GreeSE Papers

Hellenic Observatory Discussion Papers
on Greece and Southeast Europe

Paper No. 154

Knowledge Diffusion and Financial Development Thresholds

Konstantinos Dellis

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

December 2020

HELLENIC OBSERVATORY
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Konstantinos Dellis[1]

ABSTRACT

Foreign direct investment (FDI) has grown strongly as a major form of international capital transfer over the past decades. Countries all over the world compete for direct investment flows, as they are considered less volatile than portfolio investment and are expected to spur long-term growth. The attraction of FDI flows depends *inter alia* on a number of host country attributes, including macroeconomic, geographical, and institutional variables. Additionally, the extent to which FDI inflows contribute to domestic productivity and long-term growth is conditional on characteristics that shape a country's absorptive capacity. This paper uses country-level data from OECD economies over the 2005-2016 period to empirically gauge the effect that FDI inflows have on recipient country productivity and innovative performance. Furthermore, it examines the potential of threshold effects regarding the development of the host economy financial system insofar as the latter is considered a conducive force for spillover effects. In the vein of the trade-growth literature we measure the effect of the foreign R&D stock weighted by bilateral capital goods imports and FDI flows looking at Total Factor Productivity and Patents per population at the economy-level. The results indicate that the depth and efficiency of the destination country financial system provides a mediation mechanism for the realization of positive externalities associated with MNC presence. Most of the financial variables appear to facilitate knowledge spillovers above a certain threshold value irrespective of that being exogenously or endogenously determined. Finally, this exercise yields fruitful policy lessons for Greek economy. More specifically, the ongoing process of restructuring the stressed domestic financial system combined with the incremental completion of the Banking and Capital Markets Union at the EU level could serve as a conduit for speeding the catch-up process to the technological frontier.

[1] Post-doctoral researcher, University of Piraeus, Greece, kdellis83@gmail.com

1. Introduction

According to Endogenous Growth Theory innovation is the pivotal driver of productivity growth and the improvement of living standards (Romer, 1986; Aghion & Howitt, 1992). Innovation can be developed through activities carried out domestically as well as through the absorption of useful knowledge and technology from external sources (Grossman and Helpman, 1991). The inherent traits of knowledge that serves as a public good allow for it to spill over and thus create positive externalities in productivity. These spillovers contribute to the technological improvements of firms or even countries outside the source of the innovation. To be more precise, knowledge spillovers are defined as the ability of a firm, industry or country to gain from technological improvements of its partners as these are expressed by their cumulative R&D stock (Grilliches, 1979; Keller, 2004). Elaborating on this notion, *pure* knowledge spillovers are derived from the imperfect appropriation of codified and non-codified knowledge embodied in production activities (Seck, 2012), thus not referring to imperfect pricing of knowledge and technological advances in traded inputs (*rent* spillovers)[2] .

The implication of these knowledge spillovers for the innovation potential of economies that lack the domestic capabilities and are far from the technological frontier has spurred a voluminous literature that aims to identify and gauge the extent of these knowledge transfers as well as the mediating mechanisms (channels) through which useful knowledge transcends firm, industry or national boundaries (Peri, 2005; Mancussi, 2008; Smeets, 2008; Gorodnichenko *et al*., 2014). The early influential work of Jaffe *et al.* (1993; 1995) used patent citations as its focal point, underlining that technology spillovers can be traced by the citation from a patent to another. The pivotal work of Coe & Helpmann (1995) owing to the theoretical model developed by Grossman & Helpmann (1991) spawned the rich *trade-growth* literature of knowledge spillovers according to which imports and exports of intermediate inputs were the perennial mechanisms of knowledge transfer across economies. The subsequent empirical literature approximates external knowledge through a trade-weighted sum of foreign R&D stock and examines its effect on domestic productivity or innovation creation through reduced form equations (Keller, 2002; Guellec & de la Potterie, 2004; Coe *et al*, 2008; Seck, 2012). Apart from trade of intermediate goods, studies identify FDI (Javorcik, 2004; Lee, 2005) and mobility of high-skilled employees (Le, 2010; Drivas *et al.,* 2016; Morales, 2019) as conduits of knowledge transmission. Having said that, a set of local economic, technological, and institutional characteristics create a country's *absorptive capacity* (Cohen & Levinthal, 1989)

[2] We shall be referring to a broader sense of knowledge spillovers or knowledge transfer throughout the text, since it is challenging to empirically identify the two sub-categories of spillovers described above.

and explain the fact that the spillover process is far from uniform (OECD, 2001; Ozturk, 2008; Crescenzi *et al.*, 2020; Gorodnichenko *et al.*, 2020).

In the present study, we aim to empirically measure the magnitude of knowledge spillovers from trade and FDI flows, accounting for the variation in the host country financial development to condition the effect of the latter. To this end we use a panel dataset from 23 OECD economies and a rich set of previously unavailable financial system indicators. Following the trade-growth literature, we assess the impact of financial development thresholds as determinants of the non-linear effect of external knowledge using endogenous panel threshold econometric techniques (Caner & Hansen, 2004). Our results show that the effect of foreign knowledge is not uniform across institutional environments. Sound financial institutions matter for the culmination of knowledge spillovers through FDI inflows when we focus on domestic patenting activity whereas MNC presence does not appear to exert positive effects on host economy productivity.

Firstly, we discuss the theoretical underpinnings behind this exercise, while the third section of the paper briefly reviews the relevant empirical literature. Section 4 presents the data in hand and describes the analytical framework, before moving to the empirical results in Section 5. Finally, we assess the importance of the findings for the Greek economy in Section 6 and Section 7 concludes.

2. Theoretical Framework

Ever since the pioneering work of Grossman & Helpman (1991), the importance of knowledge transfer has lied at the epicenter of endogenous growth theory. Firms, regions or entire economies that are far from the technological frontier can benefit from achievements and knowledge created in an external environment and do not need to finance their own innovative processes (Grilliches, 1979; Aghion & Howitt, 1992)[3]. Market transactions such as trade of intermediate goods and FDI as well as non-market mechanisms such as patent citations serve as transmission mechanisms thus allowing for knowledge spillovers and productivity increases for technological laggards (Keller, 2002; 2004, Peri & Urban, 2005). However, the positive externalities are realized in a manner that is far from uniform and depends heavily on a set of host country economic and institutional attributes (Fagerberg, 1994; De Mello, 1999; Aghion & Howitt, 2005). This phenomenon is asserted in the empirical literature considering FDI flows and economic growth and is in line with the notion of *absorptive capacity* described by Cohen

[3] The importance of productivity spillovers is enhanced in the face of declining own R&D efficiency and the rise of the intangible economy (Aghion et al, 2019; Miyagawa, 2019)

and Levinthal (1989)[4]. The degree to which the recipient unit commercializes the externally created knowledge has been theoretically and empirically examined through the inclusion of numerous parameters that capture the economic, social, and institutional environment of the host firm/economy[5]. In this study, we attempt to shed light to the conducive role played by the financial system development of the host economy.

According to Alfaro *et al*. (2004) the financial markets play a pivotal role in the knowledge transmission process, considering the effects of both the banking sector and the host market. Apart from the established growth enhancing effect of well-developed financial markets the authors show that they can also indirectly promote productivity growth through the externalities created by trade and MNC participation. In the process of acquiring external knowledge which increases productivity domestic firms need to expand and hire employees, hence rely on financing. This argument is even more relevant in the case of horizontal FDI spillovers through the absorption of employees previously working for MNCs in the sector. Moreover, the export capacity of domestic firms (which is absorptive capacity) depends on depth of the local financial system and the financing opportunities for potential exporters. Alfaro *et al*. (2004; 2010) provide a theoretical model which explains the importance of sound domestic financial conditions for the realization of backward linkages through FDI inflows. More specifically, only financially non-constrained firms can become suppliers for MNCs and thus benefit from vertical spillovers (Javorcik & Spatareanu, 2008). According to Hermes & Lensink (2003) "FDI and domestic financial markets are complementary with respect to enhancing the process of technological diffusion, thereby increasing the rate of economic growth" (p. 147). Having said that, it is rational to postulate that trade-induced spillovers are also conditioned by the access to finance for domestic firms, the stability of the banking sector and the availability of non-baking sources of corporate finance such as venture capital and a developed private bond market. Finally, the importance of the functioning of the domestic financial sector as a conduit for productivity spillovers through trade and FDI is also justified within the context of the *National and Regional Systems of Innovation* theory (Cooke & Morgan, 1998; Lundvall, 1992; Nelson, 1993) which captures all aspects of economic, social and institutional performance in a certain region that shapes its capacity to assimilate knowledge created outside its barriers. Crescenzi & Rodriguez-Pose (2011) identify the attributes of the local innovation system as greater determinants for innovation output than the region's own R&D intensity. In the sense that there exists a social filter (Boschma, 2004; Rodriguez-Pose, 1999) shaped by contradicting forces (Crescenzi & Rodriguez-Pose, 2011) which determine to a large extent the dissemination of external knowledge and hence spur domestic productivity, the depth and governance of the financial system can be viewed as an integral part of this process.

[4] According to Barnard and Cantwell, (2006) "Even if knowledge originates elsewhere or is carried by external actors, the receiving node has to play an active role to animate and recreate that knowledge in a new context".

[5] The various approaches to absorptive capacity are discussed in the next section of the paper.

The access of domestic firms to ample sources of finance, bearing in mind the uniqueness of financing innovative projects (Hall & Lerner, 2010; EIB, 2018) is pivotal for the positive externalities from trade and MNC presence to culminate and for the enhancing effect on domestic productivity.

3. Literature Review

The empirical literature on technology transfer and knowledge spillovers has expanded exponentially after the theoretical foundations of endogenous growth theory in the latter part of the 20th century. Scholars have attempted to measure the extent to which external knowledge enhances domestic productivity growth and the mechanisms which act as catalysts in the process. As elaborated by Keller (2002; 2004) the dominant approach relies on the construction of foreign knowledge stocks following the seminal contribution of Coe & Helpmann (1995) and incorporating them in reduced form equations for some measure o domestic (or sectoral productivity). The coefficient of this foreign knowledge term is interpreted as the partial elasticity of domestic productivity (usually TFP) with respect to knowledge created outside national boundaries. Nonetheless, the foreign knowledge component must be constructed through a weighted average scheme of all trading partners' knowledge stock. The most common weight in the literature is the ratio of bilateral intermediate imports over total imports or partner GDP, hence the term "trade-growth literature" coined by Keller (2004). The inclusion of the import-weighted foreign knowledge stock has yielded significant positive coefficients in numerous studies (Keller, 2002; Lee, 2005; Coe *et al*, 2008; Drivas *et al.,* 2016) thus pointing to the existence of positive productivity externalities available through international trade.

Having said that, long-term capital flows in the form of FDI are postulated to act as conduits for knowledge transfer insofar as the Multinational Corporations (MNCs) that undertake them possess higher levels of technology and organizational skills (Javorcik, 2004). Traditionally, scholars distinguish between horizontal spillovers (within the same sector or industry) and vertical spillovers, which in turn are divided into backward and forward linkages (Gorg and Strobl, 2005). Horizontal positive spillovers can occur through imitation (reverse engineering) from domestic firms and local employees leaving the multinational to start their own enterprise (Aitken and Harrisson, 1999). Empirically, the studies seek to quantify these FDI-induced knowledge spillovers using sectoral data productivity combined with the presence of inward FDI flows in that sector as well as upstream and downstream sectors to capture horizontal and vertical spillovers. A growing body of empirical work points towards the establishment of

technology transfer through the operations of MNCs[6] with the most robust results referring to the positive vertical spillover effects[7] of FDI flows (Javorcik, 2004; Gorodnichenko *et al*, 2014; Blalock & Gertler, 2008; Stancik, 2007; Gorg *et al*., 2008; Javorcik & Spatareanu, 2008). A meta-analysis for transition economies by Iwasaki & Tokunaga (2016) reveals that there is significantly greater support in the literature for certical FDI spillovers through backward linkages than horizontal and forward vertical linkages (see for example Javorcik & Spatareanu, 2005; 2008; Gorodnichenko *et al.,* 2020). The record is much more ambiguous when one turns to horizontal spillovers stemming from FDI presence in a specific industry/sectors as the negative competition effect sometimes proves more powerful thus reducing overall productivity and innovation performance (Aitken and Harrisson, 1999; Abraham *et* al., 2007; Javorcik & Spatareanu, 2008; Kosova, 2010). Existence of positive intra-industry spillovers through demonstration effects and labor turnover is documented mostly in studies concerning advanced economies (Haskel *et al*., 2007; Keller & Yeaple, 2009). Apart form the aforementioned methodology, the transmission mechanism of FDI flows has been incorporated in the trade-growth literature and bilateral FDI flows have been used to construct the weights for the levels of foreign R&D stock to create the measure of external knowledge. The results are mostly in favor of the notion of international knowledge transmission of knowledge (van Plottensberg & de la Potterie, 1999; Lee, 2005; Seck, 2012; Drivas *et al*., 2016) although the horizontal and vertical spillover effects cannot be disentangled due to the nature of the underlying data.

Finally, a recent strand of literature acknowledges the salient impact of face to face interactions in the dissemination of external knowledge (Feldman, 2000) and considers the mobility of high-skilled personnel as a vessel for knowledge transfer across national borders. The influential work of Miguelez (2009) underscores the role of the migration of inventors[8] in the transmission of new ideas and the boost on innovation capacity of the destination region. According to the theory. job movements enable an inventor to take advantage of knowledge - not only codified, but also tacit - accumulated by other inventors in their past jobs and share it in later jobs. A number of studies have extensively investigated the migration of inventors as a potential channel of market-generated knowledge diffusion with the effects corroborating the theoretical underpinning to a large extent (Kim & Marschke, 2005; McNeil, 2005; Breschi & Lissoni, 2009 Le, 2010; Guiri & Mariani, 2013; Gagliardi, 2015). Nonetheless, it should be noted that the empirical exercise to measure this effect is challenging since national systems of innovations and, hence innovative performance of a country or region act as pulling factors for the movement decisions of inventors (Florida, 2002; Argawal *et al*., 2006; Mellander & Florida, 2007; Miguelez & Moreno, 2014).

[6] Crespo & Fontoura (2009) provide a comprehensive survey of the relevant literature.
[7] See Havranek & Irsova (2011) for a meta-analysis on the subject.
[8] Inventors are high-skilled individuals that have registered at least one patent (Miguelez, 2012).

Complementary to the vigor of the transmission mechanism, the incidence and magnitude of the knowledge spillovers depend on the absorptive capacity of the firm, region or country (Griffith *et al*, 2003). According to Crescenzi & Rodriguez-Pose (2011), the integration of own R&D efforts, external knowledge transmitting through the various channels and local absorptive capacity shape the framework of innovation in a region. The empirical literature on knowledge spillovers has identified an array of local traits that constitute a region or country prone to innovation through the absorption of external technology[9]. The role of domestic human capital is underscored as a major mediating factor in a number of studies irrespective of the transmission channel (Engelbrecht, 1997; Chiang, 2005; Coe *et al*., 2008; Criscuolo & Narula, 2008; Madsen, 2014; Tang & Zang, 2016) as well as own R&D and innovation performance of the region (Guellec & de la Potterie, 2004; Aldieri & Cincera, 2007; Lin & Saggi, 2007; Gorodnichenko *et al*, 2014). Moreover, the overall institutional functioning of the recipient economy shapes the pre-requisites for the absorption of external knowledge[10]. Numerous studies have focused on the conducive role of infrastructure (Tang & Zang, 2016; Malerba *et al*., 2007), ease of doing business (Coe *et al*., 2008; Seck, 2012) and intellectual property rights (Crespo & Fontoura, 2009; Gorodnichenko *et al*., 2014), among others, thus pointing to the non-linear nature of the spillover procedure. In the same vein, many scholars account for the role of the domestic financial development as a channel for FDI-induced productivity spillovers to find significant support to their hypotheses (Hermes & Lensink, 2003; Desai *et al*, 2005; Blundell-Wignall & Roulet 2017). The efficiency and depth of domestic financial institutions matters for the commercialization of positive externalities associated with trade and FDI flows (Djankov & Hoeckman, 1999; Louri & Dimeli, 2001; Campos & Kinoshita, 2008).

4. Data and Methodology

4.1 Stylized Facts

In order to empirically gauge the magnitude of cross-border knowledge spillovers and the potential financial development thresholds that act as absorptive capacity we use data for a balanced panel of 23 OECD economies from 2005 to 2016. The dependent variable is domestic innovation production , which is proxied by the number of patent applications filed under the Patent Cooperation Treaty (PCT) in a certain country per year following Acs *et al.* (2002), derived from OECD's *Directorate for Science, Technology and Industry database*. In addition, we

[9] See Crespo & Fontoura (2009) for a review on the shaping of absorptive capacity in the case of FDI.

[10] According to Louri & Dimeli (2004) "Their (spillovers) magnitude and scope depend on the development stage of the economy, particular characteristics of the host markets, the structure of industries, institutional factors, trade regimes as well as attributes of the local workforce".

include Multi-factor Productivity (MFP) as the dependent variable in some specifications, defined as an index (2010=100) drawn from the OECD Main Statistics Database. Knowledge stocks, domestic and foreign, are approximated by perpetual inventory method using R&D data extracted from OECD's *Main Science and Technology Indicators* (PPP USD).[11] Furthermore, inward FDI stock and flows are derived from the OECD's *International Direct Investment Statistics* under Benchmark Definition BMD3[12], while data for countries' Gross Fixed Capital Formation from the OECD's *Annual National Accounts*. As there is no single metric of financial sector development, the study uses an array of financial development indicators compiled by the IMF and the World Economic Forum. Details on the variables and their definitions are provided in Appendix A2.

As show in Graph 1, the period under scrutiny is characterized by poor to modest overall productivity growth once put in a historical perspective (Gordon, 2016). Decomposing the dataset with reference to the 2008 financial crisis it is notable that average productivity growth is zero or negative for many economies. With the notable exception of Ireland, no country has experienced a surge in productivity growth compared to the pre-crisis period. Nonetheless, there is substantial cross-country variation in productivity growth rates within the group of advanced economies which is valuable from an empirical perspective since MFP is our main dependent variable. Innovative activity as measured by patents[13] (in terms of output) is not uniform across the globe or even across advanced economies (see Figure A1 in the Appendix). As underscored by Feldman and Kogler (2010) the creation of knowledge and the advances in new technologies in production is spatially concentrated despite the advances in communication technologies and the increased interdependence in the globalized economy. Innovative firms and sectors tend to be geographically fragmented (Botazzi and Peri, 2003; Audretsch and Keilbach, 2008; Deltas and Karkalakos, 2013) owing, to a large extent, to the importance of non-codified knowledge and face-to-face interactions (Soete, 2011). As can de observed in Table 1 the distribution of patents across countries and years is highly skewed with USA, Japan and South Korea dominating the field throughout the selected years in absolute numbers.

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[11]The main idea of the perpetual inventory method is the construction of yearly R&D stocks by adding each year's R&D expenditures and subtracting each year's depreciation of existing stock by a specific rate. We construct own and foreign country's R&D stocks by using a 15% depreciation rate. As in conventional literature, we have tried different depreciation rates, e.g., 10%, and 20%, with overall similar results.

12 The most recent vintage of OECD FDI data (BMD4) accounts for the presence of Special Purpose Entities (SPEs), however the availability of bilateral data prior to 2013 is very scarce. Nonetheless, the importance of addressing the measurement issue in the case of FDI flows net of the presence of Special Purpose Entities (SPEs) is underscored in Dellis *et al* (2020). The robustness checks attempt to gauge FDI inflows more accurately, albeit with the cost of fewer observations in the sample.

[13] There is no perfect metric for innovation and relying on patents poses caveats (see Argente *et al.*, 2020), however it is broadly used in the literature (OECD, 2010).

Table 1: Descriptive Statistics

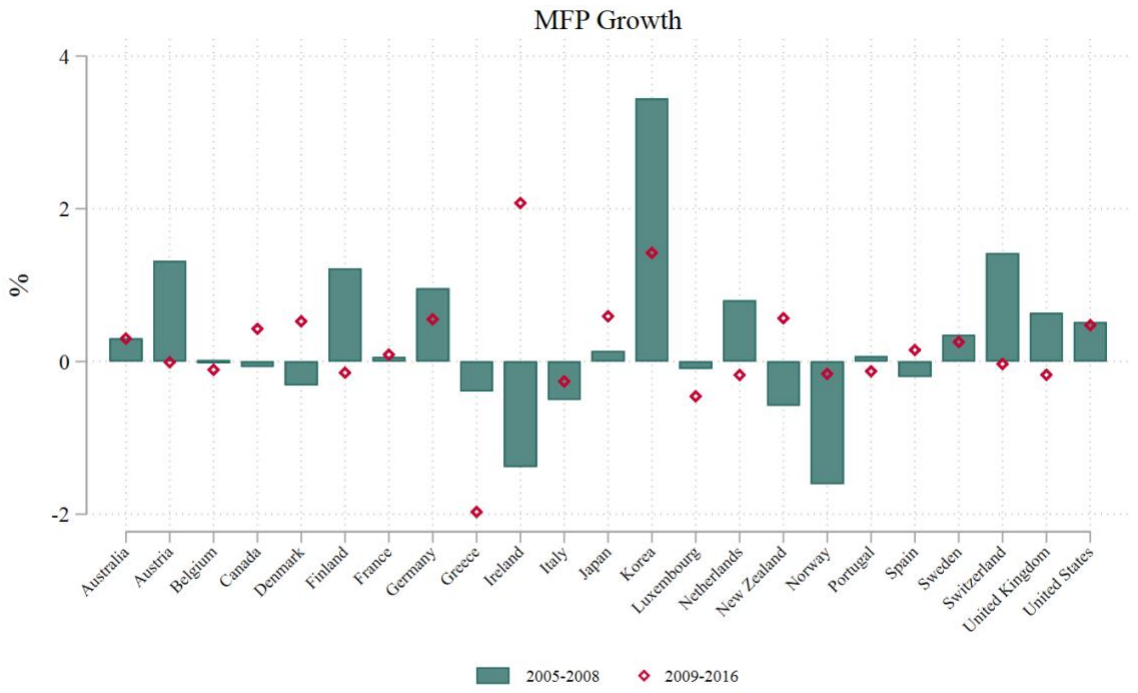
	Mean	Median	min	max	St.Dev
MFP Index (2010=100)	100.334	100.195	84.66	109.907	3.003
MFP growth	.186	.261	-6.3	8.304	1.739
Patents under PCT	6709.182	1879.92	37.789	58934.27	12374.91
Patents per Population	.148	.126	.008	.361	.092
Patents % GDP	.004	.003	0	.01	.002
log Domestic R&D Stock	24.87	24.867	21.816	28.412	1.485
log Foreign R&D Stock (FDI)	8.865	9.118	3.115	12.069	1.607
log Foreign R&D (Capital Imports)	21.623	21.663	18.919	24.18	1.08
Financial development index (IMF)	.76	.762	.5	1	.103
Financial institutions index (IMF)	.807	.821	.569	1	.102
Financial markets index (IMF)	.696	.718	.349	1	.147
Financial institutions depth (IMF)	.738	.721	.282	1	.178
Financial Markets Index (WEF)	4.818	4.943	2.524	6.169	.711
Financial Efficiency Index (WEF)	4.475	4.585	2.238	5.814	.704
Private Credit % GDP (WB)	111.404	104.34	48.892	212.901	35.505

Data from the European Commission note the lagging performance of the European economy in R&D intensity and innovation compared to the US, Korea and Japan (*European Innovation Scoreboard*, 2018*)*. Moreover, within the EU innovation performance is fragmented with no signs of convergence looking at patents per capita (see Veugelers, 2017). These developments raise the question on whether foreign knowledge can enhance productivity in laggard countries through the bilateral relationships in the fields of trade and FDI flows. The data on the foreign R&D stock underline the increased importance of this specific source of technology (Graphs 2 and 3), albeit with a small plateau phase the year after the eruption of the financial crisis. The revival in trade and FDI flows[14] after 2009 provide with larger stocks of foreign R&D under both weighting schemes. The trade-related flows are significantly larger than the FDI-weighted external knowledge stocks, however both variables exhibit a degree of persistence as countries occupying the top places among the OECD group do not change over time. Foreign R&D stock based on FDI weights shows a trend of reduced dispersion after 2012, with the Greek economy however remaining at the last position in the relevant table throughout the course of these 12

[14] FDI-weighted foreign R&D stock uses bilateral FDI flows in absolute terms, since the data refer to net flows and can take negative values as well. For reasons of robustness we also use a three-year moving average of these flows in our estimations.

years[15]. More specifically, the 5 highest pair-year observations in terms of bilateral FDI flows are documented in 2015 and 2016 with USA being the host economy in all of them and with flows that go beyond 350 billion USD per year compared to the sample average of 30 billion when we account for all firms operating in the host economy . Amongst them, inflows from Luxembourg[16] in 2015 reached the highest value in the sample of 182 billion followed by Swiss FDI in the US from 2016 at 72 billion.

Graph 1: Multifactor Productivity Growth



Source:OECD

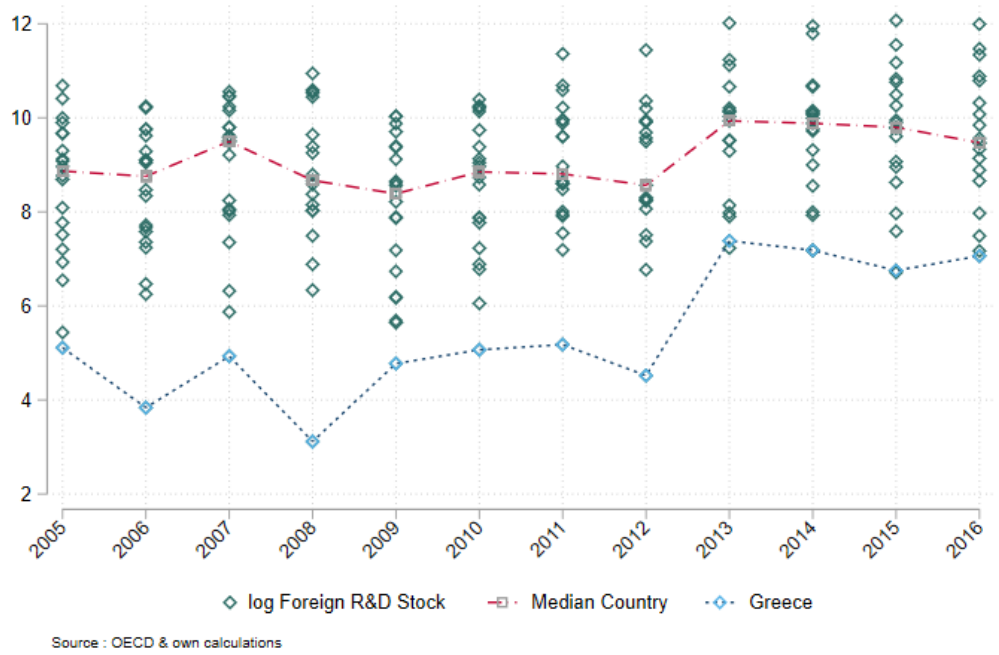
Among the highest capital goods transactions USA is the host economy in the top 17 country-pair observations, while the next three places refer to Canadian capital imports from the United States. Imports of Chinese capital goods in the USA surged from 75 USD billion in 2013 to almost 900 billion in 2015 and 2016[17].

[15] It requires mentioning the FDI flows to Greece have increased substantially the years following 2016 (Bank of Greece, 2020).

[16] Data on FDI flows are to be approached with caution, especially for countries with a high SPE presence such as Luxembourg and the Netherlands (see Dellis *et al*., 2017 for a discussion).

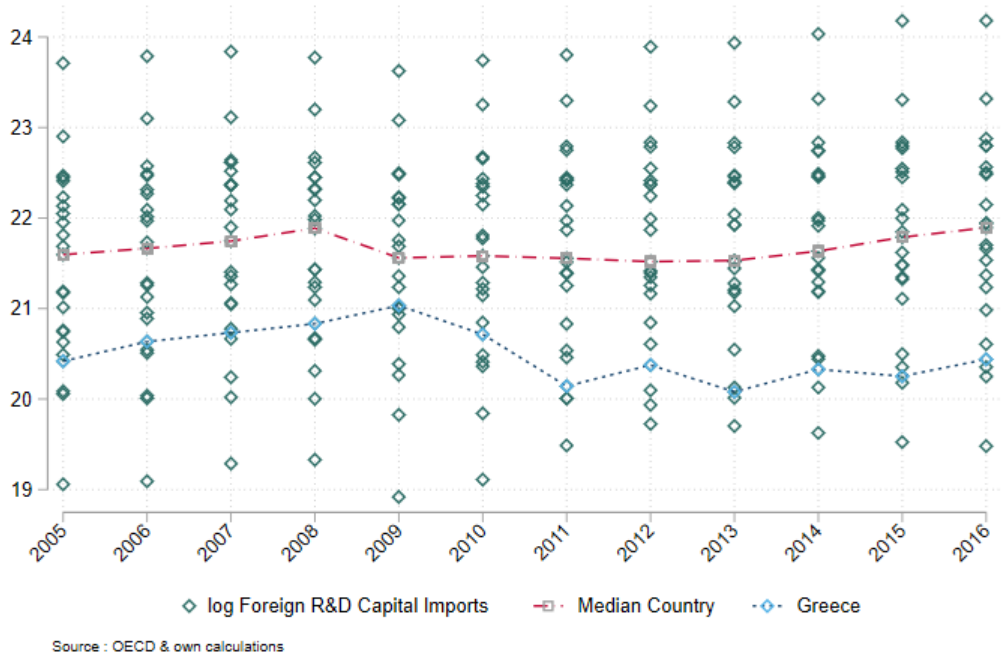
[17] The four highest transactions in capital goods involve the exports from China to the USA (2013-2016).

Graph 2: Foreign R&D Stock – FDI Channel



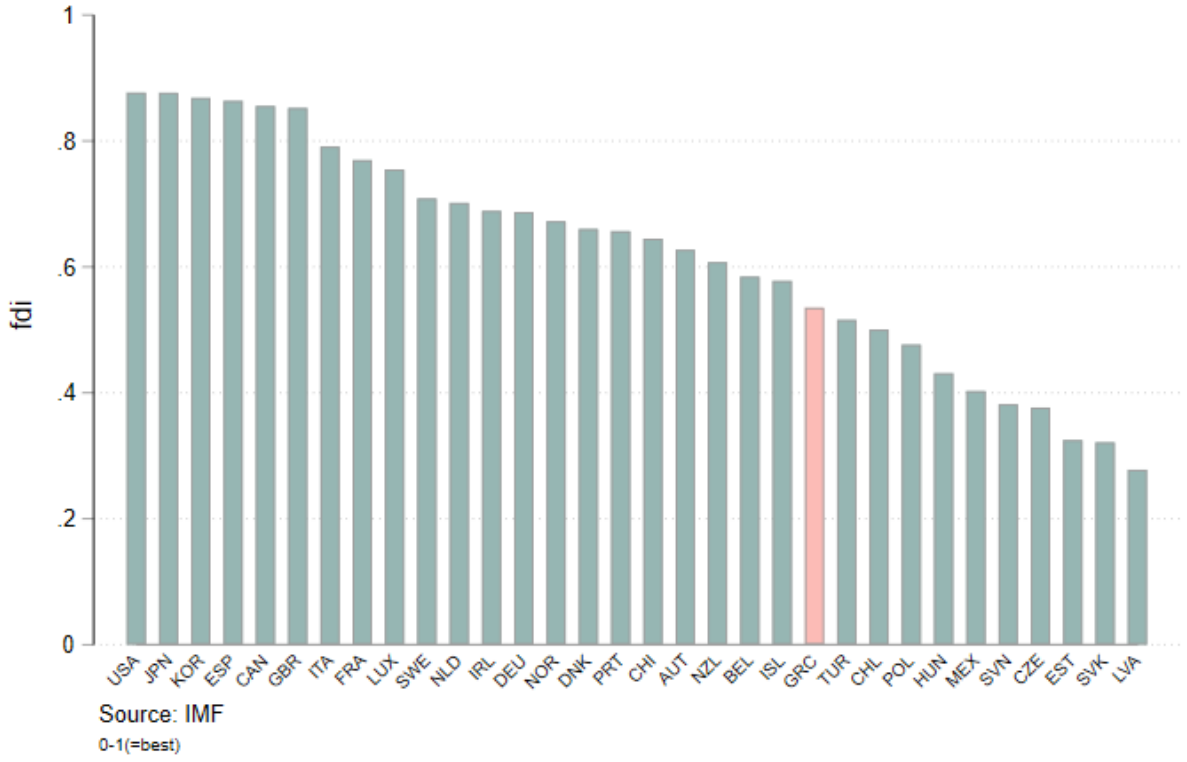
It is, therefore, no surprise that the US economy steadily receives the lion's share of external knowledge through the trade of intermediate capital goods (the top observations in Graph 3) and is notably followed by Germany and the United Kingdom. The upward trend in Greek foreign knowledge stock from the trade channel came to an abrupt stop in 2008 and has been stabilized in the bottom decile of the distribution for the years that followed. The aggregate value of capital imports for the Greek economy dropped sharply from 11 billion in 2009 to marginally above 5 billion in 2005 reflecting the sharp drop in the country's GDP following the financial crisis.

Graph 3: Foreign R&D Stock – Trade Channel



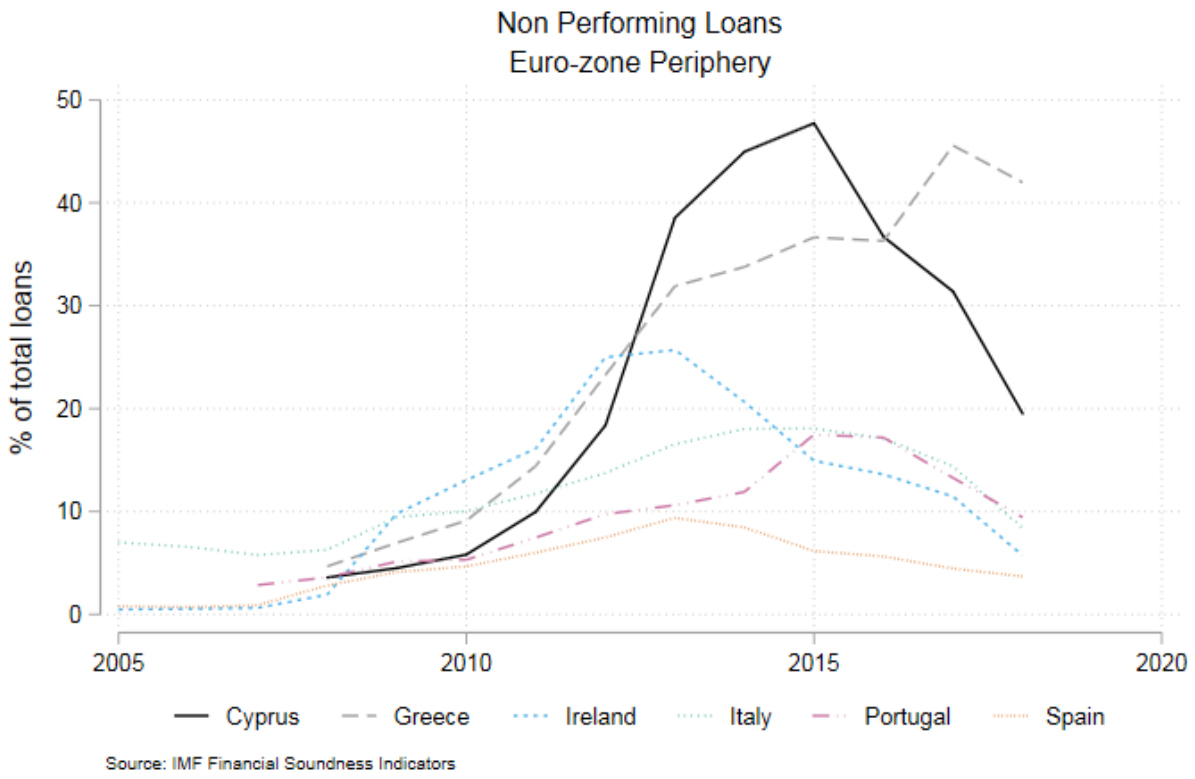
Despite the fact that there is no single metric for the development and effectiveness of the financial system, the variables and indicators available for the IMF, the WEF and the World Bank provide with some stylized facts regarding the position of the economies in the sample. Among the composite financial development indexes, there is no pronounced heterogeneity as shown Graph 4, however there exists a fragment between the leaders and laggards with the latter group composed primarily of transition economies. The last decade of the 20th century marked a rigorous financial development environment for high- and low-income OECD economies and was noteworthy in the peripheral EU countries (Spain, Portugal, Greece, Ireland). The global financial crisis kept this development to a halt and by 2010 led to a decrease in the IMF financial development indicator particularly in the economies of the periphery. When looking at specific indicators we can detect some variation in the behavior of the components of the financial system as can be seen in Graph 5 which plots the evolution of non-performing loans in certain EU economies. Even values close to 10% of total loans for Italy are significantly higher than the sample averages (mean 4.3%, median 3.1%) once we exclude the outliers (Greece and Cyprus). The burden on non-performing loans lies heavy on the financial conditions for SMEs especially in Greece and hampers the growth potential (Bank of Greece, 2019).

Graph 4: Financial Development Index



Another area of divergence within the advanced country group is the depth f the financial system in terms of the availability of options for corporate external financing. Stock market capitalization was 143% of GDP in the US, 99% in Japan ,67% in Spain and 22% in Greece for 2016, thus indicating a very diverse space of equity financing in the data. The same conclusions apply when one turns to the WEF indicator that captures the availability of venture capital, where data for 2015 reveal a score of mere 1.8 for the case of Greece and 2.1 for Italy (scale of 1 to 7, mean value 3.4) with no signs of improvement during the period in question . The degree of variation within the OECD country group has increased after the financial crisis of 2008-09 and thus provides with a fruitful set of indicators that can be used as proxy for the absorptive capacity of an economy that expects to gain from trade and capital flows.

Graph 5: Non-Performing Loans



4.2 Empirical Specification

The empirical methodology follows the trade-growth literature (Coe & Helpman, 1995; Keller, 2004) based on the theoretical premise of the *Knowledge Production Function*[18] (Grilliches, 1986; Audretsch & Feldman, 1996). In the same vein as Drivas *et al.* (2016) both channels of external technology are included in the estimated equation as possible inter-dependencies across different channels and omitted factors (e.g. technology shocks) when estimating single equations of knowledge flows could hamper the efficiency of the estimates (Drivas *et al*, 2014)

Our baseline specification is the following

[18] Details on the derivation of the reduced form from the theoretical model are presented in the Appendix.

$$F_{it} = a^D lnRD_{it}^D + \sum_{j=1}^{2} a_j^F \; lnRD_{ijt}^F + \gamma I_{it} + \sum_{j=1}^{2} \delta_j^f \; lnRD_{ijt}^F * I_{it} + \alpha_\iota + u_{it} \qquad (1)$$

The dependent variable (F_{it}) is the number of patents normalized by GDP or population of the host economy or MFP. We focus on patents to gauge innovative activity of the recipient economy following a bevy of empirical studies (Cantwell & Iammarino, 1998; Bottazi & Peri, 2005, Drivas *et al*, 2016; Crescenzi *et al*, 2020) keeping in mind the drawbacks highlighted *inter alia* in Archibugi (1992)[19].The coefficient of interest is α^f which measure the partial elasticity of local productivity with respect to the foreign R&D stock (as constructed using import and FDI weights). Both external knowledge variable are interacted with an institutional dummy (I_{it}) which takes the value of 1 if institutional performance is high in the respective country-year observation and 0 otherwise to capture the non-linear effects of foreign R&D stock due to domestic absorptive capacity. Finally, all specifications include country fixed effects and time fixed effects where stated. The models with continuous dependent variables are estimated with OLS and standard panel estimation techniques, however emphasis is given in the Dynamic and Fully Modified OLS models (DOLS and FMOLS) once we delve into the time series properties of the underlying variables. After establishing panel cointegration (see Results Section) through the appropriate testing procedures we report FMOLS and DOLS results which to utilize the information concerning the long run relationship and allow the short run dynamics to be potentially heterogeneous (Seck, 2012). As a robustness exercise we estimate regressions with the number of patents as the dependent variable using the Negative Binomial Model.

In addition, we allow for potential endogenous thresholds in the effect of domestic financial development with the estimation of the Panel Threshold Models (Hansen, 1997; Caner & Hansen, 2004).

$$F_{it} = a^D lnRD_{it}^D + \sum_{j=1}^{2} a_j^F \; lnRD_{ijt}^F I(Q_{it} < \gamma) + \sum_{j=1}^{2} \beta_j^f \; lnRD_{ijt}^F I(Q_{it} > \gamma) + \alpha_\iota + u_{it}$$
(2)

I is the indicator function to distinguish between the two regimes, Q_{it} is the value of the respective financial or institutional variable and γ is the endogenously determined threshold value. The difference between coefficients α^f and β^f and its statistical significance provides

[19] For example, patented innovations represent only a fraction of total innovative output and the intrinsic value of each patented innovation is not equal.

information on the existence of threshold values of domestic financial variables in the knowledge dissemination process.

5. Results

Prior to presenting the results from the empirical estimation we must turn to the time-series properties of the underlying variables. Applying the proper panel stationarity tests, we can then infer whether there exists a co-integrating relationship among the variables. If this is the case, it is preferable to use the DOLS or FMOLS estimators, which have similar asymptotic properties and improve the simple properties of the OLS estimator (Seck, 2012). Following Pesaran (2007) we deploy the CIPS panel unit root test which is robust to cross-sectional dependence in the data. The test for cross-sectional dependence in the data (Pesaran & Hashem, 2006) rejects the null hypothesis of independence for all the series in question (MFP, patents, domestic R&D stock, foreign R&D stock), hence it is necessary to use a stationarity test which accounts for cross-sectional dependence. Table 2 presents the result for the dependent and independent variables. The null hypothesis of a unit root is not rejected for any of the series except for the foreign R&D stock based on the FDI weighted average. The results of the conventional panel unit root tests[20] are presented in the Appendix. Having said that, table 2 presents the results for the Pedroni Cointegration tests (2001). Under the null hypothesis the test statistic for all categories follows the standard normal distribution, hence we reject the null of no cointegration in the underlying data and proceed with the DOLS estimations

Table 2: Panel Unit Root Test (CIPS)

log MFP	log Patents/Pop	log Patents/GDP	log R&D Domestic	log Foreign R&D Trade	log Foreign R&D FDI
-1.3235	-0.0602	-1.7209	-0.9228	-1.5067	-2.3054

Critical Values are: -2.07 (10%), -2.17 (5%) , -2.34 (1%)

All tests include 2 BG lags

[20] see Hlouskova and Wagner (2006) for a discussion on the performance of the various tests.

Table 3: Pedroni Panel Cointegration Test

Statistic	Panel	Group
v	-1.178	
rho	2.696	4.625
t	-7.342	-8.573
Adf	-3.513	-4.845

Table 4 depicts the results from the baseline estimations with the linear form of the patent variable (scaled by population and GDP). In columns (1) and (2) the domestic R&D stock emerges as a major determinant of patenting activity with substantially high and significant partial elasticity, whereas only the R&D stock through trade of capital goods exerts positive effects albeit with a smaller elasticity.

Table 4: Baseline Regressions – Dependent Variable: Patents/GDP

VARIABLES	1 Patents/Population DOLS	2 Patents/GDP DOLS	3 Patents/Population DOLS	4 Patents/GDP DOLS	5 Patents NB	6 Patents NB
log Domestic R&D	0.483***	0.194***	0.910***	0.718***	0.275***	0.279***
	(0.000)	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)
log Foreign R&D FDI	-0.025***	-0.016***	0.048***	0.068***	0.037***	0.045***
	(0.000)	(0.007)	(0.000)	(0.000)	(0.001)	(0.001)
log Foreign R&D Imports	0.304***	0.096*	0.046*	-0.312***	-0.004	-0.009
	(0.000)	(0.077)	(0.065)	(0.000)	(0.932)	(0.856)
Import Share			0.053***	0.004	0.122***	0.104*
			(0.000)	(0.600)		(0.088)
log Foreign R&D FDI* Imp Share			-0.001***	-0.001***		-0.020
			(0.000)	(0.000)		(0.403)
log Foreign R&D FDI* Imp Share			-0.001***	0.001*		0.010
			(0.000)	(0.079)		(0.383)
Constant	-20.808***	-12.933***	-22.038***	-18.531***	-2.568	-2.643
	(0.000)	(0.000)	(0.000)	(0.000)	(0.115)	(0.111)
Observations	206	206	233	233	219	219
R-squared	0.999	0.999	0.999	0.999	-	-
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No
LR Statistic	-	-	-	-	54.95	55.72

*** p<0.01, ** p<0.05, * p<0.1
2 Lags and 2 Leads of independent variables included
bartlett kernel applied

Columns (3) and (4) include the import share over home country GDP as in Coe *et al*. (2008) and show a positive effect of both channels in patents per head (Column 3). In addition, Columns (5) and (6) report the coefficients from the count regressions with the number of patents as the dependent variable. Both models refer to Negative Binomial rather than Poisson estimation as the LR test statistic rejects the null hypothesis of equi-dispersion[21]. The FDI-induced foreign knowledge component is robust and has a positive effect on the incidence of patents in these

[21] Poisson regressions with country fixed effects yield similar results.

estimations while the trade related foreign R&D stock does not appear to be significant. The partial elasticity of the foreign knowledge stock ranges from 0.04 to 0.07 in these specifications in line with the findings by Coe *et al* (2008) and Poldahl (2012), and slightly greater than the implied results of Lee (2005) and Malerba *et al.* (2007).

Table 5: DOLS Regressions with Absorptive Capacity – Dependent Variable: Patents/GDP

VARIABLES	1 Financial Development (IMF)	2 Financial Institutions Development (IMF)	3 Financial Institutions Depth (IMF)	4 Financial Markets Development (IMF)	5 Financial Market (WEF)	6 Private Credit % GDP
log Domestic R&D	0.512***	0.727***	0.180*	0.526***	0.437***	0.532***
	(0.007)	(0.000)	(0.093)	(0.000)	(0.003)	(0.000)
log Foreign R&D FDI	0.008	0.042***	0.015	0.026***	0.031**	0.013
	(0.715)	(0.000)	(0.122)	(0.004)	(0.030)	(0.111)
log Foreign R&D FDI*Inst	0.013	-0.029	0.000	-0.075***	-0.053*	0.017
	(0.701)	(0.405)	(0.972)	(0.004)	(0.051)	(0.342)
log Foreign R&D Trade	-0.331***	-0.234***	-0.313***	-0.192***	-0.224***	-0.227***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
High Institution	-0.064	0.484	0.104	0.717***	0.602*	-0.000
	(0.851)	(0.134)	(0.402)	(0.004)	(0.022)	(0.999)
Constant	-12.089**	-19.785***	-4.284	-15.641***	-12.392***	-14.760***
	(0.018)	(0.000)	(0.127)	(0.000)	(0.001)	(0.000)
Observations	211	211	211	211	211	211
R-squared	0.997	0.997	0.997	0.997	0.997	0.997
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1
2 Lags and 2 Leads of independent variables included

bartlett kernel
applied
All R&D Stock Variables are measured with 1 Lag.

Country Fixed Effects Jointly Significant at 1%

On top of the baseline regressions, we draw a first attempt on the non-linear effects of FDI-induced foreign knowledge by defining high institutional performance as the country-year observations that belong in the top quantile of their respective distribution. The possible non-linear relationship is examined at this preliminary stage through the inclusion of an interaction term of the foreign R&D stock with the indicator variable that takes the value of 1 in the case of high-quality financial institutions. Interestingly the measure stemming from the bilateral FDI flows interacted with domestic financial development appears to exert a negative influence on patents in all specifications, as depicted in Table 5 thua corroborating the findings of Havranek & Irsova (2011) . By contrast, the relationship is reversed once we look at the effect on MFP in Table 6. The negative effect of MNC presence in the economy, perhaps stemming from adverse competition effects (Aitken & Harrison 1999; Haskel *et al*, 2001) is significantly ameliorated in four out of six specifications through the prevalence of sound financial institutions. The overall effect is still marginally negative, with the exception of the effect of domestic credit (last column). The domestic R&D stock and trade -weighted foreign stock are significantly growth augmenting with the partial elasticities corroborating previous empirical findings (Coe & Helpmann, 1995; Seck, 2012; Farcasso & Marzetti, 2015)

Aside from using exogenously determined thresholds for the financial variables, we allow for the value of the cut-off point to be endogenously determined from the data. Table 7 presents the results from the Panel Threshold model based on the theoretical work of Hansen (1999; 2004). We allow for the coefficient of the external knowledge stock to differ across values based on an endogenously determined threshold value of the financial variable in question. Looking at the results in Table 7 referring to patents as the dependent variable, it is notable that in five out of six specifications the effect of FDI-weighted foreign R&D is amplified after a certain financial development threshold[22]. Moreover, in the case of Financial Institutions Depth, the positive effect of external knowledge is statistically significant only after the endogenously determined threshold value (Column 3). The existence of a threshold value is statistically significant at the 10% level for all but one specification, whereas the threshold levels lie below the respective sample means of the chosen financial variables. The results corroborate the previous findings on the importance of own R&D in the process of increasing productivity.

[22] Estimations with two endogenously determined thresholds yield insignificant results for the second threshold and are not tabulated.

Table 6: DOLS Regressions with Absorptive Capacity – Dependent Variable: MFP

VARIABLES	1 Financial Development (IMF)	2 Financial Institutions Development (IMF)	3 Financial Institutions Depth (IMF)	4 Financial Markets Development (IMF)	5 Financial Market (WEF)	6 Private Credit % GDP
log Domestic R&D	0.182***	0.155***	0.208***	0.178***	0.218***	0.152***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
log Foreign R&D FDI	-0.022***	-0.014***	-0.020***	-0.015***	-0.017***	-0.017***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
log Foreign R&D FDI*Inst	0.014***	-0.016***	0.011***	-0.011	0.019***	0.029***
	(0.000)	(0.001)	(0.000)	(0.347)	(0.000)	(0.000)
log Foreign R&D Trade	0.049***	0.103***	0.065***	0.076***	0.059***	0.083***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
High Institution	-0.114***	0.128***	-0.103***	0.120	-0.234***	-0.210***
	(0.000)	(0.003)	(0.001)	(0.304)	(0.000)	(0.000)
Constant	-0.851	-1.393***	-1.735**	-1.351	-1.915***	-0.869
	(0.101)	(0.000)	(0.026)	(0.179)	(0.000)	(0.153)
Observations	209	209	209	209	209	209
R-squared	0.871	0.898	0.862	0.863	0.884	0.888
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

pval in parentheses

*** p<0.01, ** p<0.05, * p<0.1

2 Lags and 2 Leads of independent variables included

bartlett kernel applied

All R&D Stock Variables are measured with 1 Lag.

Country Fixed Effects Jointly Significant at 1%

Table 7: Threshold Regressions[23]– Dependent Variable: Patents/GDP

One Threshold Regression

VARIABLES	1 Financial Development (IMF)	2 Financial Institutions Development (IMF)	3 Financial Institutions Depth (IMF)	4 Financial Markets Development (IMF)	5 Financial Market (WEF)
log Domestic R&D	0.654***	0.707***	0.616***	0.583***	0.517***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
log Foreign R&D Trade	-0.163***	-0.240***	-0.222***	-0.201***	-0.110**
	(0.001)	(0.000)	(0.000)	(0.000)	(0.026)
log Foreign R&D FDI < Threshold	0.023**	0.022**	0.017	0.018*	0.030***
	(0.033)	(0.037)	(0.110)	(0.079)	(0.004)
log Foreign R&D FDI > Threshold	0.030***	0.038***	0.036***	0.033***	0.009
	(0.009)	(0.001)	(0.001)	(0.002)	(0.369)
Constant	-19.244***	-18.874***	-16.969***	-16.579***	-16.766***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	143	143	143	143	130
R-squared	0.520	0.575	0.557	0.560	0.553
Number of cnt	13	13	13	13	13
Country FE	Yes	Yes	Yes	Yes	Yes
Threshold Value	0.731	0.877	0.705	0.754	3.573
Threshold Test P-value	0.830	0.0600	0.100	0.0400	0.0600

pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Bootstrap Estimation of Threshold after 100 Iterations
All R&D Stock Variables are measured with 1 Lag.

Country Fixed Effects Jointly Significant at 1%

The forces behind productivity spillovers appear to be governed by different principles based on the findings presented in Table 8. Using total factor productivity as the dependent variable, only trade-induced foreign knowledge has growth-enhancing effects with the coefficients lying at the high end of the respective literature summarized above. The presence of MNCs reduces domestic productivity, albeit with a smaller intensity after the threshold level of domestic financial development except for private credit. This result is in line with the conclusions met by

[23] Panel Threshold regressions require balanced panels, hence this set f results refers to 13 countries form the sample.

Aitken & Harrison (1999) and Havranek & Irsova (2011) and could reflect the fact that we have not distinguished between horizontal and vertical spillovers rather included total FDI inflows at the country level. Having said that, the results from Tables 7 and 8 could also point to the inherent specialty of the innovation-finance nexus (Hall & Lerner, 2010; Brown *et al*, 2013) whereby the increased risks of innovative production and the lack of adequate collateral in many cases reduce the availability of the necessary resources o promote innovation. Given a certain threshold of financial development increases the chances of domestic firms learning from products and processes embedded in FDI inflows and thus promoting local innovative output in the form of patents.

Table 8: Threshold Regressions[24]Dependent Variable: MFP

One Threshold Regression

VARIABLES	1 Financial Development (IMF)	2 Financial Institutions Development (IMF)	3 Financial Institutions Depth (IMF)	4 Financial Markets Development (IMF)	5 Financial Market (WEF)
log Domestic R&D	0.065***	0.095***	0.081***	0.083***	0.122***
	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
log Foreign R&D Trade	0.047***	0.043***	0.041***	0.046***	0.037**
	(0.001)	(0.005)	(0.007)	(0.001)	(0.016)
log Foreign R&D FDI < Threshold	-0.012***	-0.013***	-0.014***	-0.014***	-0.013***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
log Foreign R&D FDI > Threshold	-0.008**	-0.011***	-0.010***	-0.010***	-0.009***
	(0.032)	(0.002)	(0.003)	(0.002)	(0.002)
Constant	2.003***	1.354**	1.745***	1.578***	0.769
	(0.001)	(0.021)	(0.003)	(0.005)	(0.194)
Observations	143	143	143	143	130
R-squared	0.311	0.250	0.264	0.321	0.352
Number of cnt	13	13	13	13	13
Country FE	Yes	Yes	Yes	Yes	Yes
Threshold Value	0.822	0.881	0.718	0.725	3.761
Threshold Test P-value	0.270	0.920	0.480	0.190	0.280

pval in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Bootstrap Estimation of Threshold after 100 Iterations

All R&D Stock Variables are measured with 1 Lag.

Country Fixed Effects Jointly Significant at 1%

[24] Panel Threshold regressions require balanced panels, hence this set of results refers to 13 countries form the sample.

6. Policy Implications and the case of Greece

In the case of Greece, resolution of the commercial banks' balance sheets is the number one challenge as identified by the Bank of Greece in the 2017 Governor Report (Bank of Greece, 2018). The results of the previous section underline the importance of the restoration of the domestic financial system for the bolstering of absorptive capacity as well. The Greek economy is not close to the global technological frontier in any sector (EIB, 2018), however shares the traits of a middle-income country with substantial gains to be reaped through technology transfer. Combined with the efforts to integrate domestic firms in reshaped Global Value Chains in the wake of the COVID-19 pandemic needs to be coupled with the deepening and re-building trust in the financial system the through the implementation of necessary reforms (Bank of Greece, 2019). Table 9 clearly depicts the ground to be covered in order for the Greek economy to reach the financial variable thresholds stemming from the empirical results[25]. The last column calculates the 'distance to frontier' measure with the threshold value being set to 100. With the notable exception of the World Bank indicators for private deposits and liquid liabilities, the level of the relevant financial variables stands between 50-75% of the threshold value in most cases (see also Graphs A3 and A4 in the Appendix). The latter implies that there is considerable action to be taken to increase the absorptive capacity of the economy and maximize the growth-enhancing effects of FDI inflows. The reform process can be emboldened by regional policy coordination and ongoing objective of the EU. More specifically, enhanced diversity funding sources is at the epicenter of the policy discussion in the EU with the proposed introduction of the Capital Markets Union (CMU) which is aimed to complement the Banking Union.[26] This initiative is aimed to provide complementary funding to bank lending across EU countries thus facilitating capital accumulation irrespective of the firms' location. The data reveal that the score of the Greek financial system is below the respective threshold variables in almost all institutional categories. Consequently, the ability to benefit from technological advanced created outside the national level can be invigorated through improvements in the financial systems combined with a set of reform policies addressed to the domestic R&D production.

The aforementioned conclusions are in line with one of the main policy targets outlined in the IMF's *Global Financial Stability* Report (2017) which highlights that "Policymakers and regulators should fully address crisis legacy problems and require banks and insurance companies to

[25] The values for the Greek economy refer to 2016, except for the World Bank Indicators where the latest available data is for 2015.

[26] In her speech given for the "EURO at 20" joint Conference in Dublin (June 2018) Managing Director of the IMF Christine Laggard underscored that "[…] the euro area needs truly integrated financial and capital markets that allow companies to raise financing across borders more easily and support investment".

strengthen their balance sheets in advanced economies. This includes putting a resolution framework for international banks into operation, focusing on risks from weak bank business models to ensure sustainable profitability, and finalizing Basel III". That said, policymakers should keep in mind that the rapid de-regulation preceding the financial crisis had adverse effects on the stability of the financial system. Hence, the liberalization process aiming at dismantling rigidities should be coupled with the implementation of necessary regulations and safety nets (IMF, 2017). In addition, the emergence of financial institutions depth as a robust determinant in the results highlights the importance of private sector credit and pension fund assets[27]for the availability of diverse sources of funding for domestic enterprises (ECB, 2017). Working towards amplifying the set of institutions able to provide capital contributes to efficient and flexible domestic corporations, which in turn can collaborate with MNCs and deliver economic growth. As stated in Section 2.2 the existence and quality of domestic clients and suppliers skews foreign capital towards the host economy.

Table 9: Greece and Threshold Levels

Indicator	Greece	Threshold Level	Distance to Threshold
Financial Market Index (WEF)	2.52	3.20	78.78
Financial Efficiency Index (WEF)	2.24	3.57	62.65
Venture Capital Index (WEF)	1.81	2.75	66.04
Bank Soundness Index (WEF)	2.74	5.67	48.29
Bank Deposits % GDP	94.93	98.18	96.69
Liquid Liabilities % GDP (WB)	99.54	98.18	101.38
Private credit by banks % GDP (WB)	115.04	101.30	113.56
Financial Development Index (IMF)	0.54	0.73	74.14
Financial Institutions Index (IMF)	0.57	0.88	64.90
Financial Markets Index (IMF)	0.50	0.55	91.66
Financial Institutions Depth (IMF)	0.33	0.70	46.22
Financial Institutions Access (IMF)	0.55	0.94	58.48
Financial Institutions Efficiency (IMF)	0.76	0.62	122.71
Financial Markets Depth (IMF)	0.51	0.75	67.94
Financial Markets Access (IMF)	0.58	0.52	111.84

[27]The indicator includes private credit, pension fund assets, mutual fund assets and insurance premia as a percentage of GDP (Svirydzenka, 2016).

7. Conclusion

In this paper we use data for 23 OECD economies to evaluate the non-linear effect of knowledge and technological advances developed outside national boundaries as postulated by the theory of knowledge spillovers (Grilliches, 1979; Aghion & Howitt, 1992, Coe & Helpmann, 1995). In the vein of the trade-growth literature we measure the effect of the foreign R&D stock weighted by bilateral capital goods imports and FDI flows. In addition, we account for domestic absorptive capacity (Coe & Levinthal, 1989) defined by the level of financial development of the host economy. Given the lack of a universally acclaimed variable to measure the concept of financial development we use a range of financial variables from the IMF, the World Economic Forum, and the World Bank. On top of standard econometric techniques and controlling for the existence of panel cointegration among the underlying variables, we use Panel Threshold analysis allowing for the cut-off point of financial performance to be endogenously determined. Our results indicate that trade-induced productivity spillovers are significant and robust across specifications, whereas foreign R&D appears to have a negative effect through the intermediate imported inputs channel. The results on the FDI-weighted foreign knowledge stock indicate that the depth and efficiency of the recipient country financial system can be viewed as a factor of absorptive capacity thus mediating the positive externalities form MNC presence. Most of the financial variables appear to facilitate knowledge spillovers above a certain threshold irrespective of that threshold being exogenously or endogenously determined. One should apply caution to these results, considering data issues concerning “true” bilateral FDI flows according to the OECD BMD4 definition. Nonetheless, a fruitful policy lesson for financially strained economies is that learning from the technological frontier to foster innovative activity can be more feasible in the context of a sound and developed financial system. In the case of the Greek economy, the ongoing process of structural reforms aiming at the reinvigoration of the domestic financial system and the incremental completion of the Banking and Capital Markets Union could serve as a conduit for speeding the catch-up process to the technological frontier.

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Appendix

A1. Theoretical Model

In its simple form, the production function of innovation of a region can be expressed as follows (Grilliches, 1979):

$$Q_{it} = (A_{it})^{\gamma}(A_{it}{}^{\alpha})^{\mu} \quad \text{(A1)}$$

where *Q* is the innovative output, proxied by the number of patents produced in country *i* at time *t*; *A* is own, homegrown knowledge stock, proxied by R&D stock accumulated from past and current R&D investments in country *i*; and A^{α} is the stock of external and accessible (hence the *a* superscript) to country *i* knowledge stock, proxied by R&D accumulated in countries other than country *i*.

Knowledge flows take place when an idea, generated in region, country or institution, is learned by another region, country or institution. If knowledge flows manage to perfectly and completely spill over, then the amount of external knowledge that eventually reaches country *i* is simply the summation of all borrowed knowledge that comes from all other countries. In reality, however, the diffusion of knowledge flows across states may be less than complete; only a share of research results from other countries reaches country *i*. The external accessible to country i R&D activity can be described by:

$$A_{it}{}^{\alpha} = \sum_{j \neq i} f_{ij} A_{jt} \quad \text{(A2)}$$

Where f_{ij} is the share of knowledge learned in country *i* originated in country *j*.

Substituting equation (2) into equation (1) and by taking logs, equation (1) yields:

$$lnQ_{it} = \gamma lnA_{it} + \mu ln \sum_{j \neq i} f_{ij} A_{jt} \quad \text{(A3)}$$

Foreign R&D stock for country *i* and year *t* that reaches country *i* via different channels, (i.e., trade of intermediate goods and FDI) and is constructed as:

$$R\&D_{it}^{f} = \sum_{i \neq j} (w_{ij,t}^{k} R\&D_{j,t}^{d}) \quad \text{(A4)}$$

where the weighting scheme $w_{ij,t}^{k}$ is calculated in the empirical literature(Lichtenberg and de la Potterie, 1998; Coe and Hoffmeister, 1999; Lee, 2005; Coe *et al*, 2008; Seck, 2012) trade-weighted (if the channel is trade), FDI-weighted (if the channel is FDI) and bilateral flows.

$$w_{ij,t}^{1} = \frac{IMP_{ij,t}}{GDP_{j,t}} \qquad \text{(A5)}$$

$$w_{ij,t}^{2} = \frac{FDI_{ij,t}}{KForm_{j,t}} \qquad \text{(A6)}$$

A2. Variables and Descriptions

Variable	Unit	Description	Source
Domestic R&D stock	USD million	Perpetual Inventories Method assuming 15% and 20% rate of depreciation	OECD
Foreign R&D Stock Capital Import weight	USD million	Weighted Sum of R&D Stock of partners	OECD/ Authors' Calculations
Foreign R&D Stock FDI weight	USD million	Weighted Sum of R&D Stock of partners	OECD/ Authors' Calculations
Multifactor Productivity Index	Index (0-100)	2010=100	OECD
Patents (PCT)	Number	Patents filed under the Patent Cooperation Treaty (PCT)	OECD
Financial Development Index	0-1 (=more financial openness)	Aggregate Indicator	IMF[28]
Financial Institutions Index	0-1 (=more financial openness)	Aggregate Sub-Indicator	IMF

[28]International Monetary Fund: *Financial Development Database.*

Financial Markets Index	0-1 (=more financial openness)	Aggregate Sub-Indicator	IMF
Financial Institutions Depth	0-1 (=more financial openness)	Private Sector Credit to GDP, Pension fund assets to GDP, Mutual fund assets to GDP, Insurance premiums (life + non-life) to GDP	IMF
Financial Institutions Access	0-1 (=more financial openness)	Bank branches per 100,000 adults and ATMs per 100,000 adults	IMF
Financial Institutions Efficiency	0-1 (=more financial openness)	Net interest margin, Lending-deposits spread, Non-interest income to total income, Overhead costs to total assets, Return on assets, Return on equity	IMF
Financial Markets Depth	0-1 (=more financial openness)	Stock Market Capitalization to GDP, Stocks traded to GDP, International debt securities of government to GDP, Total debt securities of financial corporation to GDP, Total debt securities of nonfinancial corporation to GDP	IMF
Financial Markets Access	0-1 (=more financial openness)	Based on the percentage of market capitalization outside of top 10 largest companies to proxy access to stock markets, Total number of issuers of debt	IMF
Financial Institutions Efficiency	0-1 (=more financial openness)	Stock market turnover ratio (value traded/stock market capitalization)	IMF
Access to Credit	0-100 (=best)	Strength of credit reporting systems and effectiveness of collateral and bankruptcy laws in facilitating lending	World Bank[29]
Financial market	1-7 (=best)	Aggregate Indicator	WEF[30]
Financial efficiency	1-7 (=best)	Aggregate Sub-Indicator[31]	WEF
Sound banks	1-7 (=best)	In your country, how do you assess the soundness of banks?	WEF

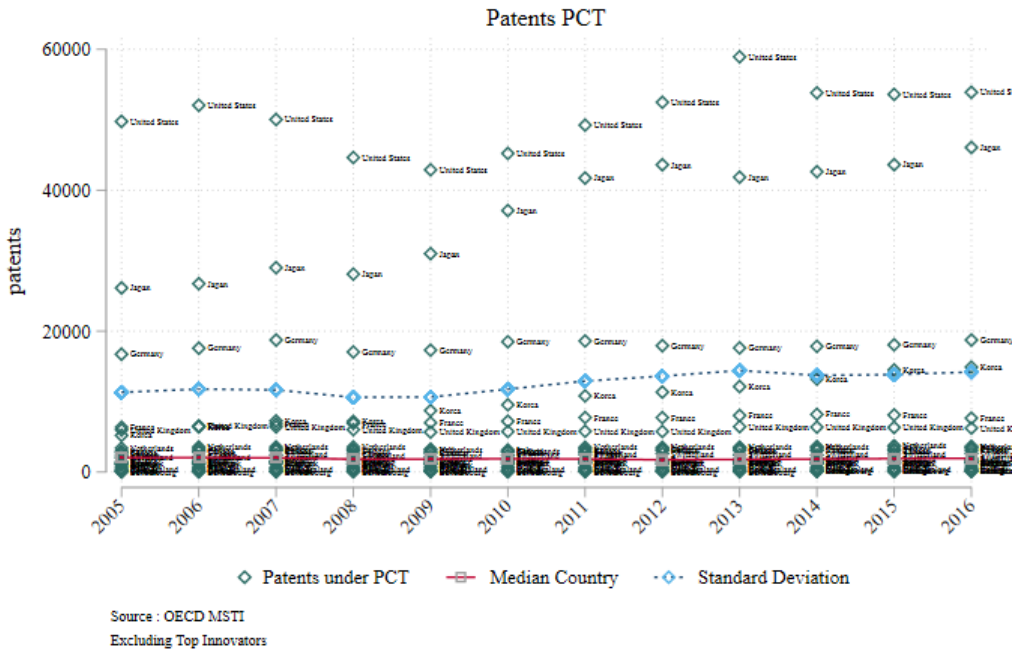
[29]Doing Business Report
[30]World Economic Forum: *Global Competitiveness Report 2017-2018.*
[31]Comprising of: Financial Services Meeting Business Needs, Affordability of Financial Services, Financing through Local Equity Market, Access to loans, Venture Capital Availability.

Venture capital	1-7 (=best)	In your country, how easy is it for start-up entrepreneurs with Innovative but risky projects to obtain equity funding?	WEF
Access to loans	1-7 (=best)	In your country, how easy is it for businesses to obtain a bank loan?	WEF
Sound money	0-10(=best)	Money growth, Standard deviation of inflation, Inflation: most recent year, Freedom to own foreign currency bank accounts	Fraser Institute[32]
Bank Deposits	%GDP	Demand, time and saving deposits in deposit money banks as a share of GDP	World Bank
Private Credit by Banks	%GDP	Private credit by deposit money banks to GD.	World Bank
Liquid Liabilities	% GDP	Ratio of liquid liabilities to GDP	World Bank[33]

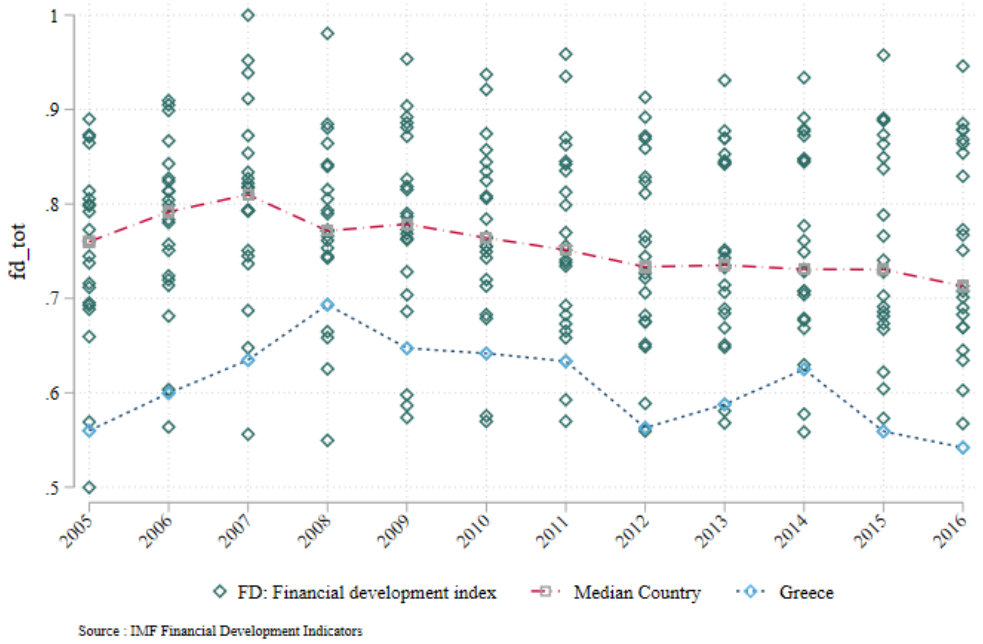
[32]*Economic Freedom Report*
[33]Financial Structure and Development Dataset.

A3. Graphs

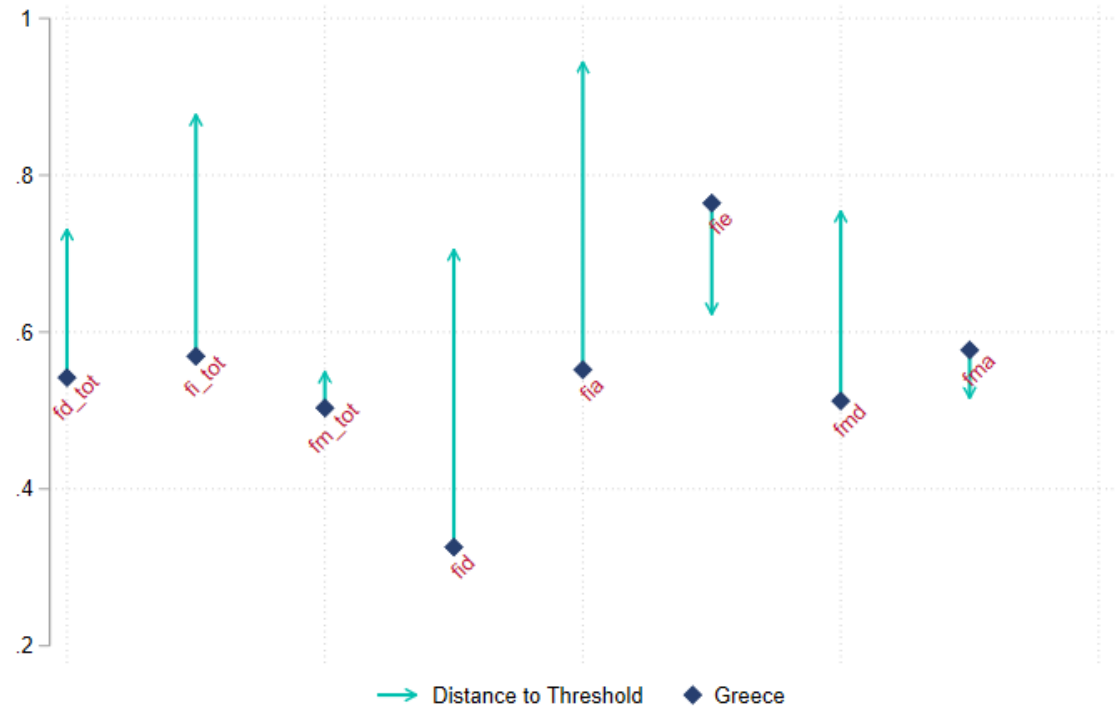
Graph A.1: Evolution of Patents per Country



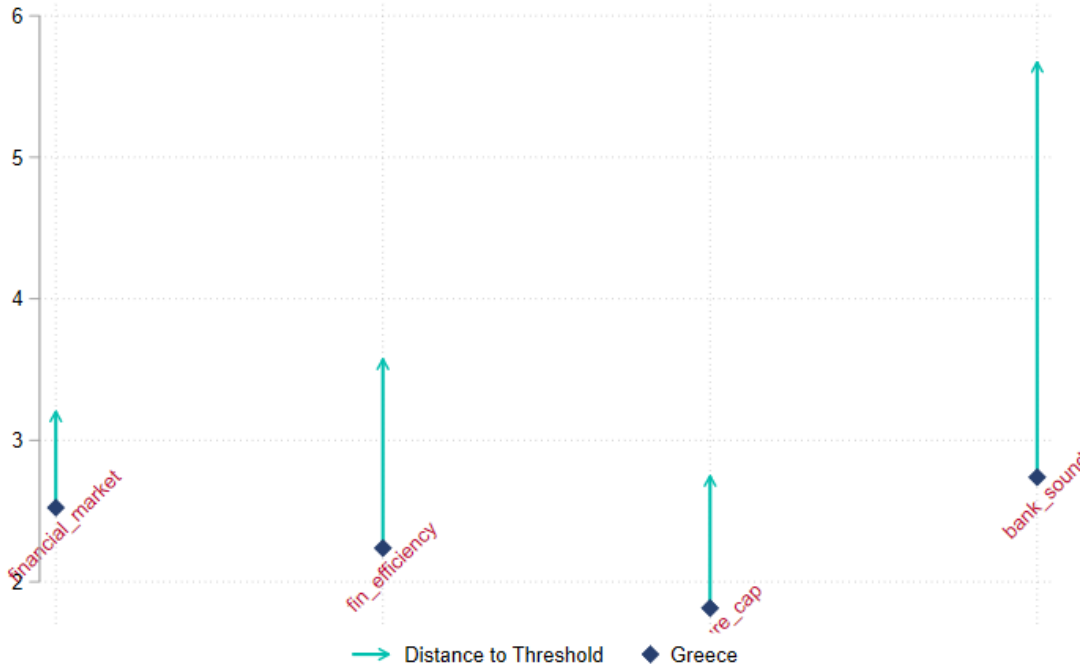
Graph A.2: Financial Development Index



Graph A.3: Financial Indicators for Greece and the Threshold Values



Graph A.4: Financial Indicators for Greece and the Threshold Values



A4. Panel Stationarity tests

	log MFP	log Patents/Pop	log Patents/GDP	log R&D Domestic	log Foreign R&D Trade
Breitung P	0.28	0.49	0.61	0.00	0.00
Breitung Stat	-0.58	-0.02	0.28	-3.92	-3.96
IPS P	0.44	0.02	1.00	0.00	0.00
IPS Stat	-0.15	-2.11	3.27	-47.77	-4.64
Fisher Chi-sq P	0.00	0.03	0.12	0.15	0.16
Fisher Chi-sq Stat	79.11	-1.83	55.05	-1.04	53.13
Fisher Normal P	0.00	0.00	0.00	0.21	0.56
Fisher Normal Stat	-4.17	85.07	-3.15	51.45	0.16
LLC P	1.00	0.00	1.00	0.00	0.00
LLC Stat	5.23	-4.12	4.81	-26.17	-21.90
Hadri Hetero P	0.00	0.00	0.00	0.00	0.00
Hadri Hetero Stat	15.73	13.54	16.61	20.70	9.58
Hadri P	0.00	0.00	0.00	0.00	0.00
Hadri Stat	24.63	21.56	21.74	25.84	13.08
Hadri Serial P	0.00	0.00	0.00	0.00	0.00
Hadri Serial Stat	6.89	7.58	7.52	7.21	3.87
HT P	0.91	0.28	0.33	1.00	0.02
HT Stat	1.34	-0.59	-0.43	2.92	-2.15
CIPS 2 BG lags P	-1.32	-0.06	-1.72	-0.92	-1.51

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