be downloaded, cleaned, uploaded to Stata, reshaped to the requisite form for panel regressions, and then merged with the other datasets. Due to inconsistencies in naming conventions for countries across datasets, we employed a CountryID method in which each country was given a unique country ID number. Because of non-consistent numbers or orders of countries, the process of assigning country ID numbers had to be performed completely manually via MS Excel. Once CountryID's were assigned, datasets were merged 1:1 in Stata on CountryID and Year, providing unique observations for each variable for each country, in each year.

The process of gathering and cleaning the data was further complicated due to the format of World Bank data, which is presented in a format that makes reshaping the data complex, requiring multiple rounds of reshaping. World Bank data and WIPO data both come in wide format. In order to merge and run our regressions as a panel dataset, we reshaped to long format. Our initial attempts at reshaping and merging the World Bank data with our other data sources resulted in inconsistent and surprising empirical regression results, also available from the authors upon request. Those results were inconsistent with expectations regarding a number of variables. Initially, our intuition was that our regressions experienced a poor fit due to biases attributable to numerous countries with near zero patent applications per capita. As a result, we initially dropped the observations with patent applications per capita below the 25th percentile. However, inconsistencies persisted, leading us to believe there were underlying issues with our data resulting from the reshaping process.

After receiving guidance from the World Bank on how to best download data for reshaping in Stata, we started again from scratch with a blank dataset. We initially reshaped the data in the World Bank online WDI portal before downloading to Stata. After reshaping into the required format for panel regressions and merging with our other data sets, this improved data set provided superior and more consistent results. Results presented below utilized this new dataset.

6. Results

We employed a general to specific method, iterating through multiple rounds of regressions before arriving at our final regression specifications. An explanation and table encompassing the full list of initial regressions run is included in Appendix B. The results of these regressions are available from the authors upon request. The full set of final regressions are summarized below. Definitions and clarifications for the variables used in this study's regressions can be found in the Glossary.

For each set of regressions, we initially ran both a random effects model and a fixed effects model. The results indicated the random effects model had significantly greater explanatory power, with higher R^2 values and more consistently significant coefficients. Furthermore, due to total sample sizes ranging from approximately 150 to 900, the fixed effects models lacked explanatory power due to small sample sizes relative to the number of countries studied. The results between the fixed effects and random effects models were generally consistent within each set of regressions. Therefore, only the random effects models are presented here. The rationale behind this choice is that, unlike the fixed effects model, the variation in a random effects model is uncorrelated with the independent variables in the model. The fixed effects model regressions are available from the authors upon request.

6.1 Pooled Random Effects Model, 1995-2015

The first set of regressions presented is a pooled data set run from 1995-2015. Regression (1) is run with no governance indicators, Regression (2) is run with the Overall Freedom Index Score and Regression (3) is run with Property Rights. The three regressions are presented in Table 4 below:

Table 4. Pooled Random Effects Model, 1995-2015

	Resident Patent Applications per Million, Pooled		
	(1)	(2)	(3)
VARIABLES	No Governance Indicators	Overall Score	Property Rights
Inward FDI (% GDP)	0.0494	0.0448	0.0506
	(0.114)	(0.115)	(0.115)
Outward FDI (% GDP)	0.00790	0.0152	0.0171
	(0.106)	(0.107)	(0.107)
R&D (% GDP)	**6.726*****	**6.933*****	**7.619*****
	(1.533)	(1.574)	(1.760)
Imports + Exports (% GDP)	0.00406	0.00946	0.00879
	(0.0191)	(0.0205)	(0.0197)
Domestic Savings (% GDP)	**0.296*****	**0.293*****	**0.294*****
	(0.103)	(0.105)	(0.104)
Year	**-0.759*****	**-0.739*****	**-0.816*****
	(0.203)	(0.208)	(0.212)
Overall Freedom Score		-0.119	
		(0.159)	
Property Rights Score			-0.0884
			(0.0820)
Upper-Middle Dummy	1.679	0.723	-0.404
	(3.009)	(3.323)	(3.626)
Lower-Middle Dummy	2.685	1.234	0.595
	(4.112)	(4.560)	(4.560)
Constant	**1,512*****	**1,480*****	**1,632*****
	(407.5)	(415.5)	(425.1)
Observations	1,166	1,156	1,156
R-squared	0.046	0.046	0.047
Wald Chi-squared	55.41	55.33	55.96
Number of CountryID	92	92	92

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

All three regressions exhibit low R^2, in line with the theory that innovation is merely a mechanism of growth. Further, there is likely a two-way causation between FDI and innovation, as increased innovative activity may in and of itself attract FDI. Hence, this study manifests lower response variable variation, and thus lower R^2 values compared to the growth models used in earlier research including Borensztein, et. al (1998), and Lin and Lin (2010).

6.1.1 FDI Net Inflows and FDI Net Outflows

Pivotal in the discussion of the results is the lack of significance in the IFDI (% GDP) and OFDI (% GDP). While the hypothesis of this study predicted a strong positive statistical correlation between these variables and innovation, the results suggest otherwise, with weak degrees of significance in FDI's effects on scaled local patent applications. This lack of statistical significance could be representative of changes in the global economy that have taken place since the publication of previous research, such as the transition to software innovation protected by copyright. In addition, the diminished explanatory power may be due to large aggregations of country data. Furthermore, we may lose explanatory power due to a lack of lags in our variables. Innovative activities take time to develop, and wouldn't occur immediately after an injection of foreign capital. Processes such as imitative activity or the diffusion of knowledge both take time, and could be more strongly observed if a lag period of several years between dependent and independent variables was included. Most importantly, pooled data lacks granularity regarding differences amongst countries of differing levels of development.

High income countries on the technological frontier with well-developed infrastructure and large R&D spending utilize fewer benefits from FDI than do countries outside the technological frontier. These countries, while still receiving managerial and technological spillover from FDI, don't receive as much marginal benefit since existing technology in countries on the technological frontier are either comparable or closer to the level of technology being diffused by FDI. Upper middle income countries receive greater marginal benefit from FDI as they are able to harness FDI not only as investment capital toward innovative activities, but also capture technological and managerial spillover through reverse engineering and technological diffusion as discussed above, consistent with the work of Lin and Lin (2010). Such innate changes in the way FDI is utilized suggest any effect may be washing out, potentially explaining the lack of significance of FDI in the pooled regressions.

6.1.2 Other Variables

R&D (% of GDP) exhibited largely positive and significant coefficients, indicating a strong relationship between R&D (% of GDP) and the patent generation process, consistent with the works of Stam and Wennberg (2009) and Lin and Lin (2010). Of the variables studied, the magnitudes of R&D (% of GDP) were most strongly positive. R&D (% of GDP) was furthermore consistently positive and significant across all three pooled regressions, indicating its robustness as a factor for innovation regardless of the inclusion of governance indicators in the regression. These results are consistent with our theoretical expectations, as precedent literature had previously demonstrated the importance of R&D (% of GDP) to the innovative process. Intuitively, R&D is important to the innovative process as it enables reverse engineering of existing high-technology products and is the process by which new innovations are created.

Domestic Savings (% GDP) was also a statistically significant explanatory variable across these regressions. Across all three, the coefficients for gross domestic savings were significant with magnitudes ranging from 0.293-0.296. Consistent with the work of Suliman, et al. (2018), the positive direction, significance, and magnitude of Domestic Savings (% of GDP) within our regressions regardless of the inclusion of governance indicators is indicative of the importance of capital availability for local innovative processes. Furthermore, the countries encompassed in the pooled regression include countries with limited access to capital markets. Thus, the consideration that these countries require local capital availability to finance capital intensive innovative processes is consistent with our results.

This is also consistent with conventional theory, as innovation relies on both R&D for the creation of new innovation, and the pool of domestic capital for investment made available through Gross Domestic Savings. The combination of significant and positive coefficients across R&D (% of GDP) and Domestic Savings (% of GDP) is consistent with our theoretical expectations that R&D is a capital-intensive process, and that the presence of local capital availability therefore plays positively into the innovative process.

The coefficients for the Year variable were negative and significant, supporting our initial theoretical predictions. This result supports the notion of several trends in innovation that have occurred throughout the period studied, namely diminishing returns to innovation over time and fundamental changes in innovative activities at the technological frontier. With technological progress, new innovations become increasingly difficult to create, as products gain complexity and cost, requiring larger available stocks of investment capital for research, consistent with Bloom, Jones, Reenan and Webb (2018). Furthermore, as existing materials, concepts and technologies are exhausted, new innovations require major technological leaps.[16]

Additionally, these coefficients could be explained by changes in the intrinsic type of innovation occurring at the technological frontier. In highly developed countries, new innovations are focusing less on patentable physical innovation, and more strongly on theoretical software based innovation such as artificial intelligence, cloud computing, and big data analysis. Such software based innovations are covered under copyright law rather than patents, and could partially explain the negative and significant coefficient for the year variable, as more recent innovations are less likely to be measured by patent applications since they fall into a wider bucket of intellectual property protection.

6.2 Country Income Group Classified Random Effects Model, 1995-2015

To reveal differences in the innovative process among countries of differing income groups, we next ran our regression independently among high income, upper-middle income and lower-middle income countries. Regressions (1) through (3) focus on the effect of the Overall Freedom Index Score, while regressions (4) through (6) focus on the effect of just the Property Rights score. The results are summarized below in Table 5:

[16] A prime example is the thinking behind Moore's Law, which predicted that the number of computer transistors per square inch in integrated circuits would double annually. This exponential growth in the power of computer chips occurred for nearly five decades beginning in the 1960s, triggering considerable development and innovation in computing. More recently, however, computing innovation has displayed diminishing returns, as existing silicon technology has approached its maximum potential, suggesting a need to develop innovation in the underlying structure of computing (i.e. quantum computing).

Table 5. Country Income Group Classified Random Effects Model, 1995-2015

	Resident Patent Applications per Million, by Income Group					
	Overall Freedom Score			Property Rights		
VARIABLES	(1) High Income	(2) Upper-Middle Income	(3) Lower-Middle Income	(4) High Income	(5) Upper-Middle Income	(6) Lower-Middle Income
Inward FDI (% GDP)	0.0161	**0.401****	0.0391	0.0224	0.328	0.0729
	(0.152)	(0.201)	(0.440)	(0.152)	(0.203)	(0.434)
Outward FDI (% GDP)	0.0213	**-0.629***	0.464	0.0134	**-0.566***	0.373
	(0.142)	(0.341)	(2.575)	(0.141)	(0.339)	(2.576)
R&D (% GDP)	**6.331****	**18.85*****	2.234	**5.831***	**18.67*****	0.599
	(3.087)	(2.417)	(5.485)	(3.396)	(2.252)	(4.465)
Imports + Exports (% GDP)	0.0182	-0.0189	-0.00799	0.00690	-0.0152	-0.00449
	(0.0422)	(0.0232)	(0.0437)	(0.0407)	(0.0228)	(0.0442)
Domestic Savings (% GDP)	**0.518***	**0.232*****	0.0588	**0.491***	**0.209*****	0.0623
	(0.294)	(0.0707)	(0.111)	(0.293)	(0.0705)	(0.111)
Year	**-1.288*****	-0.0816	-0.117	**-1.333*****	-0.138	-0.0639
	(0.335)	(0.162)	(0.251)	(0.346)	(0.151)	(0.265)
Overall Freedom Score	-0.351	0.0245	0.165			
	(0.356)	(0.116)	(0.341)			
Property Rights Score				-0.0335	**-0.118****	0.0353
				(0.176)	(0.0593)	(0.130)
Constant	**2,592*****	149.4	222.6	**2,663*****	270.0	125.1
	(669.7)	(321.8)	(500.5)	(696.0)	(303.5)	(534.2)
Observations	687	341	128	687	341	128
R-squared	0.044	0.252	0.010	0.042	0.260	0.009
Wald Chi-squared	21.67	106.87	1.27	20.73	115.16	1.10
Number of CountryID	44	30	18	44	30	18

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The R^2 values are slightly stronger in this set of regressions, particularly for upper-middle income countries. Lower-middle income countries likely lack statistical significance due to a limited number of observations and incomplete data, particularly in the early years of the study. Surprisingly, high income countries have a lower R^2 than upper-middle income countries, despite a larger and more complete dataset. Such a result may be indicative of the transition to copyright protected innovation in high income countries on the technological frontier. It could also be explained by the potential two-way causation between innovation and FDI.

By separating countries by income brackets, clear differences in the innovative process become clear. Namely, the importance of R&D and gross domestic savings to both high income and upper-middle income countries, the negative effect of time on scaled resident patent applications in countries on the technological frontier, and the benefit from FDI received in upper-middle income countries. The differences seen at this greater level of granularity are consistent with our theoretical predictions.

6.2.1 FDI Inflows and FDI Outflows

IFDI proved to be statistically significant and positive in upper-middle income countries when run with the Overall Freedom Index Score. This result is consistent with our theoretical predictions, as upper-middle income countries outside the technological frontier stand to benefit the most from IFDI. These countries have adequate levels of pre-existing infrastructure, human capital, and investment capital to convert FDI flows into new innovation. Furthermore, these countries are most likely to exhibit the catch-up effect in which countries outside the technological frontier can take advantage of technological transfer and reverse engineering to innovate at a faster rate than countries on the technological frontier, enabling them to "catch up" to countries on the technological frontier. These catch-up effects would likely be bolstered by FDI by increasing the available products for reverse engineering and fostering technological and managerial spillover. The lack of statistical significance for IFDI in upper-middle income countries when run with the Property Rights indicator is surprising, but likely best explained by a slightly worse general fit attributable to lack of control for quality of governance beyond Property Rights. The p-value for IFDI in this regression (5) is 0.106, placing it close to the marginal cutoff for statistical significance.

As the lower-middle income regression consists of fewer than 130 observations, the lack of statistical significance of IFDI in lower-middle income countries is likely due to a lack of available data. High income countries may lack statistical significance due to innate differences in their innovative process. Countries with large existing stocks of capital likely benefit less from FDI. Furthermore, high income countries are more likely to be on the technological frontier, and therefore would benefit less from technological and managerial spillover or reverse engineering, both of which are predicted as the primary methods through which IFDI fosters innovation. It should be noted that our results are likely due to innate differences amongst these economies rather than to differing levels of IFDI. As noted in Figure 2, IFDI (% of GDP) is relatively similar across high income and upper-middle income economies, particularly over the 1995-2015 period studied. Lower-middle income economies initially exhibit lower IFDI (% of GDP) over the period studied, but catch up to high and upper-middle income economies by the mid-2000's.

Inconsistent with our theoretical predictions, OFDI is both negative and significant in upper-middle income economies. Seeing as OFDI involves the transfer of capital and resources to external economies, it is possible that this process drains the native economy and local markets of its resources, thereby decreasing the overall innovative capacity of the home economy. In upper-middle income economies, global capital markets are less accessible, and so local firms must rely upon stocks of local capital and IFDI for innovative activities. While our theoretical framework expected OFDI to be positive due to increased local competition, our results suggest that the diminished local capital attributable to OFDI has a larger impact on innovative activities than does the increased competition factor. While OFDI may encourage the takeup of new knowledge abroad, the positive effects are only felt to the native economy if residents return to their native countries. If residents leave as a result of OFDI and don't return, the resulting impact leads to brain drain on the local economy.

Like IFDI, OFDI lacks significance for high income and lower-middle income economies. The lack of significance in lower-middle income countries is likely due to similar factors as with IFDI. Lack of significance for OFDI in high income countries is surprising, as theory predicts countries with adequate resources would receive positive effects from OFDI due to increased competitive pressure. The lack of statistical significance suggests a need for further research.

6.2.2 Other Variables

Consistent with the regressions outlined in Table 4, R&D (% GDP) is most consistently statistically significant across the regressions in Table 5, showing strong positive and significant coefficients in high income and upper-middle income countries, thus emphasizing its robustness as a factor necessary for effectively fostering innovation. The positive coefficient for R&D is in line with our theoretical predictions, suggesting the importance of R&D to converting capital into innovation as consistent with the work of Connolly (1998), Lin and Lin (2010), and Wei, et al. (2017). This result is intuitively expected as R&D is important to the reverse process and to new product innovation.

Of note is the finding that the magnitude of the R&D coefficient is approximately three times greater in upper-middle income countries than in high income countries. This result is consistent with both the theory that high income countries on the technological frontier are transitioning to copyright protected innovation and that upper-middle income countries are experiencing a catch-up effect consistent with the work of Choi (2004). Under this theory, R&D is particularly important to upper-middle income economies as it not only enables novel innovation, similar to high income countries, but it also enables imitative patents gleaned through reverse engineering existing products. Surprisingly, the magnitude of gross domestic savings is greater for high income countries than in upper-middle income countries.

Domestic Savings (% GDP) also demonstrates consistent significance across high and upper-middle income countries, supporting the notion that access to capital is also necessary for innovation, in line with the logic demonstrated in Suliman, et al. (2018). Such a result is intuitively expected due to the importance of access to capital for capital-intensive innovative activities. As with 6.1.2, the magnitudes of the coefficients for Domestic Savings (% of GDP) are smaller than for R&D, indicating that domestic savings is likely less important to the innovative process, as capital can be accessed both from the local economy and from global capital markets. Surprisingly, the magnitude of Domestic Savings (% of GDP) is of greater magnitude in high income than in upper-middle income economies. Such a result is not expected as high income countries are expected to have greater access to global capital markets, and thus depend less on local savings. The confounding result suggests different mechanisms at play, highlighting a need for a more granular investigation of how domestic and international capital impacts innovation. The lack of statistical significance in lower-middle income countries may be due to a lack of observations or due to a lack of relative savings.

Also noteworthy is the fact that the property rights indicator was both significant and negative for the upper-middle income bracket. This contradicts conventional theory as higher property rights should enable firms to better capture profits from new innovations and incentivize entrepreneurial ventures due to the confidence that revenue streams are secure. One potential explanation for this unexpected relationship could be excessive property rights that are so strong that they disincentivize new entrants and stifle innovation. Another explanation is that increases in property rights for countries outside of the technological frontier will initially disrupt the normal lines of business, leading to decreased innovation and patent activity. Finally, it is possible that our measure of property rights, which includes factors such as quality of land protection, doesn't properly measure the true impact to intellectual property. Finally, property rights could potentially have a different impact on the final results if lagged.

Similar to the results of Section 6.1, the Year variable exhibits a significant and negative coefficient, albeit only in the high income bracket. High income countries are typically at the technological frontier meaning they exhibit the concept of diminishing returns to innovation more than the countries in the upper-middle and lower-middle income thresholds. Because highly developed countries are on the technological frontier, new innovations are more costly. Furthermore, transitions in the type of innovation, such as greater focus on new technologies that are highly software and copyright based, rather than patentable physical innovation, may be the underlying cause of this result. Both explanations are consistent with seeing the negative and significant coefficient only in high income countries. For a more carefully outlined justification of the negative coefficients, refer to Section 6.1.2.

6.3 Key Takeaways

6.3.1 FDI Inflows and FDI Outflows

The FDI terms exhibited limited significance across the sets of regressions. When pooled, these terms did not exhibit any significance. Within the individual country group regressions, upper-middle income countries consistently exhibited significance amongst IFDI, and OFDI. IFDI was consistently positive, supporting our hypothesis. Furthermore, as IFDI was most consistently positive and significant in upper-middle income countries, our results suggest IFDI is most effective in developing countries experiencing the catch-up effect outside the technological frontier. Inconsistent with our theoretical framework, OFDI was negative. The negative OFDI term is likely due to diminished local capital available for investment, leading to a draining effect on local innovation. Also of note is the difference in importance of IFDI between country groups.

6.3.2 Other Variables

Across all regressions, there were several important trends and takeaways. First, R&D and gross domestic savings were positive and significant across all pooled regressions and in the high and upper-middle income regressions. Such consistent results underscore the robustness of these indicators, and emphasize their importance to the innovative process, particularly in high and upper-middle income countries. R&D and gross domestic savings are important for the innovative process, as they both provide the necessary capital for innovation and deploy that capital toward developing new innovation. Of note is the high magnitude of the R&D coefficient in upper-middle income countries ($\beta_3 \approx 18$), as compared to high income countries ($\beta_3 \approx 6$). R&D was particularly important for upper-middle income countries in catching up to the technological frontier. Amongst these countries, R&D was particularly important for physical innovation and reverse engineering of existing products. The lack of general significance for R&D and Gross Domestic Savings among lower-middle income countries was expected due to lack of infrastructure and investment capital for developing innovation.

While the Year variable was significant and negative across all pooled regressions, this effect was isolated to high income countries across country regressions. This buttresses the explanation that the result is attributable to both diminishing returns to innovation and changes in the type of innovation at the technological frontier.

7. Conclusion

In conclusion, there are mixed results capturing the relationship between FDI and innovation. While the hypothesis of the study predicted a positive correlation between the two, citing FDI as a vehicle for innovation by providing monetary capital for R&D, reducing selection bias, and increasing intellectual capital, the results have presented a different perspective. This study demonstrates that IFDI does have a significant and positive impact on innovation in certain situations. However, negative coefficients for OFDI were confounding, suggesting a need for further research. Such confounding results may be because innovation is only one mechanism for growth, yet we base our theoretical framework on growth literature. As such, we may lack explanatory power.

Beyond our initial hypothesis, our study revealed several important trends. R&D and gross domestic savings proved to be the two most robust indicators across all samples. In particular, these indicators were most potent in high and upper-middle income countries, suggesting their importance to the innovative process there. The Year results also were consistent with our expectations. Property Rights were significant in upper-middle income countries, but of confounding direction. This result may indicate a need to lag the governance indicators to account for an adjustment period for firms. Our property rights indicator is also subject to several limitations and lacks a focus on intellectual property rights. Of note is the observed differences between high income, upper-middle income and lower-middle income countries, suggesting innate differences in the innovative process across countries of differing levels of development.

As noted, precedent literature has explored the link between FDI and innovation within smaller communities or within individual countries. However, few researchers have performed macroeconomic studies on global impacts of FDI on innovation across economies of differing levels of institutional quality and income. This study is unique in that it employs a panel regression to study modern innovative processes across global economies of differing institutional quality and income. Thus, this study has considerable contributions to the study of the interaction of globalization and technological progress on innovation.

7.1 Future Research

Future research might expand the dataset and try to manipulate the time dimension because it naturally takes time for institutional changes to affect firm behavior. In a similar light, researchers might consider including other metrics to proxy high technology, non-hardware innovation. For instance, using copyrights would capture innovative activities in countries at the technological frontier exploring Artificial Intelligence, Internet of Things, Cloud Computing and other advanced technologies. Furthermore, future researchers may consider delineating true innovative activities from imitative activities, particularly in countries outside the technological frontier. In doing so, researchers may be able to visualize the impact of imitative technological progress in promoting the catch-up effect. A final suggested addition to this study would be developing a stock measure of human capital for all countries, and adding it as a control to the final empirical specification. This proxy ought to accurately measure the human capital that is well-positioned with technological knowledge to facilitate the innovative process. In this way, a more explicit relationship between FDI and innovation may be established.

While FDI did not remain consistent with our hypothesis, our study revealed important characteristics of how to best foster innovative processes, particularly in countries outside the technological frontier to promote catching up to high income countries. This thesis thus serves as a case study to better understand the optimal mechanisms guiding the innovative process across different countries. The intuition we develop can serve to direct policy decision across the globe, particularly in these catch-up economies. In such countries, our research suggests that focusing on providing adequate investment capital, both foreign and domestic, and deploying that capital toward R&D, is the most effective way to foster local resident innovative activities.

Appendix

Appendix A: Country Classification

Countries classified as high income had a 2015 GNI per capita in excess of $12,236 per capita; 56 countries fall in the high income range. Income per capita between $3,956 and $12,235 are defined as upper-middle income countries, of which there are 55 in this study. Lower-middle income countries, with GNI per capita ranging between $1,006 and $3,955, included 46 countries. There are 27 low income countries, with GNI per capita under $1005, which were excluded due to their limited level of patenting; as of 2017, these countries collectively account for 0.3% of global patent application filings, as illustrated in Figure 3. There were 33 additional countries lacking continuous and consistent GNI data, preventing us from classifying them by income bracket. These countries were omitted.

Figure 3. Total Patent Applications by Filing Office (2015)

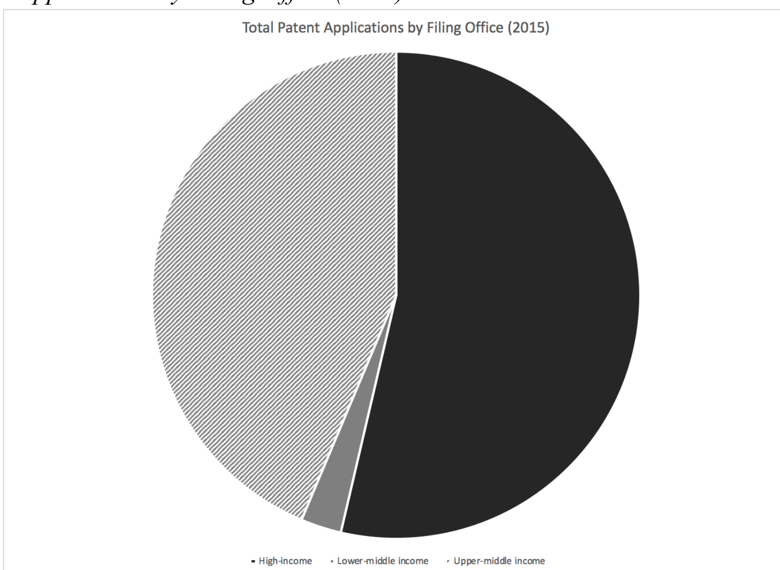

Table 6. Countries Income Classifications + Excluded Countries (World Bank)

Income Bracket	Countries
High Income	Antigua and Barbuda, Argentina, Australia, Austria, The Bahamas, Bahrain, Barbados, Belgium, Brunei Darussalam, Canada, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong SAR, China, Hungary, Iceland, Ireland, Isle of Man, Italy, Japan, Korea, Rep., Kuwait, Latvia, Lithuania, Luxembourg, Macao SAR, China, Malta, Netherlands, New Zealand, Norway, Oman, Poland, Portugal, Puerto Rico, Qatar, Saudi Arabia, Seychelles, Singapore, Slovak Republic, Slovenia, Spain, St. Kitts and Nevis, Sweden, Switzerland, Trinidad and Tobago, United Arab Emirates, United Kingdom, United States, Uruguay
Upper-Middle Income	Albania, Algeria, Angola, Armenia, Azerbaijan, Belarus, Belize, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, China, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, Equatorial Guinea, Fiji, Gabon, Georgia, Grenada, Guyana, Iran, Islamic Rep., Iraq, Jamaica, Kazakhstan, Kosovo, Lebanon, Macedonia, FYR, Malaysia, Maldives, Marshall Islands, Mauritius, Mexico, Montenegro, Namibia, Nauru, Palau, Panama, Paraguay, Peru, Romania,

	Russian Federation, Samoa, Serbia, South Africa, St. Lucia, St. Vincent and the Grenadines, Suriname, Thailand, Tonga, Turkey, Turkmenistan, Tuvalu
Lower-Middle Income	Bangladesh, Bhutan, Bolivia, Cabo Verde, Cambodia, Cameroon, Congo, Rep., Cote d'Ivoire, Egypt, Arab Rep., El Salvador, Ghana, Guatemala, Honduras, India, Indonesia, Jordan, Kenya, Kiribati, Kyrgyz Republic, Lao PDR, Lesotho, Mauritania, Micronesia, Fed. Sts., Moldova, Mongolia, Morocco, Myanmar, Nicaragua, Nigeria, Pakistan, Papua New Guinea, Philippines, Sao Tome and Principe, Solomon Islands, Sri Lanka, Sudan, Swaziland, Tajikistan, Timor-Leste, Tunisia, Ukraine, Uzbekistan, Vietnam, West Bank and Gaza, Yemen, Rep., Zambia
Low Income	Afghanistan, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Liberia, Madagascar, Malawi, Mali, Mozambique, Nepal, Rwanda, Senegal, Sierra Leone, South Sudan, Tanzania, Togo, Uganda, Zimbabwe
Excluded Countries	American Samoa, Andorra, Aruba, Bermuda, British Virgin Islands, Cayman Islands, Channel Islands, Cuba, Curacao, Djibouti, Eritrea, Faroe Islands, French Polynesia, Gibraltar, Greenland, Guam, Israel, Korea, Dem. People's Rep., Libya, Liechtenstein, Monaco, New Caledonia, Niger, Northern Mariana Islands, San Marino, Sint Maarten (Dutch part), Somalia, St. Martin (French part), Syrian Arab Republic, Turks and Caicos Islands, Vanuatu, Venezuela, RB, Virgin Islands (U.S.)

Appendix B: Initial Regression Specifications

Table 7. Regression Specifications

Note: "OS" refers to Overall Freedom Index Score
"PR" refers to Property Rights Score
"FE" refers to Fixed Effects Regressions
"RE" refers to Random Effects Regressions

Reg.	Time Period	FE/RE	HC Interact	Variables	Gov. Indicator	DV	Pooled ?
Round 1: Original Dataset							
1	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Total Patent Apps	No
2A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Total Patent Apps	No
2B	1995-2015		Yes				
3A	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Total Patent Apps	No
3B					PR		

Round 2: Original Dataset							
Reg.	Time Period	FE/RE	HC Interact	Variables	Gov. Indicator	DV	Pooled ?
1A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Total Patent Apps	No
1B	1995-2015		Yes				
2A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Total Patent Apps	No
2B	1995-2015		Yes				
3A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Resident Patent Apps per Million	No
3B	1995-2015		Yes				
4A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Resident Patent Apps per Million	No
4B	1995-2015		Yes				
5A	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Total Patent Apps	No
5B					PR		
6A	1995-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Total Patent Apps	No
6B					PR		
7A	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Resident Patent Apps per Million	No
7B					PR		
8A	1995-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Resident Patent Apps per Million	No
8B					PR		
9A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Resident Patent Apps per Million	Yes
9B	1995-2015		Yes		None		
9C			Yes		OS		
9D			Yes		PR		

Round 3: Final Dataset							
Reg.	Time Period	FE/RE	HC Interact	Variables	Gov. Indicator	DV	Pooled ?
1A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Total Patent Apps	No
1B	1995-2015		Yes				
2A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Total Patent Apps	No
2B	1995-2015		Yes				
3A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Resident Patent Apps per Million	No
3B	1995-2015		Yes				
4A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	None	Resident Patent Apps per Million	No
4B	1995-2015		Yes				
5A	1995-2015	RE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Total Patent Apps	No
5B					PR		
6A	1995-2015	FE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Total Patent Apps	No
6B					PR		
7A	1995-2015	RE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Resident Patent Apps per Million	No
7B					PR		
8A	1995-2015	FE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population	OS	Resident Patent Apps per Million	No
8B					PR		
9A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent Apps	Yes
9B	1995-2015		Yes		None		
9C			Yes		OS		
9D			Yes		PR		

10A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent Apps	Yes
10B	1995-2015		Yes		None		
10C			Yes		OS		
10D			Yes		PR		
11A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Resident Patent Apps per Million	Yes
11B	1995-2015		Yes		None		
11C			Yes		OS		
11D			Yes		PR		
12A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Infrastructure Index, Imports + Exports, GDP Constant LCU, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Resident Patent Apps per Million	Yes
12B	1995-2015		Yes		None		
12C			Yes		OS		
12D			Yes		PR		
Round 4: Final Dataset							
Reg.	Time Period	FE/RE	HC Interact	Variables	Gov. Indicator	DV	Pooled ?
1A	1995-2015	FE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	None	Total Patent Apps	No
1B						Resident Patent Apps per Million	
2A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	None	Total Patent Apps	No
2B						Resident Patent Apps per Million	
3A	1995-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	OS	Total Patent App	No
3B						Resident Patent Apps per Million	
4A	1995-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	PR	Total Patent Apps	No
4B						Resident	

						Patent Apps per Million	
5A	1995-2015	FE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent App	Yes
5B					OS	Total Patent App	
5C					PR	Total Patent Apps	
5D					None	Resident Patent Apps per Million	
5E					OS	Resident Patent Apps per Million	
5F					PR	Resident Patent Apps per Million	
6A	1980-2015	FE	Yes No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent Apps	Yes
6B						Resident Patent Apps per Million	
7A	1995-2015	RE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	None	Total Patent Apps	No
7B						Resident Patent Apps per Million	
8A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	None	Total Patent Apps	No
8B						Resident Patent Apps per Million	
9A	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	OS	Total Patent App	No
9B						Resident Patent Apps per Million	
10A	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows,	PR	Total Patent	No

				R&D, Imports + Exports, Gross Domestic Savings, Population		Apps	
10B						Resident Patent Apps per Million	
11A	1995-2015	RE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent App	Yes
11B					OS	Total Patent App	
11C					PR	Total Patent Apps	
11D					None	Resident Patent Apps per Million	
11E					OS	Resident Patent Apps per Million	
11F					PR	Resident Patent Apps per Million	
12A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent Apps	Yes
12B						Resident Patent Apps per Million	
13A	1995-2015	FE	Yes	FDI Net Inflows, FDI Net Outflows, Imports + Exports, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent App	Yes
13B					OS	Total Patent App	
13C					PR	Total Patent Apps	
13D					None	Resident Patent Apps per Million	
13E					OS	Resident Patent Apps per Million	
13F					PR	Resident Patent Apps	

						per Million	
13A	1995-2015	RE	Yes	FDI Net Inflows, FDI Net Outflows, Imports + Exports, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent App	Yes
13B					OS	Total Patent App	
13C					PR	Total Patent Apps	
13D					None	Resident Patent Apps per Million	
13E					OS	Resident Patent Apps per Million	
13F					PR	Resident Patent Apps per Million	
14A	1980-2015	RE	No	FDI Net Inflows, FDI Net Outflows, Imports + Exports, Gross Domestic Savings, Population, Upper-Middle Dummy, Lower-Middle Dummy	None	Total Patent Apps	Yes
14B						Resident Patent Apps per Million	
15A	1980-2015	FE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	None	Total Patent Apps	No
15B	1995-2015		Yes				
16A	1995-2015	RE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	OS	Resident Patent Apps per Million	No
16B							
17A	1995-2015	RE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	PR	Resident Patent Apps per Million	No
17B							
Round 5: Final Dataset							
1A	1995-2015	RE	Yes	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	OS	Resident Patent Apps per Million	No
1B					PR		
2A	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population	None	Resident Patent Apps per Million	Yes
2B			Yes	FDI Net Outflows, R&D, Imports +			

				Exports, Gross Domestic Savings, Population			
2C				FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Population			
2D					OS		
2E					PR		
Round 6: Final Dataset, Final Specification, No Human Capital							
1A	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Year	OS	Resident Patent Apps per Million	No
1B					PR		
2A	1995-2015	RE	No	FDI Net Inflows, FDI Net Outflows, R&D, Imports + Exports, Gross Domestic Savings, Year, Upper-Middle Dummy, Lower-Middle Dummy	None	Resident Patent Apps per Million	Yes
2B					OS		
2C					PR		

Glossary: Variable Definitions

A summary of all variables can be found in Table 8. Variables were constructed to capture the basis of the theoretical model and empirical specification.

Table 8. Variable Names and Definitions

Variable	Definition
Inward FDI (IFDI)	FDI net inflows are the value of inward direct investment made by non-resident investors in the reporting economy. (World Bank, 2017).
Outward FDI (OFDI)	FDI net outflows are the value of outward direct investment made by the residents of the reporting economy to external economies. (World Bank, 2017).
Research and Development (R&D)	Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development.
Imports + Exports (% of GDP)	"The value of all goods and other market services received from the rest of the world" and "the value of all goods and other market services provided to the rest of the world," respectively (World Bank, 2017). "They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments" (World Bank, 2017).
Gross Domestic Savings (% of GDP)	Gross domestic savings are calculated as GDP less final consumption expenditure (total consumption) (World Bank, 2017).
Year	Year in which the observations are studied. The year variable captures the general effect of time on the dependent variable.
Overall Freedom Index Score	The Overall Freedom Index Score encompasses" all 12 quantitative and qualitative factors of economic freedom: property rights, government integrity, judicial effectiveness, government spending, tax burden, fiscal health, business freedom, labor freedom, monetary freedom, trade freedom, investment freedom, financial freedom. Each of the twelve economic freedoms within these categories is graded on a scale of 0 to 100. A country's overall score is derived by averaging these twelve economic freedoms, with equal weight being given to each" (Index of Economic Freedom, 2017).
Property Rights	"Measure the ability to compile private property and wealth, as it is a vital motivating force for both workers and investors. Firm and secure property rights provide citizens with an incentive to undertake entrepreneurial activity because they are confident that the revenue streams, income, savings, and property from such activity is safe from government seizure or theft. Additionally important to this discussion is the "tragedy of the commons" economic phenomenon that results from shared property when individual users act according to their self-interest and consequently exploit the property. A key parameter factoring into the property rights valuation is the existence and enforcement of contractual obligations. Per the Index of Economic Freedom, the Property Rights score is an average of physical property rights, intellectual property rights, strength of investor protection, risk of expropriation and quality of land administration, weighted equally" (Index of Economic Freedom, 2017).

Upper-Middle Dummy	A dummy indicator variable taking the value of 0 or 1 to denote whether a country falls under the upper-middle income classification.
Lower-Middle Dummy	A dummy indicator variable taking the value of 0 or 1 to denote whether a country falls under the lower-middle income classification.

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