The impact of internationalization on innovation at countries' level.

The role of absorptive capacity

Abstract

This paper analyses the impact of internationalization on the innovation performance of 40 countries. Internationalization variables are represented by outward and inward foreign direct investment, and by imports and exports; innovation is proxied with triadic patent applications. We take account of the influence of absorptive capacity – in both a linear and non-linear form - in the relationship between internationalization and innovation. Our results suggest that outward FDI is positively associated with patenting. Countries with high absorptive capacity benefit more, though there are diminishing returns. We find there is a negative association between inward FDI and patenting in countries with low absorptive capacity where FDI may displace local infant activities and stun further development of related local knowledge. We find support for the view that the innovation performance of countries with low absorptive capacity benefits from imports as well as from exports.

Keywords: Internationalization, Trade, Foreign Direct Investment, Innovation, Patents, Absorptive capacity

JEL classifications: F21, F23, O30, 032, 033, C40

1. Introduction

The aim of this study is to examine the impact of internationalization on the innovation performance of countries and the role of absorptive capacity in the relationship between internationalization and innovation. The modalities of internationalization considered are: exports, imports, inward and outward foreign direct investment (FDI). Most of the work in this area has been done at the micro level facilitated by the availability of several firm-level datasets.[1] There have also been some studies linking innovation to internationalization at the macro level.[2] On the whole, a positive impact of internationalization on innovation is reported. In most of these works whether at micro or macro levels, internationalization is represented by one or two modalities only.

As far as we know there are not many studies of a group of countries together that support the existence of a causal relationship from internationalization to innovation for a variety of internationalization modalities. Filippetti, Frenz and Ietto-Gillies (2011) find strong correlations between innovation and several internationalization modalities in a study of 32 European countries. The study concludes that the association between internationalization and innovation is not spurious but likely to be a sign of a causal relationship between internationalization and innovation. The current study builds on that work by deepening the theoretical, empirical and methodological analyses in various directions. This includes an analysis of the impact of absorptive capacity (AC) on the relationship between internationalization and innovation.

For a sample of 40 countries (see Appendix A), we collected measures of: innovation performance; four modalities of internationalization; control variables; and variables relevant

[1] See Bernard and Jensen, 1995; Bertschek, 1995; Castellani & Zanfei, 2006; Kimura and Kiyota, 2006; MacGarvie, 2006; Wagner, 2007a and b; Damijan and Kostevc, 2010; Damijan et al., 2010; Lileeva and Trefler, 2010.

[2] See Grossman and Helpman, 1991; De Gregorio, 1992; Coe and Helpman, 1995; Borensztein et al. 1998; Keller, 1998; Frankel and Romer, 1999; Funk, 2001; Chang et al., 2013; Connolly, 2003; Keller, 2004; Schneider, 2005.

for arriving at AC estimates. The data covers a period of 19 years from 1990 to 2008. The contribution of the paper is in terms of support for the thesis that the internationalization of a country affects innovation. Specifically, the paper has the following contribute elements: (a) a discussion of theoretical issues around the impact of internationalization on innovation performance with emphasis on the macro level; (b) an analysis of the possible impact of internationalization – exports, imports, outward FDI and inward FDI – on innovation in the context of 40 countries at different levels of development; (c) an analysis and measurement of the role of AC in relation to the impact of internationalization on innovation.

The paper proceeds as follows. The next section discusses theoretical issues – seen in the context of the relevant literature – connected with the relationship between innovation and internationalization. Section 3 discusses the operationalization of the relationship and connected measurement issues. Section 4 is devoted to the methodology. Section 5 presents and discusses the results. Section 6 summarises and concludes.

2. The impact of internationalization on innovation and the role of absorptive capacity

In this section we discuss the main theoretical issues around innovation, internationalization and their relationship. We shall also analyse the role of absorptive capacity (AC) in modifying such a relationship. The issues are considered within the context of relevant research in the field.

2.1 Causality: a two-way process between internationalization and innovation

The causal relationship between innovation and internationalization is a two-way process. At the micro level, more innovative firms can better compete internationally and thus become more involved in foreign activities. However, internationalized firms are not only exposed to stronger competition, they are also exposed to diverse cultures and innovation environments from which they can learn, and, thus, enhance their innovation performance. This, in turn, results in a positive impact on their international competitiveness. Cumulative processes may then be set in motion in which innovation affects competitiveness and internationalization, and the latter impacts on innovation and, thus, on competitiveness. Similar two-way and cumulative processes apply at the macro level.

The impact of innovation on internationalization has been explored in various studies. Posner (1961) and Hufbauer (1966) found that trade performance, and, specifically, exports were related to the technological gap between countries. Posner's work formed the background to Vernon (1966) in which the innovation performance of firms and countries determines their export performance, then, in a time sequence, their foreign direct investment, and, eventually, both their exports and imports propensities. More recent works linking international variables to innovation include Amendola et al. (1993), Cantwell (1994), Cantwell and Sanna Randaccio (1993), Fageberger (1996), and Cassiman and Golovko (2011).

Our interest is in exploring whether there is an opposite relationship: i.e. whether internationalization has a positive impact on innovation. Such a positive relationship implies the following: (a) that there is learning from international activities with effects at both micro and macro levels; (b) that knowledge spills over across countries via international activities; and (c) that the receiving country has the relevant AC to assimilate and develop the knowledge that spills over.

2.2 The impact of internationalization on innovation

In the last couple of decades there have been many studies devoted to unpicking the role of internationalization, via imports, exports or FDI, on innovation. In the relevant literature, innovation has been measured / proxied by a variety of indicators such as productivity or process and product innovation or patents. Productivity is the measure used most frequently.

Productivity growth and productivity premia between exporters and non-exporters have been used to reach conclusions on the impact of *exports* on innovation in several works starting with the seminal research by Bernard and Jensen (1995). However, the relationship between exporting and productivity or innovation in general, could come in a variety of ways. The first one is self-selection: the more productive/innovative firms become exporters. Second, the impact of internationalization on innovation could come about via ex-ante strategic behaviour. Firms that plan to become exporters will invest and innovate in preparation for entering foreign markets. A different, third link can come about via the process of learning-by-exporting (LBE). Firms learn from contacts with customers and competitors and, indeed, the effects of customers' R&D may spillover to their foreign sellers (Funk, 2001). Customers may sometimes suggest changes to the product leading to enhanced knowledge for the seller (Grossman and Helpman, 1991). Wagner (2007a), in a meta-analysis of 54 studies related to 34 countries, finds definite evidence of a positive relationship between exporting and innovation proxied by productivity. The evidence relates to all three types of positive relationship between exports and productivity with the third one, learning-by-exporting, less strong than the other two.[3]

It should also be noted that, a growth in exports is likely to increase the scale of production and to generate economies of scale. This sets in motion a virtuous circle in which innovation leads to exports and, via increased scale, to the adoption of new technologies.

[3] Similar results emerge from Wagner (2007b). De Loecker (2007, 2010) and Manjon et al. (2012) find support for the learning-by-exporting hypothesis when the model allows a role for past exporting experience.

Kaldor (1967: 14) points out the linkages between scale of production and technical change when he writes: "We cannot really separate the effects of economies of large scale which are due to indivisibilities of various kinds (in principle, reversible) from those effects which are due to irreversible improvements in technology associated with a process of expansion." The conclusions and observations of most of the authors cited above – including Kaldor – apply to both micro and macro levels.

Imports facilitate knowledge diffusion across countries in a variety of ways and, in particular, via reverse engineering and via the acquisition of knowledge about the seller's design, production and organizational methods. The relevance of imports for learning is explored in several works. Keller (2004) finds that foreign sources of technology impact on productivity growth. MacGarvie (2006) finds that importing firms are more likely to be influenced by the technology of the country they import from than firms that do not engage in imports from that country. However, imports could also have a negative impact on innovation via the possible negative effect on the scale of domestic production leading to the constraints in the development of local knowledge. Kaldor's remarks above can be applied to a reduction as well as an increase in domestic production due to the effects of trade. In addition, imports may have negative effects on innovation particularly in countries with a poor knowledge and innovation context.[4] Imports may displace not only local infant industries (Chang, 2002) but also local knowledge with negative overall effects particularly if the displacement takes place before any new knowledge acquired from abroad may impact on the country.[5]

Links between FDI, either outward or inward, and innovation are found in several studies. Regarding *inward FDI*, Bertschek (1995), in a sample of German firms, finds that imports and inward FDI have significant positive effects on product and process innovation.

[4] Both Schneider (2005) and Keller (2007)'s results point to low impact of imports on the innovation performance of developing countries.
[5] Several studies have addressed the issue of simultaneous imports and exports and their cumulative effects which could lead to cumulative learning effects (Salomon and Shaver, 2005; Kasahara and Lapham, 2013; Damijan and Kostevic, 2010; Lileeva and Trifler, 2010; Bustos, 2011).

The stronger competition from foreign firms may encourage innovation in domestic firms. Moreover, contact with foreign suppliers may provide access to specialized and superior intermediate and capital goods. Thus, the results of this study may be due to mechanisms linked to strategic behaviour and/or to those linked to learning. At the macro level Borensztein et al. (1998) find a positive relationship between inward FDI and technology diffusion. However, foreign investment is found to be "more productive than domestic investment only when the host country has a minimum threshold of human capital" (p. 117).[6] Nonetheless, negative effects of inward FDI on innovation are also possible via the cumulative mechanisms described above for imports. Lichtenberg and van Pottelsberghe de la Potterie (1996) following an analysis of 13 countries reject the hypothesis that inward FDI supports technology transfer. A negative impact is reported by Schneider (2005), Chang et al. (2013) and Connolly (2003). On the whole, the results are far from clear cut and this is one of the reasons why we shall test the modifying role of absorptive capacity.

There seem to be fewer studies exploring the possible productivity effects of *outward FDI* on the home country. Nonetheless, the self-selection mechanism by exporters – mentioned above - seem to be valid also for this variable and, indeed, in a stronger way (Kimura and Kiyota, 2006). The very productive firms are often involved in FDI as well as in exports. In fact, exports and FDI tend to be complementary (Cantwell, 1994; UNCTAD, 2002, 2013).[7] Market penetration by one modality – exports or FDI – often paves the way for the other modality. On the supply side, sunk costs in the first modality may support the second one[8]. Moreover, outward FDI is likely to lead to opportunities for learning from other countries.

[6] Positive spillover effects of inward FDI are found in De Gregorio (1992); Blomstrom et al. (1999), Castellani and Zanfei (2003, 2006); Javorcik (2004); Poole (2010).
[7] TNCs are indeed responsible for some 80 percent of world trade (UNCTAD, 2013).
[8] The advantage of exploiting sunk costs is also mentioned in the literature on two-way trade (see note 5).

To understand how FDI – whether outward or inward – may lead to knowledge acquisition and transfer we need to briefly look at the organization of transnational companies (TNCs), the institutions responsible for FDI.[9]. Specifically, the organization of TNCs may directly contribute to knowledge acquisition and transfer across border via their double networks. The TNCs operate via networks of internal units – i.e. their set of subsidiaries and HQs – and via external networks. The latter are the networks established by each unit of the TNC and its own suppliers, distributors, customers or local universities and research centres. These two types of networks act as conduit for knowledge transfer: (a) between the TNC's subsidiaries and the local environment in a two-way process, i.e. transfer of knowledge from the local context to the TNC's subsidiary and vice versa; and (b) across countries via the internal networks of the company.[10] The extent to which the TNC's organization facilitates or hinders these knowledge spillover and learning processes partly depends on the degree of centralization in the internal organization of the company (Hedlund and Rolander, 1990) and partly on the degree of embeddedness of the company in the host economy (Granovetter, 1985; Uzzi, 1997). These issues are of great relevance in countries where TNCs and their activities play a major role, be these countries which are home and/or host to TNCs.

The arguments developed in this section – and indeed the literature results we refer to – point to considerable scope for learning via international activities in the case of all the four internationalization modalities we consider. However, there are other important elements that must be taken into account in terms of expected results. First, as pointed out in the discussion of each modality, other processes – over and above the learning process – may be in operation and in particular the following ones. There may be displacement effects which

[9] For a review of wider issues around the globalization of innovation and the role of TNCs in it, see Narula and Zanfei (2006).

[10] See Bartlett and Ghoshal, 1989; Zahra et al., 2000; Castellani and Zanfei 2004, 2006; Frenz and Ietto-Gillies, 2009).

can be particularly relevant in the case of imports and inward FDI. This means that, in countries at low level of development, local knowledge may be displaced before any new acquisition of knowledge has taken place or before synergies between local and foreign knowledge can be found and exploited. There can also be self-selection mechanisms which reinforce the positive effects of learning processes particularly in the case of exports and outward FDI. Finally, we must allow for the fact that the countries' ability to learn vary considerably. To take account of this we now turn to an analysis of the concept of absorptive capacity (AC) and its possible mediating impact on the effects of internationalization on innovation.

2.3 The role of absorptive capacity

For the learning process from international activities to take place and affect innovation performance, two conditions are necessary: there must be spillovers; and the firm, industry, country at the receiving end must possess the necessary absorptive capacity (AC) to capture the spillovers.

There is a large amount of literature on spillover effects including some critical works on the concept and its operationalization (Breschi and Lissoni, 2001). The issue of innovation and technology diffusion across countries has been addressed in several empirical studies. Coe and Helpman (1995) consider whether R&D in country A affects productivity growth in countries with which A has trade relationships.[11] Similar studies stress the role of trade patterns in raising productivity levels (Keller, 2000; Funk, 2001).[12] Others stress the relevance of institutional factors in fostering international R&D spillovers (Coe et al. 2009) or as possible barriers to the absorption of foreign knowledge (Parente and Prescott, 1994; Barbosa and Faria, 2011; Crespo-Cuaresma et al 2004; Rincon-Aznar et al. 2014; Foster-

[11] The positive conclusion of this work is not always corroborated by later ones (Engelbrecht, 1997).
[12] Nonetheless, the role of trade pattern in international R&D spillovers is questioned by the results in Keller (1998).

McGregor et al. 2014). Whether the spillovers are captured or not by the receiver, much depends on the latter's AC.

The AC concept, if not the wording, goes back a very long way. Indeed the concept seems to go back to Dr Samuel Johnson who, according to his biographer, James Boswell (1946 [1791]: p. 227) stated that: "…a man must carry knowledge with him, if he would bring home knowledge". At the macro level, Abramowitz (1986) in a work that uses historical levels and growth of productivity in 16 countries, considers the positive role of social capability – proxied by education levels and variables related to the institutional context – in the catching up rate of different countries. His social capability concept has strong resemblance to what Cohen and Levinthal – C&L - (1989; 1990 and 1994) later referred to as absorptive capacity defined as: "…the firm's ability to identify, assimilate and exploit knowledge from the environment…" (1989: 569). Several studies have since extended and utilized the AC concept following the Cohen and Levinthal work, including Zhara and George (2002) and Lane et al. (2006). All these conceptualizations define AC in terms of qualitative processes.

The AC concept has not been analysed much at the macro level with the notable exceptions of Narula and Marin (2003); Crespo-Quaresma et al. (2004); Rogers (2004) and Mahroum et al. (2008); Rincan-Aznar et al. (2014); Foster-McGregor et al. (2014). How may the level of AC impact on the relationship between internationalization and innovation? The impact may occur because AC enhances the ability to learn, or, to use C&L's words, "to identify, assimilate and exploit" knowledge developed elsewhere. On the whole, we expect AC to have a positive modifying impact regarding the effects of internationalization on innovation through its impact on learning and thus on the potential for knowledge acquisition. However, there are two further elements that must be taken into account. First, the fact that the scope for learning may vary between countries at different levels of development.

Countries at low level of development may learn more because they have more to learn and their catch-up needs are higher. Moreover, the effects of AC may be non-proportional as AC increases (Criscuolo and Narula, 2008). To the extent that the effects are non-linear we expect AC to have different impact in countries at different levels of AC. Specifically, at very high levels of AC, the scope for learning from other countries may diminish. We, therefore, test for non-linear effects of AC. We keep an open mind as to whether any of these two elements apply.

In terms of the modifying impact of AC on each of the four internationalization modalities, we can make the following observations and predictions. Regarding exports we have already mentioned the learning-by-exporting function. A country's level of AC is likely to affect its ability to learn via exports. However, the impact may vary according to the level of AC and thus to the overall level of knowledge development in the country. A country with low AC may have more scope for learning from contacts with customers in foreign countries compared to countries with a more advanced knowledge development.

As regards imports, they create scope for learning from foreign products and contacts with foreign suppliers at all levels of a country's development and AC. However, it is possible that countries with low AC may, again, exhibit more scope for learning from contacts with foreign customers.

Regarding inward FDI, countries with high AC might be able to absorb and utilize knowledge present in the country through FDI better than those with low AC. Synergies may develop between foreign knowledge and local knowledge. However, a displacement effect – particularly for economies with very low AC levels – may not be ruled out: local knowledge may be displaced without – or before – the acquisition of foreign knowledge. On the outward FDI side, investing countries may be able to learn more from the host country if their AC is high. However, non-linear effects of AC are possible.

3. Operationalizing the impact of internationalization on innovation at the macro level

We want to test the proposition that countries' internationalization affects their innovation performance. We work with a sample of 40 countries (listed in Appendix A) which constitute a large spectrum in terms of GDP per capita. All continents, and most regions within them, are represented. Nonetheless, it should be noted that the sample is not representative of the world. Over a third of the countries are from Europe. If Eastern Europe is included, this percentage rises to over 50. In the end, the list of countries was constrained by data availability.

3.1 Measuring innovation performance

Innovation is not an easily measurable concept. Traditionally, four types of measures have been used: (a) input measures such as expenditure on R&D; (b) intermediate output measures such as patents; (c) indirect output measures such as growth rates of productivity; and (d) final output measures related to new products or processes. However, data on this indicator are available only for a limited number of countries and they are few in time. We collected and used data on productivity and patents.

As we saw, many studies rely on *productivity* increases as an indicator of innovative activities. Innovation is, indeed, likely to lead to increase in productivity, though there may be lags. However, not all changes in productivity can be attributed to innovation; the scale of production may impact on productivity (Kaldor 1967).

Patents data are easily available, reliable and comparable across countries though they present sectoral bias as their use is less pronounced in some industries, including many service industries.

We computed results for growth in total factor productivity and labour productivity, for PCT applications and triadic patents, but report results of regressions only for triadic patents.[13] We normalize the patents data via population.

3.2 Measuring internationalization

The main modalities of internationalization are: trade, both imports and exports, and FDI, both inward and outward. FDI and trade are widely available in a comparable form across countries and over time. In the case of outward and inward FDI, we use stock data which are less volatile from year to year compared with flow data. The trade variables are annual flows. We normalize these internationalization variables by GDP. Joint ventures, licencing, franchising and cross-countries outsourcing activities are also likely to contribute to a strong relationship between innovation and internationalization. We do not have reliable and comparable data on them for our sample of countries.[14] We are also aware that the movement of skilled human resources across borders can be a major vehicle for knowledge diffusion (Filippetti et al., 2011; Saxenian, 2006). However, lack of data prevents us from using variables related to this important aspect of internationalization.

3.3 Measuring absorptive capacity

[13] There are three main types of patent statistics. Patents filed with individual countries' patent offices, international patent applications also referred to as Patent Cooperation Treaty (PCT) applications, and triadic patent families. Both PCT applications and triadic patents tend to be preferred over the use of data on the first type because of more reliable comparability across countries. Triadic patent families are patents filed by the same inventor for the same invention at the European, Japanese and US Patent Office. They are recorded as annual counts for the year of the first application. The reference country is the inventor's country of residence. Conversely, PCT applications are patent applications filed with a patent office under the Patent Cooperation Treaty. Triadic patents, with the higher costs incurred due to the parallel applications to three patent offices, tend to capture higher value inventions aimed at international markets (OECD, 2009).The results for the regressions not reported in the paper are available via the journal's website and can be accessed through the 'supplementary data' link.

[14] This should not be a major problem in our study because these activities are likely to give scope for FDI and/or trade which we consider.

We see the level, extension and depth of AC as the result of cumulative processes (Cohen and Levinthal, 1990 and 1994). The knowledge and innovation activities of the past matter for the country's present ability to absorb knowledge and innovation: history matters in innovation (Freeman, 1994). We operationalize the concept of AC via three different sets of macro level indicators. They are related to: (a) the knowledge context; (b) the physical infrastructure that supports connectivity; and (c) the human resources infrastructure.[15] The first of these derives from the accumulation of past knowledge and innovation and is linked to the past behaviour of the firm and non-firm sectors as well as to the knowledge infrastructure. In relation to (a) and (c), Crespo-Cuaresma et al. (2004) find that the spillover from R&D are likely to be higher the higher the receiving country's R&D and education levels. With respect to human resources infrastructure (c) all studies dealing with AC recognize its relevance and many use indicators of it as the only or main AC contributor (Abramowitz, 1986; Borensztein et al. 1998; Roper and Love, 2006; Criscuolo and Narula, 2008). We use the following indicators in the three groups. *Knowledge context* (a): expenditure on R&D; number of scientific articles; number of triadic patents applications. *Physical infrastructure* (b): Internet users. *Human resources infrastructure* (c): enrolment in secondary education; enrolment in tertiary education.

A further development in our conceptualization is that we use both linear and quadratic relationships between AC and innovation. The thinking behind the inclusion of $AC^2_{i,t}$ is to allow for different effects of AC in countries at different stages of AC development. As a country approaches the innovation frontier, the knowledge required to increase innovation becomes more complex, thus, requiring larger increases in AC to provoke similar increases in innovation (Criscuolo and Narula, 2008). With the inclusion of AC^2, and

[15] Further work on AC in terms of theoretical analysis, operationalization and estimates of indicators is in Frenz and Ietto-Gillies (2016).

expecting a negative coefficient, we are testing for diminishing returns of AC in terms of knowledge absorption and innovation.

3.4 Taking account of countries' heterogeneity

We employ the following set of control variables in the regressions: the share of value added in services and the share of employment in agriculture. In addition, we also computed the estimations including a variable that measures the output share in high and medium-high tech manufacturing industries to control for the fact that these sectors, at least traditionally, are most likely to patent. The estimations with high and medium-high tech manufacturing as a control variable are based on fewer observations.

Table 1 provides an overview of all variables, their unit of measurement and source. Descriptive statistics and correlations among the variables are in Appendix B.

Table 1 here

4. Methodology

We shall first introduce two methodologies that we use to take account of AC and then present the model(s) for estimating the relationship between internationalization and innovation.

For the first AC methodology, we group the 40 countries into two mutually exclusive groups using a two-stage clustering technique. The measure of distance is based on all six indicators listed in Table 2. The number of clusters is determined from within the data. The result is two clusters. 22 countries are classed as low and 18 countries as high AC countries (Appendix A). We run regressions of innovation on internationalization and control variables for each of the two clusters separately. The advantage of this clustering methodology – and the reason why we report on it – is that it allows us to use a wider range of variables (Table 2) in measuring AC; moreover, we have enough observations to be able to cumulate data in accordance with the first of our desired development of the AC concept. The main drawback of the clustering of countries into two mutually exclusive groups is that it substantially lowers the number of countries, and, thus, of observations in the two sets of individual regressions. This affects the reliability of the estimates as reported in Appendix C.

For this reason we develop and apply an alternative, second methodology, which allows us to regress all the 40 countries together while taking into account the role of AC. We develop a single, continuous AC variable to be used in the regressions. This AC variable is used as a modifying variable for each of the four internationalization variables. For this part of the methodology we need to have indicators for the same number of years as the variables in the regressions. This has two effects on our choice of indicators. Firstly, we cannot use cumulative values, as we do in the first methodology because it would greatly reduce the number of years. Secondly, it limits the number of indicators we can use from those listed in Table 2.[16] The reduced list contains scientific articles, Internet users, and enrolments in secondary and tertiary education (see Table 3).[17]

The values of the AC variable are factor scores. Table 4 gives the factor loadings, i.e. the correlations of each individual indicator with the factor, or latent concept, AC. The indicator 'scientific articles' has a 0.57 correlation with AC. Enrolments in secondary education has a very small loading. This is not entirely surprising. It is an indicator denoting skills at too basic a level to impact on AC. We save the scores of AC for each country over the period 1990 to 2008 and use them in the regressions.

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[16] Appendix A provides the values by country for the AC indicators in Tables 1 and 2 (as well as the grouping of countries in two clusters of high and low AC countries as in methodology 1).

[17] We also compute the AC variable with an additional indicator, R&D expenditure. R&D is available over a maximum of 12 instead of the 19 years in our dataset. The results – not presented in the paper – are highly similar to those without the R&D variable and which are presented in the paper.

Tables 2, 3 and 4 here

We now turn to the models linking innovation and internationalization. The basic model relates to our second methodology for taking account of AC. The results are presented in column 1 of Table 5 and Appendix C for the two AC clusters. The model can be described as follows:

$$\text{Innovation}_{i,t} = \beta_0 + \beta_1 \text{Innovation}_{i,t-1} + \beta_2 \text{Internationalization}_{i,t} + \beta_3 \text{AC}_{i,t} + \beta_4 \text{AC}^2_{i,t} + \beta_5 \text{X}_{i,t} + a_t + u_{i,t} \quad \text{[I]}$$

$\text{Innovation}_{i,t}$ is the number of triadic patent applications filed by country i in year t. $\text{Innovation}_{i,t-1}$ on the right hand side is the number of patents in the previous period. The lagged dependent variable is included because most innovation activities are cumulative and countries engage in innovation in a continuous, persistent way by building on and improving previous innovations (e.g. Cefis and Orsenigo 2001).

$\text{Internationalization}_{i,t}$ is a vector that combines our four independent variables related to internationalization: countries' FDI outward and inwards stocks and exports and imports. We include both $\text{AC}_{i,t}$ and $\text{AC}^2_{i,t}$ for the reasons explained in Sub-sections 2.3 and 3.3. $\text{X}_{i,t}$ is a vector of control variables. a_t are year dummies included to account for any shocks and to remove spurious changes in innovation rates linked to business cycles; and $u_{i,t}$ the usual error terms.

From this equation the following problems arise: (a) the inclusion of the lagged dependent variable introduces a problem of autocorrelation; (b) outward FDI and exports are endogenous independent variables; and (c) time-invariant country characteristics may be correlated with the explanatory variables. In this scenario the literature proposes to use a first difference transformation that eliminates the country specific fixed effects, and to instrument the lagged dependent variables as well as the endogenous regressors from within the dataset using past levels of variables (Anderson and Hsaio, 1982; Arellano and Bond, 1991). The dynamic panel regression is implemented using Stata's xtabond2 command (Roodman, 2009). Xtabond2 tests for exogeneity of the instruments and autocorrelation.

The second methodology for taking account of AC involves the use of a continuous AC variable constructed through factor analysis, which is reported in Table 4. This continuous AC variable is used as a modifying variable in the relationship between innovation and internationalization. A modifying variable changes the direction and/or strength of the relationship between a dependent and independent variable. The resulting model can be described as follows:

$$\text{Innovation}_{i,t} = \beta_0 + \beta_1 \text{Innovation}_{i,t-1} + \beta_2 \text{Internationalization}_{i,t} + \beta_3 \text{AC}_{i,t} + \beta_4 \text{AC}^2_{i,t} + \beta_5 \text{Internationalization}_{i,t} * \text{AC}_{i,t} + \beta_6 \text{Internationalization}_{i,t} * \text{AC}^2_{i,t} + \beta_7 X_{i,t} + a_t + u_{i,t} \qquad \text{[II]}$$

In this second equation, $\text{Internationalization}_{i,t} * \text{AC}_{i,t}$ and $\text{Internationalization}_{i,t} * \text{AC}^2_{i,t}$ are the interaction terms between the four internationalization variables and the AC variable (see Table 5 columns 2-5). A positive and significant coefficient of the interaction between AC and, for example, inward FDI suggests that the higher a country's AC the better able the country is to reap innovation benefits from inward FDI. If this is then coupled with a negative coefficient for $\text{Internationalization}_{i,t} * \text{AC}^2_{i,t}$, it further suggests that, while the positive impact of inward FDI increases with AC, the returns for each additional unit of AC decrease. We include the interaction terms one at a time to avoid correlations between the interaction terms affecting results.

We report the coefficients of the interaction terms also in graphical form. For the graphs the coefficients of the internationalization variables are calculated for all values of AC. This enables a much richer interpretation of the modifying role of AC as explained in Brambor et al. (2006).

5. Results

Our main regression results are presented in Table 5. Before we comment on them we report the following background work. We computed regressions with a total of five dependent variables that proxy the innovation performance of countries: triadic patent applications; PCT applications; level as well as growth in total factor productivity and labour productivity. The results using PCT applications are similar to those of triadic patents reported in Table 5. We found less significant and consistent results when we used productivity as the dependent variable. This did not come as a surprise for the reasons elaborated on in Section 2.[18]

In the following we discuss results for triadic patents only. In Table 5 the results are grouped into five columns. The first column gives the results for regressions without the modifying role of AC and AC^2. Columns 2 to 5 give results that take account of AC and AC^2 in relation to different internationalization variables.

Table 5 here

[18] The regressions with the alternative dependent variables are not robust. We further computed regressions with an additional sector control. Results are similar to those reported in Table 5. On the whole they are less significant, which could be attributed to the much lower number of observations. Finally, we used an alternative AC variable that takes into account countries' R&D. This variable is a more comprehensive measure of AC. The results are highly similar to the once reported here. All the results of the alternative regressions not reported are available via the journals website, and can be accessed through the 'supplementary data' link.

We start by discussing the first column related to model [I]. We find a positive association between outward FDI, exports and patenting, in line with our expectations discussed in Section 2.2. We find a negative association between inward FDI, imports and patenting. In Section 2.2 we argued that both inward FDI and imports might have negative effects particularly in industries and countries with a poor knowledge and innovation context, and, thus, with low AC. FDI may displace local infant knowledge and stun its further development. This model [I] was estimated also separately for two clusters; high and low AC countries. The results are not significant and are reported in Appendix C.

In Columns 2 to 5 of Table 5 - and additionally in Figures 1 to 4 below – we report results for our basic model relating innovation to internationalization allowing for a modifying effect of AC on the four internationalization variables (methodology 2). We first interpret results for *outward FDI.* Column 2 shows (a) a negative coefficient for outward FDI, (b) a positive coefficient for outward FDI *AC, and (c) again a negative coefficient for outward FDI *AC^2. From this we know that (a) where AC is zero (zero is the average score of the standardised AC variable) the coefficient of outward FDI is negative and takes a value of b=-9.87 ($p<0.01$). (b) The positive interaction with AC (b=32.6; $p<0.01$) suggests that, as a country's AC increases, so do its innovation benefits from outward FDI. In other words, the higher a country's AC the greater the impact of outward FDI on innovation. (c) From the negative coefficient of outward FDI *AC^2 (b=-13.3; $p<0.01$) we know that the modifying role of AC is non-linear, with diminishing returns on increasing AC. This modifying role of AC is visible in much greater detail in Figure 1 that plots the size of the coefficients of outward FDI at all levels of AC.

Figure 1 here

Figure 1 shows that, in order to benefit in terms of innovation from outward FDI, countries require an above average AC score. It further shows that, while the modifying role of AC remains positive up to the maximum value of AC (AC_{max}=2), the benefits that countries reap from increases in AC declines as AC reaches its maximum. In line with our expectations this suggests that countries require a certain threshold of AC to benefit from outward FDI, and, further, that the knowledge diffusion, absorption and translation into innovations becomes more difficult because the required knowledge increases in complexity.

In Column 3 of Table 5, and in Figure 2, we test the modifying role of AC in the relationship between *inward FDI* and innovation. We find that (a) at average AC the coefficient for inward FDI is negative ($b=-14.8$; $p<0.01$). (b) That the interaction with AC is positive ($b=11.10$; $p<0.01$). (c) That the coefficient for inward FDI $*AC^2$ is not significant. We interpret this to mean that countries require above average AC to benefit from inward FDI. The greater their AC becomes, the greater the impact of inward FDI on innovation continues to become (in a linear way). Figure 2 reveals this further by plotting the coefficients of inward FDI on innovation for all different levels of AC. At average levels of AC the coefficient is negative, but at the high end of the AC spectrum, this coefficient becomes positive. This is consistent with our view that, at low AC levels, FDI may displace local knowledge.

Figure 2 here

For *exports* (column 4, Table 5) we find that (a) the effect on innovation at average values of AC is negative ($b=-9.75$; $p<0.01$). (b) The interaction with AC is negative ($b=-24.9$; $p<0.01$). (c) No support for a curvilinear relationship. Figure 3 reveals that it is countries at the very low end of the AC spectrum that gain innovation benefits from exporting. With increases in AC this learning benefits for innovation decline steadily: over half of countries do not benefit, in terms of innovation, through their overall exporting activities. The countries with low AC may be the ones where domestic suppliers (i.e. exporters) are more likely to modify products at the request of customers and thus may learn through this process. This interpretation is in line with the results in Grossman and Helpman, 1991 as discussed in Section 2.

Figure 3 here

For *imports* (column 5, Table 5) our regression suggests that: (a) the coefficient is near zero at average AC (b=-4.01; p<0.10); (b) with AC the role of imports declines (b=-22.3; p<0.01); (c) AC, however, has increasing returns (b=8.98; p<0.01). What this means for the role of AC is best described with Figure 4.

Figure 4 here

While a country is at the low AC spectrum its import volumes predict a positive link with innovation. This relationship is significant from minimum scores of AC to almost average AC scores. At average levels and higher, the relationship becomes negative. In other words, high AC countries do not gain innovation benefits via imports.

In both cases, exports and imports, but specifically in the case of imports, countries with low AC reap innovation benefits. One interpretation could be that countries with low AC, which are also countries with lower levels of productivity and innovation, may learn more via importing and via exporting activities because the scope for learning is higher than for countries at high levels of AC.

6. Summary and conclusions

The main purpose of the study is to assess the impact of internationalization on countries' innovation performance. Most studies that consider the impact of international variables on innovation are conducted at the micro level. Our study is at the macro level and, unlike previous studies; we take account of possible spillover effects and of the ability of firms, sectors and countries to capture them through considering countries' absorptive capacity (AC). We operationalize AC in terms of the following three elements all considered cumulatively: knowledge context (R&D, scientific articles; past patenting activity); physical infrastructure (Internet users); and human resources infrastructure (enrolments in secondary and tertiary education). Moreover, we test for possible non-linear effects of AC.

A sample of 40 countries is selected. Innovation performance is proxied by variables related to patenting activity and to productivity levels and growth. The results of regressions with productivity variables are less significant and consistent and are not reported. Internationalization variables relate to inward and outward FDI and to exports and imports. Several control variables are used to take account of diversity between countries.

The overall conclusions on our results can thus be summarized.

- Outward FDI is positively associated with innovation. The knowledge and learning benefits countries reap from outward FDI increases with the level of AC of a country. There are, however, diminishing returns to the role of AC; i.e. the scope for learning decreases for countries with high AC.

- High AC countries benefit from inward FDI. These benefits do not extend to countries with low AC levels. We see in these results a possible displacement effect taking place in countries with low AC.
- There is support for the learning-by-exporting hypothesis for the low AC countries. Conversely, high AC countries do not appear to benefit from exporting in terms of knowledge and innovation acquisition.
- Similarly, we find support for the hypothesis that low AC countries reap benefits from imports.

In both the case of imports and exports it appears that countries where the scope for learning is higher – low AC countries – benefit more from internationalization.

There are many limitations to a study of this sort. Firstly, limitations on the side of the dependent variables: our main proxy for innovation performance, patent applications only partially captures innovation performance.

Secondly, there are also limitations deriving from the independent variables. Data availability has constrained our analysis to a consideration of FDI and trade. Other major elements of internationalization such as the cross-country movements of human resources could not be used for lack of data.

Thirdly, there are limitations also on the side of the control variables. The countries in our sample are very heterogeneous. We try to account for this via our control variables and via the range and context of indicators of AC. Data limitations mean that we may only have succeeded partially in this endeavour.

Fourthly, data availability led also to limitations on our operationalization of the AC. We believe that AC is better operationalized in terms of sets of indicators that take account of the physical, social, human and knowledge infrastructures all considered in terms of stock/cumulative values. However, limitations on the number of observations prevented us from applying this methodology in full. The alternative methodology we applied – via modifying variables – is technically good but we were limited in the number of indicators of AC we could use and we had to use them as flow rather than as cumulative/stock values.

We were always aware that a study of this sort at the macro level would present serious problems. However, the possible impact of internationalization on innovation has relevant implications for macro policy. For this reason we wanted to try and overcome them, or at least take steps in that direction. Our results warrant the effort. No doubt more needs to be done.

From our analysis and results of the combined impact of AC and internationalization the following policy implications derive. FDI contributes to innovation, but mainly, and particularly in the case of countries endowed with AC. In other words, countries who have, shall receive i.e. rip more benefits via learning. Those countries that want to join the league of receivers of knowledge and innovation from FDI, should invest in elements of AC such as – at the basic level – relevant human resources, physical infrastructure, R&D. Pasinetti argues that: "…the primary source of international gains is not mobility of goods, but mobility of knowledge….International learning must therefore remain, for any country, the major and primary aim." (1981, p. 271). In international relations he therefore advocates "…a shift of focus in our attention from the narrow subject of international trade to the basic problem of lack of international mobility of technical knowledge". (1981, p. 274). Pasinetti's focus is trade, while our study includes also inward and outward FDI. However, his overall conclusion is consistent with our results on the impact of internationalization on innovation. There are policy implications from his conclusions and our findings. If the primary element of gain in international relation is knowledge and innovation, then mobility of knowledge must take priority in policy, whatever its channel, be it trade or FDI or mobility of skilled labour. These conclusions may also have implications for the restriction of knowledge flows.

Legal or policy frameworks that inhibit the dissemination of knowledge may be a hindrance to advancement in both developed and developing economies. This conclusion is supported by the empirical results in Barbosa and Foria (2011) who write: “It appears that intellectual property protection is hindering innovation across EU industries.” (p. 1167).[19] Moreover, in his history-based study, Chang (2002: ch. 3B) highlights how the golden period for the development of the current advanced countries was characterized by very imperfect laws on intellectual property rights (see also Archibugi and Filippetti, 2010).

[19] However, Coe et al. (2009) in their study of the impact of institutions on international R&D spillovers, find that patents protection is associated with high levels of productivity.

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Tables and figures for the text

Table 1 Dependent, independent and control variables used in the regressions

Variable	***Variable description***	***Source***
Dependent variables		
Triadic applications	Number of triadic patents per million people	Organisation for Economic Cooperation and Development: Main Science and Technology Indicators
PCT applications	Number of patents filed under the patent cooperation treaty per million people	World Intellectual Property Organization: Statistics on the PCT system
Total factor productivity	Total factor productivity at constant national prices (2005=1)	Penn World Tables. Groningen Growth and Development Centre
Change in total factor productivity	Annual change in total factor productivity at constant national prices (2005=1)	Penn World Tables. Groningen Growth and Development Centre
Labour productivity	Labour productivity. GDP per person employed	World Bank. World Development Indicators
Independent variables		
Outward FDI	Foreign direct investment outward stock as a percentage of GDP	The World Bank's World: Development Indicator
Inward FDI	Foreign direct investment inward stock as a percentage of GDP	The World Bank's World: Development Indicator
Exports	Exports as a percentage of GDP	The World Bank's World: Development Indicator
Imports	Imports as a percentage of GDP	The World Bank's World: Development Indicator
Control variables		
Scientific articles	Number of scientific articles per million people	The World Bank's World: Development Indicator
Internet users	Number of Internet users per thousand people	The World Bank's World: Development Indicator
Services intensity	Value added in services over value added in manufacturing	World Bank. World Development: Indicators.
Employment in agriculture	Employment in agriculture expressed as a proportion of the labour force	United Nations' Conference on Trade and Development: UNCTADstat
High and medium-high tech manufacturing	Output in high and medium-high tech manufacturing as a percentage of total output in manufacturing	Organisation for Economic Cooperation and Development: STructural ANalysis database

Note: GDP is measured at current prices and using current exchange rates.

Table 2 Indicators feeding into the absorptive capacity grouping variable (methodology 1)

Variable	***Variable description***	***Source***
Cumulative R&D	Sum of RD expenditure in available years over sum of GDP for the same years. Years from 1996 to 2006	World Bank. World Development Indicators
Cumulative scientific articles	Cumulative scientific articles per million people The smallest number of observations in a country is 14, the largest 17. We sum and then multiply 14/(number of years available). Years from 1990 to 2006	World Bank. World Development Indicators
Cumulative Triadic applications	Cumulative Triadic applications per million people from 1990 to 2006	Organisation for Economic Cooperation and Development: Main Science and Technology Indicators
Average Internet users	Internet users per 1,000 people averaged from 1990 to 2006.	World Bank. World Development Indicators
Cumulative enrolment in secondary education	Sum of enrolment in secondary education over sum of population for the same years. 1990 to 2006	World Bank. World Development Indicators
Cumulative enrolment in tertiary education	Sum of enrolment in tertiary education over sum of population for the same years. 1990 to 2006	World Bank. World Development Indicators

Table 3 Indicators feeding into the continuous absorptive capacity variable (methodology 2)

Variable	***Variable description***
Scientific articles	Number of scientific articles per million people
Internet users	Internet users per 1,000 people
Enrolment in secondary education	Enrolment in secondary education over population
Enrolment in tertiary education	Sum of enrolment in tertiary education over population
R&D	R&D expenditure as a percentage of GDP

Note: Data source is the World Bank: World Development Indicators.

Table 4 Computing continuous absorptive capacity variables through factor analyses (methodology 2)

Indicators feeding into the factor analysis	***Factor: absorptive capacity***	
Scientific articles	0.57	0.85
Internet	0.68	0.59
Secondary education	0.06	-0.07
Tertiary education	0.61	0.33
R&D		0.83

Note: This table reports the rotated factor matrices; the rotation method is varimax; the two factor analyses – one with R&D and one without – provide only one factor with Eigenvalues greater than 1.

Table 5 Dynamic panel regressions examining the impact of internationalization on innovation and the modifying role of absorptive capacity in 40 countries between 1990 and 2008

	Triadic patents				
	(1)	(2)	(3)	(4)	(5)
Lagged triadic patents	0.83**	0.89**	0.86**	0.81**	0.83**
	(0.013)	(0.017)	(0.022)	(0.028)	(0.029)
Outward FDI	9.66**	-9.87**	5.58**	17.4**	13.8**
	(0.71)	(2.42)	(1.59)	(1.37)	(2.19)
Inward FDI	-12.2**	-6.87**	-14.8**	-11.5**	-11.9**
	(0.43)	(0.64)	(0.70)	(1.22)	(1.69)
Exports	9.20**	5.31*	16.0**	-9.75**	0.70
	(1.86)	(2.08)	(2.26)	(3.44)	(2.20)
Imports	-8.58**	-8.28**	-14.4**	9.69**	-4.01+
	(1.82)	(2.04)	(2.18)	(3.03)	(2.33)
AC	4.58**	3.11**	1.89*	15.6**	11.8**
	(0.41)	(0.49)	(0.86)	(2.38)	(1.92)
AC^2	-2.47**	-3.27**	-4.43**	-3.45*	-5.49**
	(0.13)	(0.45)	(0.40)	(1.41)	(1.09)
outward FDI * AC		32.6**			
		(3.96)			
outward FDI * AC^2		-13.3**			
		(2.29)			
inward IFDI * AC			11.1**		
			(2.37)		
inward IFDI * AC^2			0.71		
			(1.29)		
Exports * AC				-24.9**	
				(4.36)	
Exports * AC^2				0.97	
				(3.07)	
Imports * AC					-22.3**
					(4.08)
Imports * AC^2					8.98**
					(3.13)
Services intensity	-0.27	-0.75	-0.001	-1.99*	-1.20+
	(0.44)	(0.47)	(0.66)	(0.80)	(0.63)
Employment in agriculture	6.49**	4.72+	7.37*	20.9**	17.1**
	(1.95)	(2.76)	(2.74)	(5.86)	(5.22)
Constant	5.49**	7.78**	4.96*	9.19**	7.70**
	(0.83)	(0.96)	(1.91)	(1.90)	(1.57)
Observations	497	497	497	497	497
Number of countries	40	40	40	40	40
Sargan test (p-value)	0.45	0.69	0.48	0.57	0.6
AR (1)	0.05	0.05	0.06	0.06	0.06
AR (2)	0.12	0.11	0.12	0.13	0.12

Note: Estimation method is GMM using xtabond2. Outward FDI and exports are treated as endogenous.
** $p<0.01$, * $p<0.05$, + $p<0.1$
AC = Absorptive Capacity; FDI = Foreign Direct Investment
Column 1: results without the modifying role of AC; columns 2-5 allow for the modifying role of AC. Column 2 outward FDI; column 3 inward FDI; column 4 exports; and column 5 imports.

Figure 1 Coefficient of outward foreign direct investment as absorptive capacity changes

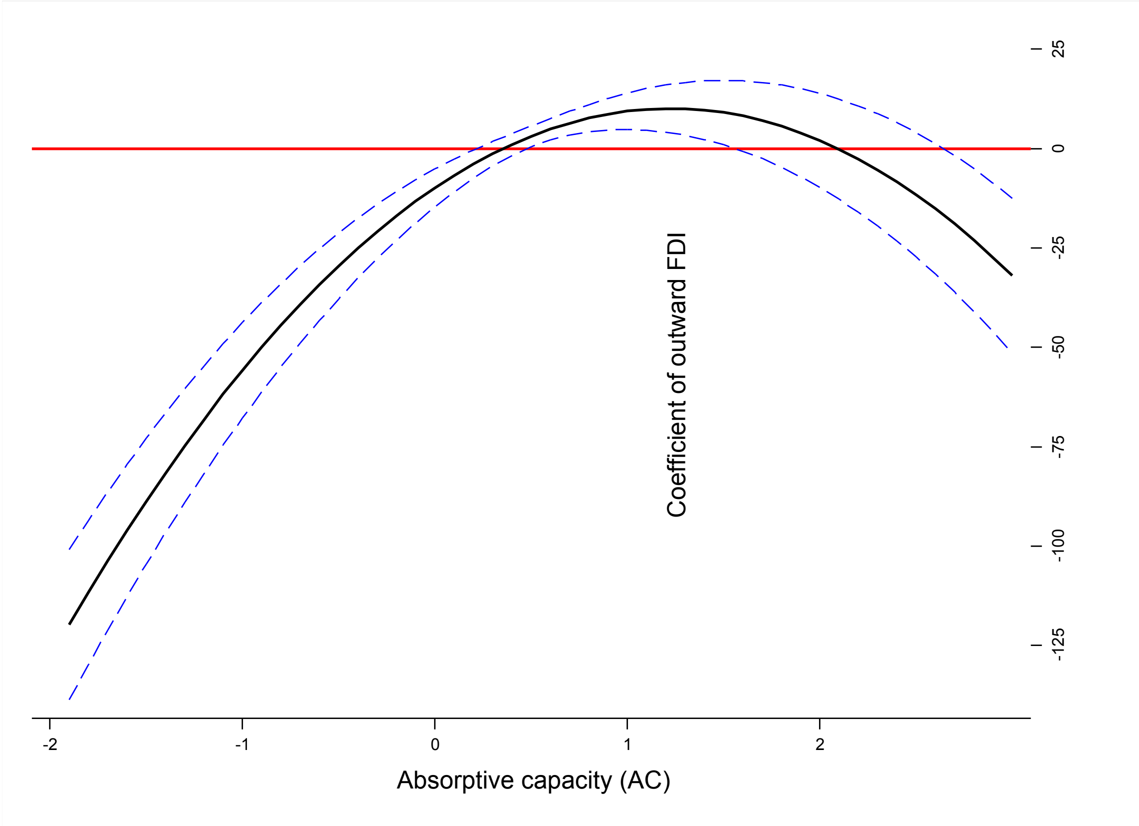


Figure 2 Coefficient of inward foreign direct investment as absorptive capacity changes

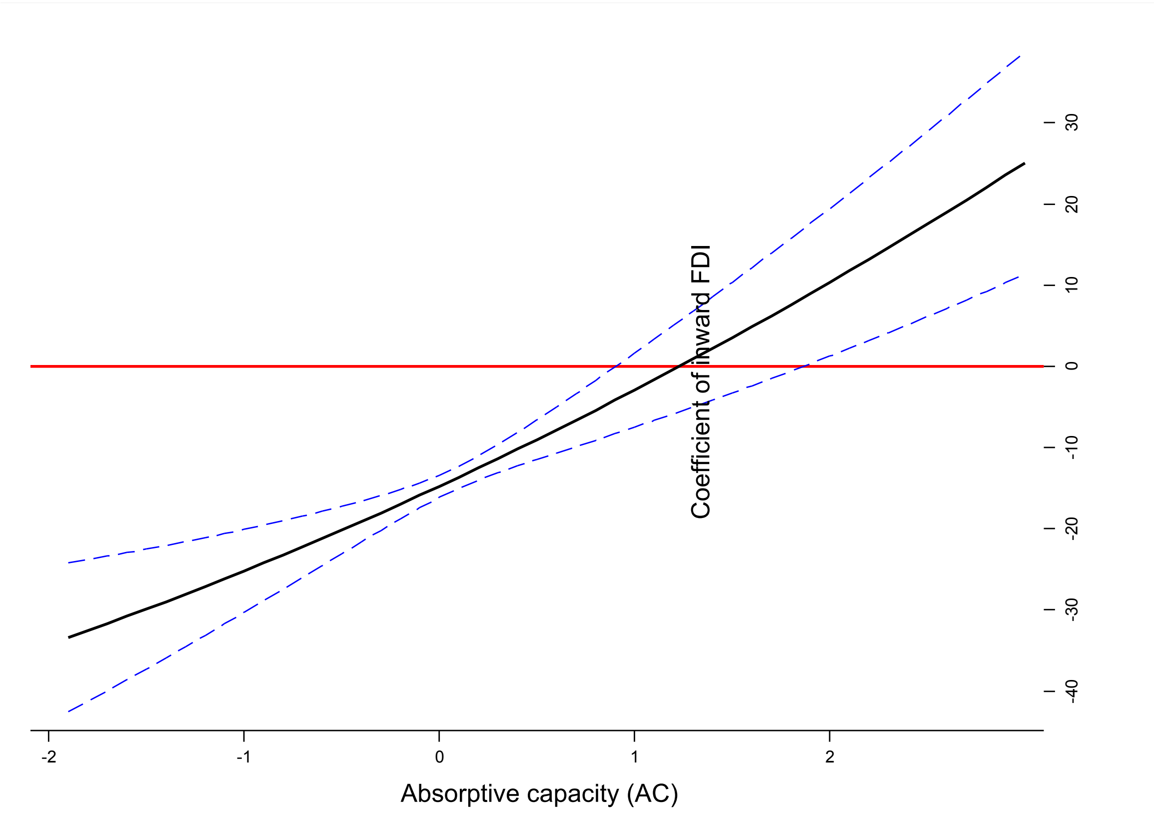


Figure 3 Coefficient of exports as absorptive capacity changes

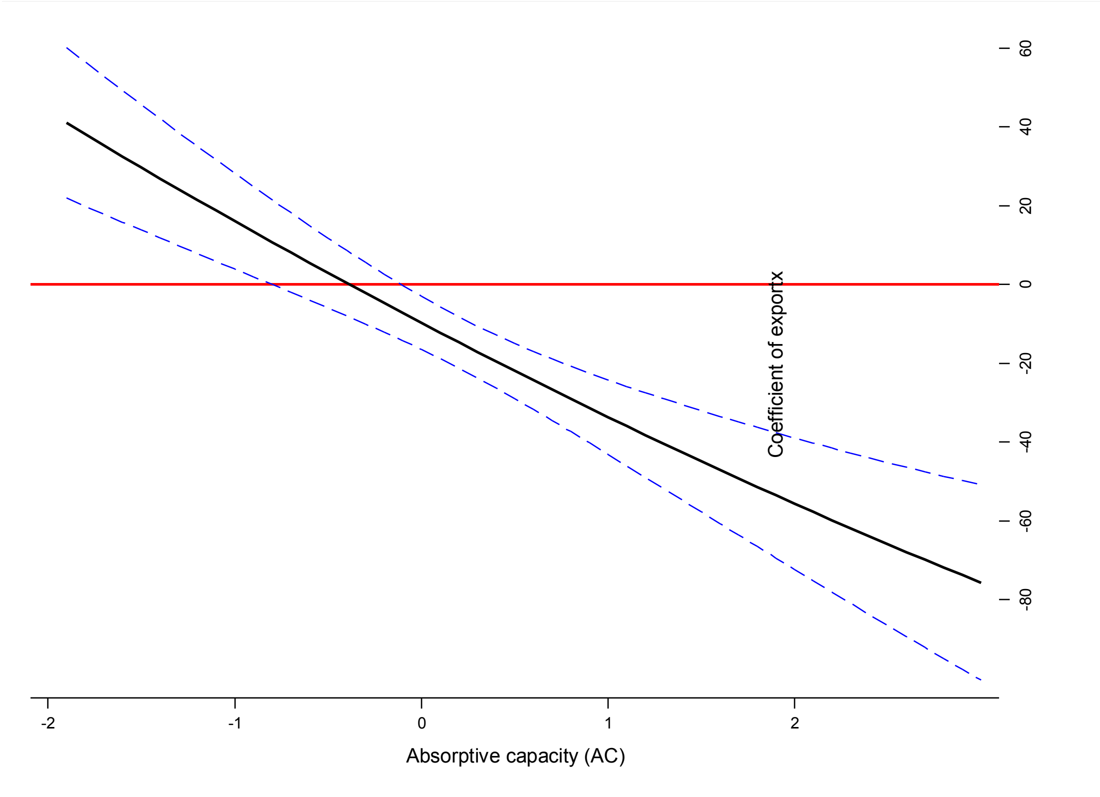
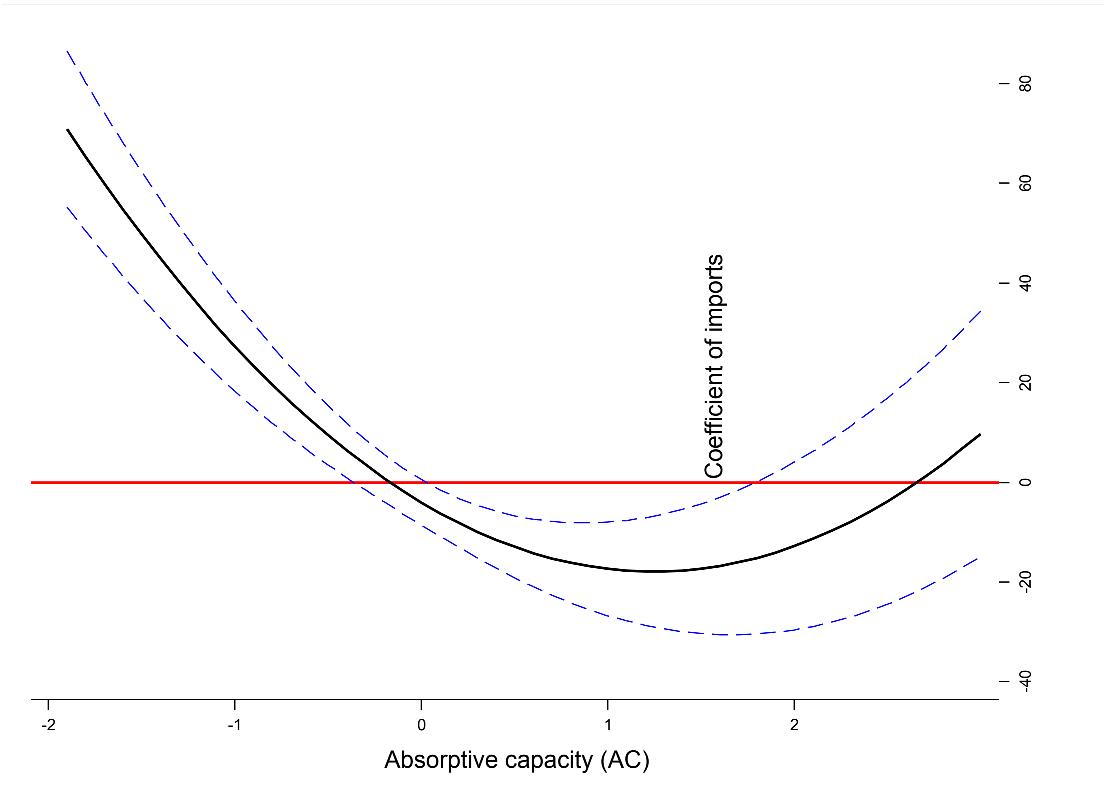


Figure 4 Coefficient of imports as absorptive capacity changes



Appendix A Accounting for the role of absorptive capacity by clustering countries

Table A.1 Clustering countries into two, mutually exclusive high and low absorptive capacity groups

Country	*AC cluster*	*Cum. R&D*	*Cum. articles*	*Cum. triadic patents*	*Average Internet users*	*Cum. sec. education*	*Cum. tertiary education*	*Average GDP per capita*
Argentina	low	1.3	30,059	2	124	0.084	0.048	6,222
Brazil	low	2.9	67,423	3	132	0.12	0.016	3,819
Bulgaria	low	1.5	12,799	4	130	0.092	0.028	1,955
China	low	3	206,143	2	59	0.058	0.007	892
Czech Republic	low	3.8	34,877	16	248	0.109	0.022	6,571
Estonia	low	2.6	3,640	22	410	0.086	0.032	5,063
Greece	low	1.7	33,183	9	165	0.073	0.039	13,820
Hungary	low	2.5	26,928	39	233	0.106	0.026	5,806
India	low	2.2	137,881	1	17	0.073	0.009	466
Ireland	low	3.7	17,646	159	296	0.093	0.038	26,296
Italy	low	3.3	247,107	125	267	0.082	0.031	22,517
Lithuania	low	2	3,209	12	216	0.112	0.033	3,794
Mexico	low	1.2	30,969	1	118	0.09	0.019	5,401
Poland	low	1.8	64,942	4	221	0.093	0.034	4,413
Portugal	low	2.5	19,199	7	240	0.077	0.031	12,152
Romania	low	1.4	9,773	1	101	0.104	0.02	2,126
Russian Federation	low	3.3	208,791	4	92	0.096	0.043	3,089
Slovak Republic	low	1.9	12,345	6	315	0.123	0.024	5,887
Slovenia	low	4.3	8,565	65	316	0.104	0.035	11,088
South Africa	low	2.5	30,425	7	65	0.094	0.014	3,601
Spain	low	3	162,531	44	282	0.095	0.04	17,003
Turkey	low	1.6	40,126	2	111	0.084	0.022	3,797
Australia	high	5.1	173,763	169	540	0.122	0.047	22,150
Austria	high	6.4	48,801	429	424	0.096	0.029	27,564
Belgium	high	5.7	69,657	367	423	0.096	0.035	26,727
Canada	high	5.7	302,869	192	549	0.083	0.056	23,961
Denmark	high	7	58,340	502	587	0.085	0.035	33,916
Finland	high	9.7	54,886	654	564	0.089	0.047	26,916
France	high	6.4	370,511	390	316	0.099	0.034	26,461
Germany	high	7.3	508,804	712	462	0.1	0.026	27,098
Iceland	high	7.8	1,912	182	675	0.114	0.034	32,292
Japan	high	9.4	646,675	1071	461	0.073	0.029	33,446
Korea, Rep.	high	7.7	90,019	339	532	0.092	0.056	11,195
Netherlands	high	5.5	155,032	657	597	0.091	0.032	27,520
New Zealand	high	3.4	33,490	130	553	0.115	0.047	16,853
Norway	high	4.8	37,980	236	553	0.086	0.041	40,050
Sweden	high	11.1	120,650	831	651	0.089	0.035	30,796
Switzerland	high	8.1	97,242	1144	565	0.079	0.023	40,294
United Kingdom	high	5.4	575,629	276	482	0.087	0.032	25,438
United States	high	8	2,524,387	506	557	0.08	0.054	31,797
Average Total		4.7	175641	240	341	0.093	0.032	16877

Note: AC = Absorptive Capacity

Appendix B Descriptive statistics and correlations

Table B.1 Descriptive statistics of relevant variables

	N	Mean	SD	Min	Max
Dependent variable					
Triadic patent applications	798	21.34	28.86	0.00	120.00
Independent variables					
Outward foreign direct investment	768	0.20	0.26	0.00	1.58
Inward foreign direct investment	770	0.27	0.29	0.00	1.90
Exports	743	0.38	0.26	0.07	2.43
Imports	737	0.31	0.23	0.03	1.67
Control variables					
Services intensity	730	2.09	0.62	0.53	3.83
Employment in agriculture	774	0.12	0.14	0.00	0.74
High and medium-high tech manufacturing	397	38.13	11.21	9.00	61.00
Absorptive capacity variables (methodology 2)					
Absorptive capacity	560	0.00	0.79	-1.45	2.01
Absorptive capacity incl. R&D indicator	339	0.00	0.89	-1.16	2.26
Absorptive capacity indicators					
Scientific articles	698	397.71	320.59	1.33	1181.11
Internet users	732	205.37	244.14	0.00	887.71
Enrolment in secondary education	703	0.09	0.02	0.04	0.15
Enrolment in tertiary education	693	0.03	0.01	0.00	0.07
R&D	485	1.55	0.97	0.31	4.86

Table B.2 Correlation matrix between variables and indicators

		1	2	3	4	5
1	Triadic patent applications	1.00				
2	Outward foreign direct investment	0.51	1.00			
3	Inward foreign direct investment	0.06	0.70	1.00		
4	Exports	0.03	0.45	0.74	1.00	
5	Imports	-0.06	0.35	0.70	0.94	1.00
6	Services intensity	0.35	0.42	0.17	-0.07	-0.06
7	Employment in agriculture	-0.39	-0.36	-0.27	-0.26	-0.24
8	High and medium-high tech manufacturing	0.58	0.30	0.23	0.18	0.13
9	Absorptive capacity	0.49	0.59	0.38	0.18	0.00
10	Absorptive capacity incl. R&D indicator	0.83	0.60	0.14	0.04	-0.13
11	Scientific articles	0.73	0.60	0.22	0.17	0.04
12	Internet users	0.40	0.61	0.46	0.29	0.18
13	Enrolment in secondary education	-0.18	-0.15	-0.03	0.16	0.06
14	Enrolment in tertiary education	0.13	0.19	0.26	0.11	0.02
15	R&D	0.83	0.41	0.04	0.05	-0.04

		6	7	8	9	10
6	Services intensity	1.00				
7	Employment in agriculture	-0.42	1.00			
8	High and medium-high tech manufacturing	-0.17	-0.56	1.00		
9	Absorptive capacity	0.48	-0.56	0.35	1.00	
10	Absorptive capacity incl. R&D indicator	0.44	-0.52	0.33	0.80	1.00
11	Scientific articles	0.49	-0.56	0.35	0.73	0.96
12	Internet users	0.36	-0.34	0.29	0.86	0.66
13	Enrolment in secondary education	-0.08	-0.28	-0.10	0.07	-0.08
14	Enrolment in tertiary education	0.36	-0.52	0.16	0.77	0.37
15	R&D	0.29	-0.42	0.39	0.66	0.93

		11	12	13	14
11	Scientific articles	1.00			
12	Internet users	0.48	1.00		
13	Enrolment in secondary education	0.02	-0.01	1.00	
14	Enrolment in tertiary education	0.40	0.51	0.09	1.00
15	R&D	0.80	0.52	-0.07	0.30

Appendix C Regressions for different absorptive capacity country groups

Table C.1 Regressions of triadic patents applications on internationalization variables for 22 low and 18 high absorptive capacity country clusters

	Triadic patent applications	
	Low absorptive capacity countries	High absorptive capacity countries
Lagged triadic patent applications	0.30**	0.99*
	(0.04)	(0.05)
Outward foreign direct investment	6.99**	-2.68
	(1.58)	(3.81)
Inward foreign direct investment	-0.52	-2.66
	(0.70)	(3.03)
Exports	9.56**	12.87
	(0.68)	(17.53)
Imports	-8.98**	-12.64
	(0.60)	(24.82)
Services intensity	0.60**	1.47
	(0.21)	(1.44)
Employment in agriculture	-1.72*	8.92
	(0.63)	(67.71)
Constant	-0.56	-2.44
	(0.43)	(7.93)
Observations	359	287
Number of countries	22	18
Sargan (*p*-value)	0.00	0.28
AR (1)	0.22	0.04
AR (2)	0.30	0.10

Note: Estimation method is GMM using xtabond2. Outward FDI and exports are treated as endogenous. Note that the regression for low AC countries fails the Sargan test of validity of instruments.
** $p<0.01$, * $p<0.05$, + $p<0.1$

The results for the low AC cluster are very similar to those for all countries taken together (Table 5 col. 1). Outward FDI and exports have a positive association with the innovation proxy. Imports have a negative association. While we argued above that such a negative association could be linked to low levels of AC, up to this point our results remain inconclusive. Among the high AC countries imports and inward FDI show a larger, negative, albeit now non-significant, coefficient. However, the regressions are not robust, specifically in the case of the low AC country cluster. The smaller number of countries poses a constraint on the regressions as the number of instruments exceeds the number of countries.

Additionally, in grouping countries into high and low AC countries, we make the assumption that AC is not a continuous scale variable, but a binary concept that allows forming clusters of countries with relatively comparable, homogeneous AC scores. In reality, this is not the case; within each of the two clusters countries' AC differs and this matters. Not only do the AC scores vary within clusters across countries, they also vary over time, with later years producing higher AC scores within countries. For these reasons we are not too confident on the first methodology.