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Understanding the diversity of cooperation on innovation across countries: Multilevel evidence from Europe

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ABSTRACT

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Abstract

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1. INTRODUCTION

Sagas have been written about cooperation on innovation. Availability of direct evidence on cooperation from innovation surveys triggered a burgeoning body of empirical research on this topic that is increasingly conducted by using econometric methods on micro data (see, for example, Miotti and Sachwald 2003, Veugelers and Cassiman 2004, Lööf 2009 and references to a number of earlier papers therein). Strategic alliances between firms and other organizations or with each other have been shown to be increasingly prevalent mode of technology development (Hagedoorn 2002). As a result, there is now fairly extensive empirical literature on the micro aspects of why, how and with whom firms cooperate on innovation.

So far much less has been done, however, to compare the cooperative behaviour of firms in the innovation process across countries. Most of the existing studies have been limited to evidence from a single country, rarely a small number of national datasets (Dachs et al. 2008, Abramovsky et al. 2009, Arvanitis and Bolli 2012, De Faria and Schmidt 2012), and hence confined to the study of cooperation in a given or little varying institutional context. More extensive cross-country comparative research focused exactly on broader national differences, on the heterogeneity of cooperation in different national settings, remains missing.

The aim of this paper is to help in filling the gap. Using macro data from 26 countries and a large micro dataset of 28,674 firms from 15 countries derived from the fourth wave of Community Innovation Survey (CIS4) we attempt to pin down what lies behind the cross-country differences in the propensity of firms to cooperate on innovation. Several hypotheses with regards to the expected impact of the national framework conditions, namely the quality of research infrastructure, openness and size of the country, are proposed and econometrically tested. The results show that there is considerable heterogeneity in innovation cooperation across countries and that a substantial part of these differences can be explained by the conditions under consideration.

The paper proceeds as follows. Section 2 provides a brief discussion of the key issues at stake and formulates the hypotheses. Section 3 introduces the macro evidence, brings in indicators of the national framework conditions and provides results of exploratory regression estimates based on the macro data. Section 4 presents the micro dataset and describes how the firm-level variables have been constructed. Section 5 delineates the multilevel multinomial logit model, debates methodological issues and explains interpretation of the estimated coefficients. Section 6 gives estimates of the multilevel model based on the micro dataset, hence formally testing the central hypotheses of the paper. Section 7 pulls the strands together.

2. TAKING STOCK OF THE ISSUES

Micro motives for cooperation on innovation are well understood. Cooperation unlocks the internal constraints for innovation. Arrangements to cooperate on innovation facilitate access to external sources of knowledge, allow the partners to pool complementary resources, spread costs and risks among them and deepen division of labour in the innovation process (Gulati 1998, Sachwald 1998, Miotti and Sachwald 2003). Although some of these external resources can be purchased on markets for technology, others are embodied in people and organizations, which makes them hard to obtain through market transactions, and hence require interactive learning between users and producers to transfer efficiently (von Hippel 1976, Lundvall 1988, Maskell and Malmberg 1999). More interesting in the context of this paper, however, is the question of whether and to which extent the forces driving cooperation differ in different institutional settings.

National conditions that frame the process of interactive learning that underpins innovation has been extensively studies in the literature on innovation systems (Lundvall 1992, Nelson 1993 and Edquist 1997). Historical, institutional and political factors are highlighted in this line of research to shape the innovative behaviour of firms, the context specific capabilities of which are portrayed as evolving along path-dependent national trajectories. The ability of firms to capitalize on external knowledge embedded in social networks is therefore seen as crucial for success in innovation. At the core of the systemic approach is the idea that the innovative behaviour of firms needs to be understood in the context of what is dubbed in this paper as the national framework conditions. From this follows the first baseline hypothesis that if the national context matters, there should be significant differences across countries in the propensity of firms to innovate in the cooperative manner.

Looking from the systemic perspective, denser networks of cooperation between firms and other organizations hallmark a vibrant innovation milieu; a well-functioning innovation system, as these interactions facilitate reciprocal access to knowledge generated in different parts of the system (OECD 2001, European Commission 2009). From this follows the most obvious refinement of the baseline, which we call the "hinterland" hypothesis, that advanced framework conditions in terms of, for instance, state-of-the-art research infrastructure offer better opportunities for cooperation, and therefore firms embedded in environment like this have higher propensity to cooperate than elsewhere. Yet this is going to work well only for explaining domestic cooperation.

An important matter of concern in this respect is the distinction between nearby, henceforth domestic, and distant, henceforth foreign, cooperative linkages. Some of the relevant partners are located conveniently close, whereas others can be found only abroad. It is likely that firms favour to cooperate in their proximity, if anything to avoid costs and obstacles of venturing far away, as all kinds of - not exclusively geographical - barriers stand in the way. It is reasonable to assume that firms start searching for partners in close proximity and extend the screening to more remote locations only if they cannot find a relevant match nearby. Hence, firms choose domestic over foreign partners for cooperation, if there are partners with the desired complementary resources in the national innovation system. A lack of relevant partners domestically, however, forces firms to engage with foreign partners, as they have no choice but to escape the poverty at home through cooperating abroad.

From this follows the "diaspora" hypothesis of foreign cooperation on innovation, according to which firms operating in adverse framework conditions, such as those prevalent in less developed countries, cooperate abroad more frequently, as compared to firms embedded in an advanced innovation system. If the national framework conditions weak, in other words, firms are more likely to venture into cooperation abroad. Hence, this thesis postulates that excessive foreign cooperation, meaning more frequent than can be ceteris paribus expected, is a symptom of underdevelopment, of desperate firms emigrating for cooperation abroad, not of the virtuous interactions that are underlined in the literature on systems of innovation. Arguably, this take on foreign cooperation throws fairly different light on the nature of these linkages than the standard mantra maintained in the existing literature.

Yet another and considerably more trivial reason why firms might not be able to find relevant domestic partners for cooperation, though equally important to bear in mind, is that their home country is small. Size of the country is likely to matter for natural reasons, because firms in larger countries are by principle less likely to interact - trade, invest or cooperate - across national borders, because there are more domestic organizations to do business with. Even the most developed small country innovation systems do not provide every element of knowledge that indigenous firms need in the innovation process. According to the “size matters” hypothesis, therefore, firms located in small countries have higher propensity to cooperate abroad than their counterparts in large countries.

Openness of the economy, regardless of the size, plays a distinct role, too. Apart from geography, history and economic structure, the intensity of economic transactions across national borders reflects policies that can be directed at promoting (or restricting) the involvement of the country in the global economic system. And this should also have consequences for the frequency of cooperation on innovation abroad. If on one hand the economy is autarkic, for political or whatever reasons, there is low potential for foreign cooperation. Going global through trade, investment and other means, on the other hand, opens avenues for innovation cooperation along the same route. From this follows the “openness” thesis that firms operating in more open national systems are more likely to team up with foreign partners.

Furthermore, not only the central tendency of firms to cooperate on innovation but also the characteristics of firms, including their strategies, incentives and motives, that induce cooperation are likely to differ by country. In other words, different kinds of firms cooperate on innovation in different national settings. For instance, it is feasible to assume that a typical cooperation arrangement looks quite different in terms of what kinds of partners are involved in Germany as compared to the Czech Republic. From this follows the second baseline thesis that the characteristics of firms that explain their cooperative behaviour in the innovation process substantially differ by country.

One prominent aspect of the cooperative arrangements in which there is likely to be a noticeable cross-country difference is the extent to which various kinds of firm-level capabilities - or generally speaking resources - are engaged in the joint projects; hence in the capability-content of these deals. More specifically, it is feasible to expect that in advanced countries cooperation arrangements are predominantly instruments for a reciprocal access to strategic resources, as the standard textbook story tells us. However, in less developed countries, where firms are less technologically capable, cooperation on innovation could well be more prominently an instrument of technology transfer.

Arguably, firms may need help from external organizations, some of which may materialize in formal cooperative agreements, to actually make up for limited internal capabilities. For instance, a foreign supplier of advanced machinery may engage in a cooperative project with a low capable indigenous user in order to deploy the imported technology efficiently, in order to adjust the technology to different local conditions. Also firms is less developed countries may cooperate with a public laboratory, because they cannot afford to maintain a regular R&D department by themselves, not because they aim to pool their advanced strategic resources with scientists.

Generally speaking, firms in less advanced countries may strive to cooperate precisely because of limited internal capabilities to solve problems arising in the innovation process alone, even though more capable firms in advanced countries could ceteris paribus figure out the identical problem without involving others in the innovation process. From this follows the "asymmetry of capabilities" refinement of the second baseline, according to which cooperation on innovation is less intimately related to - particularly advanced innovative - capabilities of firms operating in countries with less developed innovation systems and vice-a-versa.

Until relatively recently, questions like these must have been jumped over in the econometric research on innovation cooperation because suitable data for examining these hypotheses did not exist. But opportunities for doing this have improved considerably with the availability of large micro dataset from multiple countries. Econometric estimates based on microdata that investigate cooperation on innovation are therefore being increasingly synchronised using the same model on datasets from different countries, so that the results can be directly compared between them.

Dachs, et al. (2008) in an early comparative attempt based on CIS3 data found strong differences in the factors explaining cooperative innovation in Austria and Finland and hence concluded that the behaviour of firms is much deeper rooted in the underlying national conditions than the existing literature has assumed so; this is arguably encouraging for the attempt launched in this paper.

Abramovsky et al. (2009) examined cooperation on innovation using the CIS3 data from France, Germany, Spain and the United Kingdom and emphasized that the findings for Spain differ from the rest, although a closer look at the results reveals that there were also quite many other intriguing differences in estimated coefficients by country, particularly in the impact of R&D intensity, appropriability, constraints and scale.

Arvanitis and Bolli (2012) further enriched the comparison to the CIS3 data from five countries, namely Belgium, Germany, Norway, Portugal and Switzerland, but despite their apparent heterogeneity, they concluded that the main results on firm-level factor affecting the propensity to innovation cooperation hold across the investigated countries. It should be noted, however, that some exceptions in this respect have been detected in this paper, particularly for domestic cooperation, too. And a formal test indicated that the countries should not be pooled for the analysis.

De Faria and Schmidt (2012) using again the CIS3 data from Portugal and Germany reported that characteristics of firms cooperating with foreigners are generally quite similar. Nevertheless, one major difference were detected with regards to the propensity to export, as in Germany exporters turned out to be more likely to cooperate abroad than non-exporters, whereas in Portugal this was not the case.

Finally, Srholec (2009) represents probably the largest comparative attempt so far based on the CIS3 data distributed by Eurostat from twelve countries. The main focus was on the role of foreign ownership. The results indicated that foreign affiliates were more likely to channel knowledge through innovation cooperation and that there were important differences in this respect between countries. Nevertheless, the comparison was limited only between the areas of Western Europe, Central Europe, Baltics and Balkan, which revealed broad patterns in the data but more specific hypotheses were not tested.

By separately estimating the identical model in different countries, however, we are able to detect whether there are national differences, which is often the case, but we do not know what really drives them. In other words, this kind of comparative research using microdata is greatly limited in the sense that we can only speculate what are the reasons for the observed differences in the estimated coefficients. Moreover, we cannot learn anything from these studies about the mechanisms how the micro and macro effects interact with each other. Of course, this is because the researchers have not been allowed to pool the national datasets for confidentiality reasons, but this limitation does not hold for multi-country micro datasets, such as the one used in this paper.

3. MACRO

Before examining the CIS4 microdata, which has been released for the restricted sample of 15 countries, we consider aggregated evidence from the full sample of 26 countries of the EU/EFTA area, for which the relevant data has been collected.[1] Eurostat (2013) reports the aggregated data by the location of a partner for cooperation on innovation with the distinction between those at home, in other European countries and in other foreign countries. Many firms simultaneously cooperate with a partner in more than one location. Unfortunately, because of this we are not able to pin down the proportion of firms that cooperate exclusively at home and that engage with both a domestic and a foreign partner, which is a pivotal distinction for our purpose as shown below. Nevertheless, we are at least able to derive the proportion of firms cooperating exclusively with foreign partners, on which we therefore focus in this section. [2]

For macro predictors we need indicators that capture the salient framework conditions. First, as crude measures of the potential for domestic cooperation, we use information on scientific articles, patenting, R&D spending and protection of intellectual property rights; hence variables that have been readily employed in the literature to capture national differences in technology and innovation (Furman et al., 2002, Archibugi and Coco 2004, Fagerberg and

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[1] CIS4 data on innovation cooperation by location of the partner is not available for Iceland, Ireland, Switzerland and the United Kingdom. Aggregated data by location of the partner is also not reported by Eurostat (2013) for Slovenia, even though the required information is present in the microdata by Eurostat (2009), and hence has been imputed from the latter source.

[2] The number of firms cooperating exclusively with foreign partners can be computed by deducting the firms cooperating at home from the total number of cooperative innovators. The number of firms cooperating exclusively with domestic partners, however, cannot be computed, because information on how many firms cooperated with partners abroad, regardless of the foreign country, is not reported in the aggregated data. Since a closer look at the micro dataset reveals that most firms cooperating abroad have partners simultaneously in other European countries and elsewhere, and the degree of overlap between these categories highly differs by country, we cannot simply add them to get the general prevalence of foreign cooperation, as this would entail a heavy bias by country. Attempts to estimate this number turned out futile given the limited information at hand.

Srholec 2008). Second, the openness of a country needs to be accounted for. For this purpose, we use information on imports of goods and services, foreign direct investment and debit licence payments. Finally, the size is measured by working-age population of the country.

To limit influence of shocks and measurement errors occurring in specific years, we use the macro predictors in the form of three-year averages over the period 2002-2004. All of the predictors are used in logs to limit the influence of outliers, except of the index of intellectual property protection, and whenever appropriate adjusted to size of the country, hence expressed per capita or in % of GDP. Sources and definitions of these indicators are reported in Appendix Table A1.

Since the indicators are excessively correlated to each other, hence raising serious concerns of multicollinearity, we use a factor analysis, namely the method of principal factors, to create composites that concisely represent the underlying characteristics. Factor analysis has been used widely in the social sciences and more recently in research on innovation, for example, by Fagerberg and Srholec (2008), Srholec (2010) and Srholec (2011). The main idea behind this method is that indicators representing the same latent dimension in the data are likely to be strongly correlated and that this fact can be leveraged to construct a composite variable of their joint impact; see Basilevsky(1994) for more details.

Table 1 presents the factor analysis of the technology indicators. Only a single principal factor with eigenvalue higher than 1 is detected, which accounts for 82.3% of the total variability. So-called factor loadings, which are the correlation coefficients between the original indicators and the retained principal factor, are reported. Indeed, the correlations are very high. The principal factor, denoted by INFRA, is used as a broad proxy of the quality of research infrastructure, representing the framework conditions in terms of the opportunities for cooperation at home. Of course, the hinterland thesis assumes a positive impact of this variable on the frequency of domestic cooperation, while the diaspora thesis holds if there is a negative impact on foreign cooperation. Only the latter thesis can be directly tested using the aggregated data.

Table 1: National research infrastructure (INFRA): Factor analysis results

	Factor loading
Scientific and engineering articles (per mil. people)	0.93
PCT patent applications (per mil. people)	0.95
Business sector R&D (% of GDP)	0.89
Public sector R&D (% of GDP)	0.82
Protection of intellectual property (index)	0.93
Number of observations	26

Source: Appendix A1.

Table 2 gives the factor analysis of the openness indicators. Again, only a single principal factor with eigenvalue higher than 1 is detected, the second eigenvalue is 0.092 only, so we retain one factor that accounts for 46.9% of the total variability. As the factor loadings indicate, the indicators are very well represented by the composite, except perhaps of the debit licence payments.[3] The principal factor, denoted by OPEN, is used to proxy for openness of the economy. Needless to say, we expect this factor to be positively associated with the odds of foreign cooperation.

Table 2: Openness (OPEN): Factor analysis results

	Factor loading
Imports of goods and services (% of GDP)	0.74
Inward foreign direct investment stock (% of GDP)	0.83
Debit licence payments (% of GDP)	0.42
Number of observations	26

Source: See Appendix A1.

All of the macro indicators have been standardized by deducting mean and dividing by standard deviation, so that these variables enter regressions with mean of zero and standard deviation equal to one. Since they are expressed in the same units of standard deviation, hence on the same scale, the magnitude of their estimated coefficients can be directly compared with each other. In other words, the so-called standardized beta coefficients are reported.

[3] A closer scrutiny of the data does not reveal any particular reason for the lower loading, such as a outlier, however, the observations are more dispersed around the trend line for the debit licence payments than for the other two indicators.

Table 3 provides exploratory regressions based on the macrodata. The dependent variable of the proportion of innovative enterprises that cooperated on innovation exclusively with foreign partners is regressed against the INFRA, OPEN and SIZE predictors. The first column shows results using ordinary least squares (OLS), the second column gives coefficients derived from OLS robust to outliers following the procedure by Li (1985) and in the third column are presented results of the ordinary OLS excluding major outliers based on Cook's distance; Malta has been implicated as the only major outlier.

Overall, the model performs remarkably well, a healthy part, as much as 60 percent, of the cross-country differences is explained. The pivotal finding is that the coefficient of INFRA is highly significant and negative. All else equal, therefore, the tendency to cooperation exclusively abroad decreases with the quality of national research infrastructure, which yields support to the diaspora hypothesis. If firms resort to cooperation abroad only, this seems to be a testimony to insufficient supply of relevant partners at home. OPEN comes out with significantly positive coefficient, which supports the thesis that the general openness matters, too. SIZE has a large and negative coefficient, confirming that firms in large countries cooperate more frequently at home. Nevertheless, estimates of this coefficient are the most susceptible to outliers.

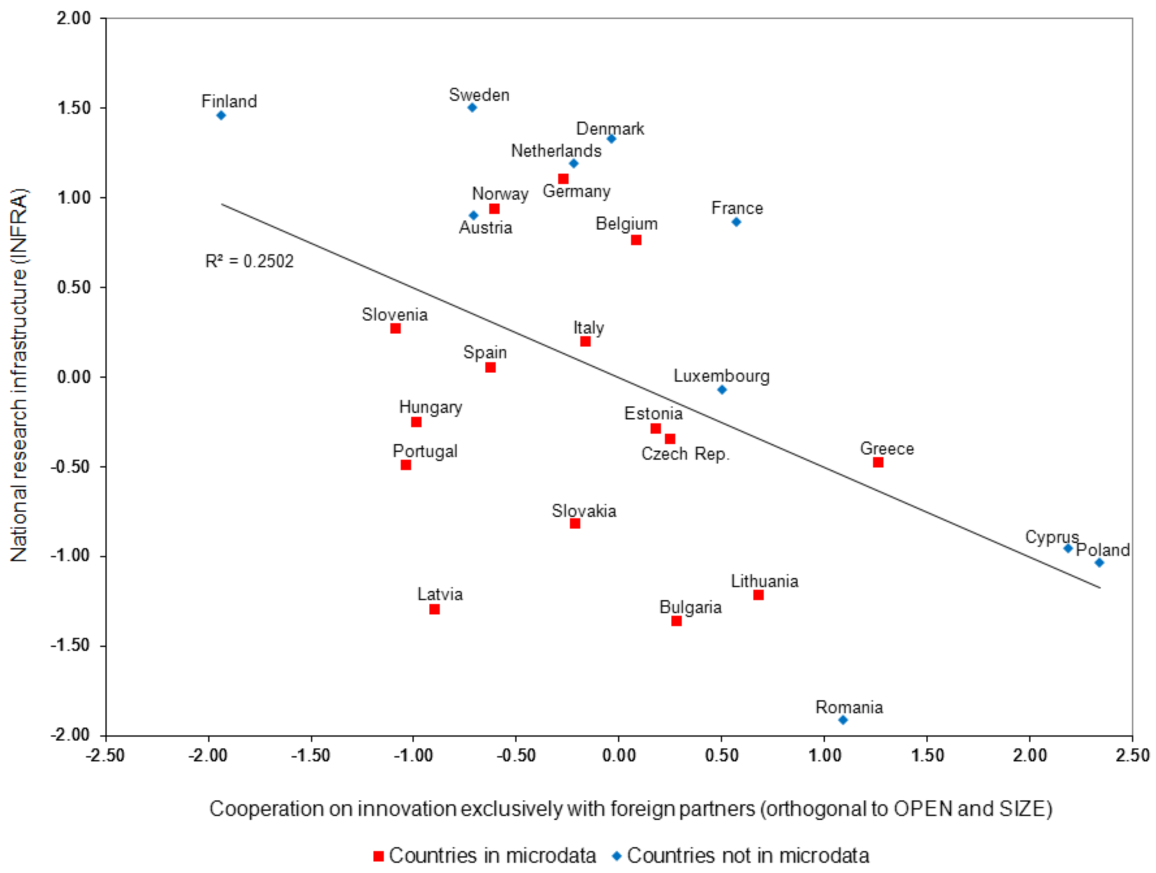
Table 3: Exploring exclusively foreign cooperation on innovation

	(1) Ordinary OLS	(2) Robust OLS	(3) OLS excluding Malta
INFRA	-0.35 (2.86)***	-0.27 (2.50)**	-0.39 (2.97)***
OPEN	0.27 (2.49)**	0.28 (2.24)**	0.40 (2.69)**
SIZE	-0.43 (2.07)**	-0.24 (1.87)*	-0.33 (1.60)
R^2	0.61	0.39	0.60
F	7.24	10.47	13.31
Number of observations	26	26	25

Note: Absolute value of robust t-statistics in brackets; *, **, *** denote significance at the 10, 5 and 1 percent levels.

Figure 1 depicts the main insight of the last estimate by country. The INFRA composite on the vertical axis is plotted against the frequency of exclusively foreign cooperation orthogonal to OPEN and SIZE, hence independently of the openness and size, on the horizontal axis. The figure confirms that there is generally a negative relationship. The great majority of countries with advanced research infrastructure records below average score on the adjusted cooperation variable and vice-a-versa. If the sample is restricted to countries in the micro dataset, marked by red squares, eliminated are those in the upper left corner, namely Finland, and in the lower right edge, such as Cyprus, Poland and Romania, hence, if anything, reducing the negative correlation.

Figure 1: National research infrastructure and the propensity to foreign only cooperation on innovation



It should be stressed that after the factors analysis the macro predictors do not suffer from a serious problem of multicollinearity anymore, neither in the full or restricted micro dataset sample of countries, which confirms that these variables capture distinct characteristics of the national systems. More detailed descriptive overview of the macro variables is provided in Appendix Table A2.

4. MICRODATA

The main thrust of the analysis is based on a large multi-country CIS4 micro dataset disseminated by Eurostat (2009). Following the third edition of Oslo Manual (OECD 2005) a harmonized questionnaire and methodology was used to collect information about innovation activity over the period 2002-2004. Nevertheless, there are some prevailing national differences with regards to design of the questionnaire, industry coverage, reference period, or imputation of the missing data, which had to be dealt with; details on how this has been done are available from the author upon request. Firms from the following fifteen countries are included: Belgium, Bulgaria, Czech Republic, Estonia, Germany, Hungary, Greece, Italy, Latvia, Lithuania, Norway, Portugal, Slovakia, Slovenia and Spain.[4]

All firms have been asked to provide basic information about the number of employees, group membership or distance of their market but only those firms that claimed to innovate have been asked to provide further details on their innovation activity. Since the cooperative behaviour concerns only those firms that attempted to innovate, and there is a lack of instrumental variables that could identify the selection, we restrict the sample to innovation active firms only; i.e. those that introduced a new product, a new process or reported not yet completed or abandoned innovation activities. It is therefore important to bear in mind that the presented evidence refers to the sub-sample of innovating firms and should be interpreted accordingly.

The dependent variables are derived from the set of questions on whether the firm cooperated on any of its innovation activities with other organizations.[5] Firms were further asked to indicate whether they cooperated with a partner in their home country or a partner located abroad. To learn more about what drives cooperation with foreign in contrast to domestic partners, we create dummy variables with three mutually exclusive outcomes delineated as follows: i) COforONLY has value 1 if the firm cooperated only with foreign partners; ii) COboth has value 1 if the firm cooperated both with domestic and foreign partners at the

[4] Eurostat (2009) data availability dictates the country composition of the micro sample. Romania is not included in the analysis, because of missing data on location of the cooperation partner.

[5] In the harmonized CIS4 questionnaire innovation cooperation was defined as active participation with other enterprises or non-commercial institutions on innovation activities; pure contracting out of work with no active collaboration was emphasized to be not regarded as cooperation.

same time; and iii) COdomONLY has value 1 if the firm cooperated only with domestic partners.[6]

Scale advantages are essential to control for. Size of the firm given by the number of employees has been perceived as confidential information, and therefore not included in the datasets. Only classification of firms into three broad categories at the beginning of the reference period has been provided, from which we derive three dummy variables with value 1 for SMALL (0-49 employees), MEDIUM (50-249 employees) and LARGE (more than 250 employees) firms. SMALL is used as the base category.

Two control variables are derived from the question whether the firm is a part of an enterprise group, which provides the firm with extended reach both organizationally and geographically. Affiliated firms were further asked about the country where the head office is located, which we use to derive two mutually exclusive variables for the group membership. FORGP is a dummy with value 1 if the firm is affiliated to a group with headquarters abroad, hence a proxy for organizational proximity to prospective foreign partners. DOMGP is a dummy with value 1 if the firm is affiliated to a group with headquarters in the same country, hence a proxy for home-based ownership networks.[7]

Next, the dataset contains information on which geographic markets the firms sell goods or services with a distinction between local, national, other EU and all other countries. EXP stands for a dummy with value 1 if the firm delivered abroad, thus representing market proximity to foreign locations.

Most importantly, firms were asked to report details about inputs, resources and capabilities devoted to their innovative efforts. A traditional measure in this domain is whether the firm engaged in research and experimental development (R&D) activity that is routinely used to represent not only the capability of firms to generate new knowledge but also to absorb relevant inputs from outside (Cohen and Levinthal 1990). RDIN dummy has value 1 if the firm engaged in R&D in-house. Besides the intramural activity, firms were asked to indicate

[6] Since one of the micro predictors accounts for the information whether the firm is affiliated to a group, for more see below, internal cooperation arrangements with other firms affiliated to the same group are excluded from the definition; hence the dependent variables only refers to external cooperative linkages.

[7] Unfortunately, the questionnaire does not allow us to identify whether the domestic-based group has operations in other countries, so that this dummy covers not solely domestic groups, but also home-based multinational corporations.

whether they purchased extramural R&D services, from which follows the RDEX dummy with value 1 if the firm answered affirmatively.

Another relevant question refers to the openness of firms to sources of information from outside, which captures their absorptive capacity from a different angle (Veugelers and Cassiman 2004). Firms were asked to indicate importance of information for their innovation projects from a number of various sources. To avoid overlap between the dependent cooperation variables and the explanatory variable derived from this question, we do not take into account the same sources to which the question about cooperation refers to, such as suppliers, customers, competitors, research organizations, etc., but consider other external sources, only. INFO dummy has value 1 if the firm indicated either i) conferences, trade fairs, exhibitions; ii) scientific journals and trade/technical publications; or iii) professional and industry associations as highly important information sources.

Another relevant data in this domain refers to appropriability conditions of the firms' knowledge base given by their ability to protect intellectual property rights by patents or other means. For this purpose, the survey provides information about using formal methods to protect technology developed by the firm. PROTECT is a dummy which takes value 1 if the firm applied for a patent, registered an industrial design, registered a trademark or claimed a copyright.

Finally, industry dummies are derived from a classification that broadly follows alphabetical NACE, rev. 1.1 structure with 14 categories covering firms in both industry and market services. Food and tobacco manufacturing (DA) is used as the base category. More detailed industrial classification was not provided in the dataset, because of confidentially concerns. Definition of the industry dummies is available from the author upon request.

Table 4 provides descriptive overview of the micro dataset. After omitting observations with missing records, the sample includes information for 28,674 innovating firms. About a third of the firms engaged in innovation cooperation with at least one external partner, of which, 14.9% cooperated exclusively with partners at home, 13.7% cooperated with both domestic and foreign partners and 2.6% cooperated exclusively with partners abroad. Arrangements on cooperation only with domestic partners are therefore far more prevalent than those only with foreigners and most firms that cooperate abroad also tend to involve a domestic cooperation partner; this holds for every country in the sample. Geography, distance and borders no doubt matter, as firms lean towards cooperating with partners at home. Nevertheless, there is a remarkable variability in the respective cooperative propensities by country that begs for explanation.[8]

Table 4: Descriptive overview of the dependent variable by country

	Total	COforONLY Foreign only	CObоth Foreign & domestic	COdomONLY Domestic only	Number of observations
Belgium	0.481	0.058	0.288	0.135	1,222
Bulgaria	0.211	0.038	0.096	0.077	2,216
Czech Rep.	0.481	0.047	0.264	0.170	2,225
Estonia	0.359	0.053	0.198	0.107	903
Germany	0.286	0.012	0.115	0.159	2,498
Greece	0.251	0.040	0.104	0.107	402
Hungary	0.486	0.038	0.225	0.223	942
Italy	0.177	0.005	0.034	0.138	4,932
Latvia	0.432	0.039	0.252	0.141	433
Lithuania	0.596	0.071	0.313	0.211	549
Norway	0.450	0.027	0.269	0.155	1,346
Portugal	0.240	0.017	0.112	0.112	2,055
Slovakia	0.446	0.046	0.326	0.074	677
Slovenia	0.498	0.054	0.305	0.139	653
Spain	0.278	0.019	0.079	0.180	7,621
Total	0.312	0.026	0.137	0.149	28,674

Source: Eurostat (2009).

One cursory observation that needs to be highlighted at this point is that the cooperativeness of firms operating in the former socialist countries that entered the EU in the previous decade is not systematically lower than in the “old” EU members, especially if compared to those in Southern Europe. And this is particularly the case of foreign cooperative linkages, which tend to be several times more prevalent in the new EU members than in their South European counterparts.

[8] Table 4 and Appendix Table A2 do not contain exactly the same figures because observations with missing records are excluded from the micro sample and because the aggregated data are adjusted for the sampling fraction, non-response and no longer existing enterprises. Nevertheless, the correlation is 0.93 and 0.87 for the total and exclusively foreign cooperation, respectively; thus the difference is small.

Southern European countries have been described to have fragile innovation systems; however, this has been understood to be even more the case of the new EU members. Paasi (1998) found innovation systems in transitions countries relatively less efficient than in the market economies. Radosevic (2004) expressed doubts about growth prospects of the Central and Eastern European countries precisely because of fragmented innovation systems. Högselius (2005) reported major gaps in systemic interactions among actors of the Estonian national innovation system. In other words, more cooperation does not necessarily signify a well-functioning innovation system; quite the opposite in fact seems to hold for the foreign cooperative linkages.

As far as the micro predictors are concerned, the various kinds of firms are well represented in the sample. About a fifth of the firms are large, a third of them are medium, from which follows that roughly a half of the sample consists of small firms. Affiliates to a domestic group are more frequent than those with headquarters abroad, accounting for a forth and a sixth of the observations, respectively. Slightly more than half of them are exporters. Almost three-fifths of the innovating firms engage in intramural R&D activity, about a third of them purchase external R&D services, nearly the same proportion protect their knowledge base by the formal methods and one fifth of them deem the external information sources as highly important for their innovative efforts.

But far more interesting than descriptive tabulations like these are the estimated relationships of these variables to the respective propensities of firms to cooperate, and the underlying cross-country differences thereof, which is investigated in a multilevel econometric framework in the next section.

5. A MULTILEVEL MULTINOMIAL MODEL

Macro analysis of a problem that is rooted in micro behaviour may be deceiving. Macro-level relationships are not necessarily reproduced at the firm-level because the variance between firms is lost when aggregated data is used. Even if countries with certain characteristics display more prevalence of cooperation on innovation, this cannot be strictly speaking generalized to how firms behave. One can easily fall into the trap of the fallacy of the wrong level. More specifically, in this case there is an acute risk that the macro analysis suffers from the so-called “ecological fallacy”, when inferences about the nature of individuals are deduced from inference for the group to which those individuals belong (Goldstein 2003).

A major reason for this problem is that macro-level relationships found in studies based on aggregated data may be compositional. For example, it has been shown that large, outward looking and technologically capable firms are more likely to cooperate. Hence, a country may appear with more prevalent cooperation due to the concentration of this kind of firms rather than the hypothesized country-level factors. Likewise, there are known to be large differences in cooperativeness of firms between industries, hence industrial composition may transcend in the differences between countries. By looking solely at the aggregated data, therefore, it remains unclear whether the observed country-level patterns are an artefact of distinctly national framework conditions.

A complex contextual phenomenon, such as cooperation on innovation, cannot be fully understood at any single level of analysis. The decision of a firm to cooperate can be best described as driven by factors that are firm-level and higher-level, such as national institutions. It cannot be emphasized enough, however, that the firm should always remain the ultimate unit of the analysis. It is pertinent to confirm, whenever possible, whenever data availability permits, the aggregated relationships detected in macro studies by evidence at the individual level. One approach that has the potential to circumvent the risk of committing the fallacy of the wrong level is multilevel modeling.

According to Hox (2002), a multilevel analysis concerns relationships between variables that are measured at different hierarchical levels. A multilevel, sometimes also called a hierarchical, random coefficient or mixed-effect, is then a model that relates a dependent variable to predictor variables at more than one level. Suppose a multilevel model has 2-level structure with firms at level-1 nested in countries at level-2. Since the dependent variables in this study are discrete categorical, a multinomial logit model needs to be estimated, the specification of which is the following:

Level-1 model:

(1.1) $\text{Prob}(Y_{ij}=k \mid \beta_{j(k)}) = \text{Prob}(k)$

(1.2) $\text{Log}\,[\text{Prob}(k)/\text{Prob}(K)] = \beta_{0j(k)} + \sum_{q=1}^{Q} \beta_{qj(k)} X_{qij}$

Level-2 model:

(1.3) $\beta_{0j(k)} = \gamma_{00(k)} + \sum_{s=1}^{S} \gamma_{0s(k)} Z_{sj} + u_{0j(k)}$

(1.4) $\beta_{qj(k)} = \gamma_{q0(k)} + \sum_{s=1}^{S} \gamma_{qs(k)} Z_{sj} + u_{qj(k)}$

where i is a firm, j is a country, there are k = 1, ..., K discrete outcomes of a dependent variable Y_{ij} at level-1 with K as the base category, X_{ij} denotes a vector of level-1 predictors q = 1, ..., Q, Z_j refers to a vector of level-2 predictors s = 1, ..., S and u_j are normally and independently distributed random effects with a constant variance = σ^2_u. Prob(k) thus refers to the probability that firm i operating in country j falls into category k. By logic of the multinomial model $\text{Prob}(Y_{ij} = K) = 1 - \sum_{k=1}^{K-1} \text{Prob}(Y_{ij} = k)$. Hence, there are K-1 sets of equations to be estimated.

From this follows that γ_{00} is the estimated grand mean of the log-odds of the outcome across countries, γ_{0s} are the country-level effects on this intercept, u_{0j} indicates that the countries vary around that intercept due to unobserved heterogeneity, γ_{q0} are the estimated means of the respective firm-level slopes across countries, γ_{qs} are the cross-level interactions between the firm- and country-level predictors and u_{qj} indicate that these firm-level slopes vary not only as a function of the country-level predictors but also as a function of unobserved country effects.

At level-1 the equation refers to firm-level relationships. If the level-2 equations were not specified, the level-1 relationships could have been by principle estimated separately for each country. A multilevel model emerges, if we let the intercept β_{0j} and most importantly the slopes β_{qj} to become random variables. Since the level-2 effects are identified by the subscript j, we have a hierarchical system of regression equations at different levels, where we allow each country to have a different average outcome and a different effect of the respective firm-level predictors on the outcome. Although there is a different firm-level model for each country, the level-2 equations tell us that the estimated intercept and the respective slopes differ simultaneously across countries.

By substituting the level-2 equations for β_j in the level-1 model we arrive to a "mixed" formulation, which reduces the entire model to a familiar regression format, where the dependent variable becomes the sum of a fixed part denoted by the set of γ coefficients and a random part of the model denoted by the set of u_j residuals. [9] As discussed by Goldstein (2003), the presence of more than one residual term makes the traditional estimators inapplicable and therefore specialized maximum likelihood procedures must be used to estimate these models. For the purpose of this paper we use the full penalized quasi-likelihood estimator developed by Raudenbush et al. (2004) and implemented in specialized statistical software Hierarchical Linear and Non-linear Modeling (HLM) version 6.08.

So far multilevel modeling has been rarely used to study innovation. Srholec (2011) looked at the impact of national framework conditions on the propensity of firms to introduce product innovation. Srholec and Verspagen (2011) conducted a multilevel decomposition of variance in firm's innovation strategies by country and industry. A few other relevant applications can be traced in the field of regional studies. Srholec (2010) examined with the help of a multilevel model the role of knowledge-driven urbanization economies for innovativeness of firms. Fazio and Piacentino (2010) and Van Oort, et al. (2012) used multilevel methods to investigate the regional variability of firm-level productivity, growth and survival, though innovation per se does not merit much of their attention. To the best of my knowledge, however, this paper is the first attempt to study cooperation on innovation using an explicitly multilevel model.

6. MULTILEVEL ESTIMATES

[9] Note that there are no terms for the level-1 residuals, because for a multinomial outcome in the multilevel framework the variance is completely determined by the population means, so that these residuals are not separate terms to be estimated.

Given the dataset at hand, the firm-level dependent variable Y_{ij} is derived from the $COforONLY_{ij}$, $COboth_{ij}$ and $COdomONLY_{ij}$ dummies, the respective values 1 of which denote the three mutually exclusive outcomes k = 1, 2 or 3, so that the base category K refers to non-cooperating innovative firms. On the right-hand side $X_{ij} \in$ ($LARGE_{ij}$, $MEDIUM_{ij}$, $DOMGP_{ij}$, $FORGP_{ij}$, EXP_{ij}, $RDIN_{ij}$, $RDEX_{ij}$, $INFO_{ij}$, $PROTECT_{ij}$) are the firm-level predictors, $Z_j \in$ ($INFRA_j$, $OPEN_j$, $SIZE_j$) are the country-level predictors and a possible dependence by industry is controlled for by including industry dummies.

In the full model, there are Q + 1 country-level equations, S country-level effects on the intercept, Q firm-level slope effects, S ∗ Q cross-level interaction terms and last but not least Q + 1 random effects to be estimated; particularly the cross-level elements are numerous. But there is a variety of reduced specifications that can be estimated depending on the research question in mind. Since the number of countries is relatively small in this paper, the number of coefficients that is viable to estimate is limited. Hence, we build the model from bottom-up by adding coefficients in several steps into an increasingly complex specification.

It is useful to strip the model to the bone and start with the "null" specification, which does not include any predictors, and the only purpose of which is to estimate u_{0j}, hence the intercept variance explained by the higher level. From this we can calculate the so-called intraclass correlation coefficient (ICC). In a linear model, $ICC = \sigma^2_{u0} / (\sigma^2_{u0} + \sigma^2_e)$, where σ_e stands for variance of the level-1 residuals e_{ij}, which however is not estimated in a logit multilevel model. Following the latent variable approach by Rodríguez and Elo (2003, pg. 37), we assume that e_{ij} follows standard logistic distribution, which has variance $\pi^2/3$; thus σ^2_e is roughly 3.29, and $ICC = \sigma^2_u/(\sigma^2_u + \pi^2/3)$. If this coefficient is low, the data can be safely pooled together, because there is not much higher-level variability. But if the intraclass correlation is high, the hierarchical structure of the data cannot be neglected.

Table 5 gives the ICC calculations. Results of the null model indicate that as much as 23.4% and 26.2% of the variance in $COforONLY_{ij}$ and $COboth_{ij}$, respectively, is accounted by differences between countries, which strongly confirms that the underlying structure of this data is hierarchical. Somewhat surprisingly, this is much less for $COdomONLY_{ij}$. National conditions are therefore more relevant for the arrangements of firms on cooperation involving a foreign partner, than those that do not. Nevertheless, 6.8% is still relevant, considering that the existing multilevel studies rarely detected more than 5% of variability in firm-level outcomes to be accounted by various territorial units (Fazio and Piacentino 2010, Van Oort, et al. 2012, Srholec and Verspagen 2011).

Table 5: Intraclass Correlation Coefficient (ICC) for the intercept

	(1) COforONLY Foreign only	(2) CObоth Foreign & domestic	(3) COdomONLY Domestic only
Multinomial null model	0.234	0.262	0.068
Multinomial base model	0.170	0.169	0.053
Number of firms		28.674	
Number of countries		15	

Furthermore, we calculate the ICC for the “base” model, in which the firm-level predictors and industry dummies are added but the country-level predictors remain left out, and which is used as a benchmark below. After this addition, the ICC decreased a bit, as these variables also carry an element of cross-country heterogeneity, i.e. differ both within and between countries, however, the unaccounted country-level variability remains substantial. Overall, these results highlight the sensitivity of the firm-level outcomes to the national framework conditions and therefore support the first baseline thesis that there are important differences across countries that deserve a more elaborate explanation.

So far we have been able to establish that there is considerable diversity by country, but we do not know what drives these differences. Next, we estimate the so-called “intercept-as-outcome” multilevel model, in which the country-level variables are added as predictors of the intercept. By using this specification, we test the hypothesis that the specific characteristics of national framework conditions directly influence the central tendency of firms to engage in the respective cooperation on innovation, which refers to the main research questions of this paper. To improve interpretability of the results, we re-standardized the country-level predictors within this sample of countries, so that these variables enter the estimate with mean of zero and standard deviation equal to one.

Table 6 provides the results. Odds ratios are reported for the fixed coefficients; hence a ratio higher than one indicates a positive impact and vice-a-versa. The main finding is that the country-level predictors are statistical significant at the conventional levels for the first two outcomes of exclusively foreign cooperation and simultaneously foreign and domestic cooperation, for which the largest random effects have been detected above, but none of them come out anywhere close to be significant in the last equation on exclusively domestic partners.

Let us first consider the impact on exclusively foreign cooperation. All three of the country-level predictors have the expected signs. All else equal to zero, a firm operating in a country with $INFRA_j$ one standard deviation below the mean, thus in underdeveloped research infrastructure, is estimated to be 1.47 times more likely to cooperate exclusively abroad. Hence, this result firmly supports the diaspora thesis that a major reason why firms undergo the trouble of cooperating abroad is the deficiency of relevant partners at home. $OPEN_j$ came out positive, while $SIZE_j$ has a negative impact, which confirms the openness and size matters hypotheses, respectively. Generally speaking, the multilevel analysis reconfirms the macro findings.

Second, there is the impact on the propensity of simultaneously cooperating at home and abroad. Admittedly, the combined outcome is much more difficult to pin down, because of the limited information in the data about these cooperation deals. It would be preferable to know, for instance, the relative importance of (or resources devoted to) the partners by location. Yet as it is now, we can only speculate about the nature of this mixed category from the econometric results. Given the fact that the odds ratios of the country-level predictors for combining both are fairly similar to the propensities of exclusively foreign cooperation, the data seems to indicate that the foreign element is dominant. Most interestingly, the diaspora driver prevails over the hinterland thesis, albeit the statistical significance of this coefficient drops to six percent level.

Table 6: Results of the multinomial "intercept-as-outcome" multilevel model

	(1) $COforONLY_{ij}$ Foreign only	(2) $COboth_{ij}$ Foreign & domestic	(3) $COdomONLY_{ij}$ Domestic only
Country-level:			
$INFRA_j$	0.68 (2.82)**	0.73 (2.09)*	0.90 (0.79)
$OPEN_j$	1.42 (2.49)**	1.42 (2.30)**	1.19 (1.36)
$SIZE_j$	0.61 (3.34)***	0.54 (3.66)***	0.93 (0.52)
Firm-level:			
$LARGE_{ij}$	1.53 (3.75)***	2.38 (14.72)***	1.28 (4.51)***
$MEDIUM_{ij}$	1.26 (2.46)**	1.21 (3.76)***	1.04 (0.96)
$DOMGP_{ij}$	1.87 (6.03)***	1.63 (9.38)***	1.20 (4.10)***
$FORGP_{ij}$	2.43 (8.78)***	1.42 (6.16)***	0.85 (2.91)***
EXP_{ij}	1.97 (6.59)***	2.05 (13.58)***	0.82 (4.73)***
$RDIN_{ij}$	1.66 (5.36)***	2.66 (17.87)***	1.74 (12.80)***
$RDEX_{ij}$	2.15 (9.13)***	3.86 (30.71)***	2.91 (27.97)***
$INFO_{ij}$	1.26 (2.54)**	1.83 (12.96)***	1.14 (2.99)***
$PROTECT_{ij}$	1.43 (4.28)***	1.92 (14.96)***	1.33 (7.31)***
Constant	0.01 (22.65)***	0.01 (25.17)***	0.11 (16.71)***
Industry dummies	Yes	Yes	Yes
σ_u	0.43 (127)***	0.51 (590)***	0.42 (298)***
ICC	0.054	0.072	0.051
Log-likelihood		-67,381.62	
AIC		134,931.24	
BIC		135,625.39	
Number of firms		28.674	
Number of countries		15	

Note: Full penalized quasi-likelihood estimation; odds ratios and absolute value of T-ratios in brackets reported for the fixed coefficients; standard deviation and chi-square in brackets reported for the random effect; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Of course, we do not claim that every foreign linkage is diasporic, as evidence from advanced countries clearly vindicates that this is not the case. But the results yield support to the thesis that at least in this sample of countries a notable part of them are of this kind. It is fully acknowledged, however, that this result might turn out quite different, if more advanced countries, such as Finland, Sweden or Denmark, are included in the sample. It remains a challenge for future research on more extensive micro datasets to find out whether this result is sensitive to the composition of the sample.

Third, the results are inconclusive for the exclusively domestic cooperation. Hence, the hinterland thesis of domestic cooperation does not hold if tested against this data, at least to the extent to which the variables in hand properly account for what they are supposed to measure. Admittedly, this is surprising in the view of the emphasis on domestic linkages in the literature on national innovation systems. It well might be that the system-level studies suffer from some sort of ecological fallacy when considering what underpins linkages - in terms of strategies, incentives and motives actually pursued by firms – in domestic cooperative networks. Yet again we need to keep in mind the possible sample composition bias, as several poster examples of the best performing innovation systems are not covered, so strong conclusions need to be avoided at this point.

As far as the firm-level slope coefficients are concerned, the results are well in line with expectations. $LARGE_{ij}$, $MEDIUM_{ij}$, $DOMGP_{ij}$, $RDIN_{ij}$, $RDEX_{ij}$, $INFO_{ij}$ and $PROTECT_{ij}$ came with a positive and in most cases highly significant impact across the board. Larger, domestically affiliated and more capable firms are therefore confirmed to be more likely to cooperate regardless of location of the partner. But there is a notable difference in the estimated coefficients of $FORGP_{ij}$ and EXP_{ij}, which switched from significantly positive in the equations on cooperation involving foreign linkages to significantly negative in the last equation on exclusively domestic partners; hence confirming the finding of Veugelers and Cassiman (2004) that international business, particularly foreign ownership, tends to be negatively associated to domestic cooperation.

So much for what we have been able to explain, but equally insightful in the context of multilevel modeling is the residual variance. After the country-level predictors have been included, the intercept random effects, thus the ICC, drops about three-times for the foreign only cooperation and two-times for the combined category; confirming that a healthy part of the heterogeneity across countries has been accounted for. Nevertheless, the results also indicate that a noticeable part - between 5 to 7% - of the cross-country differences remains unexplained by the predictors.

Some of these differences could be very difficult to ever measure properly, including cultural background, the extent of trust or social capital. Furthermore, cognitive differences between respondents in different countries could lead to measurement errors of the micro variables, which collapse into the residuals, too. For example, what is “novel”, “major” or “highly important” might have been perceived differently by country; leaving aside nuances that might have been lost in translation of the questionnaire. Although we have been able to identify systematic patterns in the data, there is arguably a limit to how much can be explained by quantitative methods like these. To illuminate the rest is a task for qualitative research.

Table 7 provides robustness tests with regards to the estimator. First, we estimate a plain multinomial logit model, in which the random effects are omitted. Second, we abandon the multinomial framework and estimate equations for the three outcomes separately, however, accounting for the random effect. If only the random effect for the intercept is included, this model can be estimated as the standard random-effects logit. Finally, we give up the random effects again and estimate three separate ordinary logit models. Using probit instead of logit does not make much difference. Only results of the country-level predictors are reported for the sake of saving space.

Table 7: Results of country-level predictors by estimator

	(1) $COforONLY_{ij}$ Foreign only	(2) $COboth_{ij}$ Foreign & domestic	(3) $COdomONLY_{ij}$ Domestic only
Multinomial logit:			
$INFRA_j$	0.73 (5.86)***	0.86 (5.64)***	0.96 (1.49)
$OPEN_j$	1.56 (8.51)***	1.53 (16.11)***	1.25 (9.46)***
$SIZE_j$	0.62 (9.38)***	0.52 (25.80)***	0.97 (1.05)
Random effects logit:			
$INFRA_j$	0.75 (2.59)***	0.77 (2.04)**	0.96 (0.44)
$OPEN_j$	1.25 (1.99)**	1.34 (2.31)**	1.10 (0.94)
$SIZE_j$	0.69 (3.19)***	0.57 (4.06)***	1.08 (0.67)
Ordinary logit:			
$INFRA_j$	0.75 (5.40)***	0.88 (4.83)***	0.97 (1.36)
$OPEN_j$	1.37 (6.18)***	1.40 (13.49)***	1.16 (6.44)***
$SIZE_j$	0.73 (6.22)***	0.54 (25.65)***	1.15 (5.66)***

Note: Odds ratios and absolute value of z-statistics in brackets reported; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

It should be noted that an important caveat of the multilevel model is the assumed orthogonality of the estimated random effects, particularly vis-a-vis the country-level predictors. Unfortunately, not much could have been done about this potential source of endogeneity, because valid instruments are extremely hard find, which is admittedly a chronic problem for empirical research on innovation. As a crude indication of the extent to which this is a problem, however, it is instructive to compare results of a model with and without the random effects. Overall, the main conclusions remain intact; the odds ratios appear qualitatively similar, which is reassuring. But standard errors produced by the estimators without random effects are about at least two-time lower, resulting in substantially higher statistical significance of the coefficients. By controlling for the unobserved heterogeneity across countries, we obtained statistically more efficient estimates, which if anything are more "conservative", as Goldstein (2003) puts it, than those derived from models without the random effects.

Yet there are two discrepancies that deserve to be mentioned in the third column. $OPEN_j$ becomes positively significant for exclusively domestic cooperation, if the random effects are excluded, which at first seem hard to comprehend, but perhaps can be interpreted as a competition effect, meaning that firms in open economies are extra stimulated to utilize every bit of useful knowledge nearby. $SIZE_j$ turns out with a positively significant impact on the same outcome in the ordinary logit model, which is along with expectations, as size increases the odds of finding a relevant partner. Nevertheless, the fact that these coefficients become significant, only if the random effects are omitted, signals that particularly these two are most susceptible to the aforementioned bias.

In the next step of building the model, we examine differences of micro-level relationships across countries. A powerful feature of multilevel modeling is that with the help of this method we can relax the assumption that the impact of firm-level predictors is constant across countries and therefore consider the thesis that not only the estimated intercept but also the slope coefficients are affected by country-level differences, including unobserved heterogeneity thereof. In other words, we aim at answering the question whether the country-effects differ for different kinds of firms. A first step towards testing this thesis is to allow for the slope random effects, from which the ICC of the slope coefficients can be computed in the same way as for the intercept.

Table 8 shows results of this exercise. To avoid estimating too many coefficients at once, given limits of the data, we add the slope random effects for the respective firm-level predictor one at a time, thus we run nine separate estimates. The main finding is that the random variance of the slopes is much lower than of the intercept. Only two of the ICC for slopes turned out in the range of 5 to 8%, thus somehow relevant, but two-thirds of them ended up less than 3%. Hence, the estimated firm-level relationships seem to be largely similar across countries. It should be also noted that adding the slope random effects did not much alter the other estimated coefficients, so the main results are robust in this respect.

Table 8: Intraclass Correlation Coefficient (ICC) for slope coefficients

	(1) $COforONLY_{ij}$ Foreign only	(2) $COboth_{ij}$ Foreign & domestic	(3) $COdomONLY_{ij}$ Domestic only
$LARGE_{ij}$	0.031	0.007	0.004
$MEDIUM_{ij}$	0.025	0.010	0.003
$DOMGP_{ij}$	0.013	0.011	0.024
$FORGP_{ij}$	0.054	0.001	0.029
EXP_{ij}	0.018	0.019	0.038
$RDIN_{ij}$	0.018	0.073	0.045
$RDEX_{ij}$	0.011	0.033	0.019
$INFO_{ij}$	0.015	0.034	0.016
$PROTECT_{ij}$	0.035	0.038	0.023
Number of firms		28.674	
Number of countries		15	

Consequently, we refrain from presenting estimates of the full "slopes-as-outcome" model, in which the cross-level interaction terms are added. If this model is estimated, however, as can be expected given their small random variance, only a few of the cross-level interactions are at least weakly statistically significant, so that these results does not warrant a closer scrutiny. From this follows that the second baseline hypothesis of substantial cross-country diversity in the impact of the firm-level predictors is not supported by the data and thereby the "asymmetry of capabilities" refinement does not hold either.

7. CONCLUSIONS

Arrangements to cooperate on innovation facilitate access to external sources of knowledge. Some of these sources can be found domestically, but for some of them firms need to venture abroad. While most of the existing studies on this topic focused on the micro aspects, we compare innovation cooperation across countries. By combining extensive macro and micro evidence obtained from CIS4 data, we found that national framework conditions matter particularly for the propensity of firms to cooperate with foreigners. Several significant country-level differences that explain foreign cooperation have been identified. The results are shown to be robust with regards to the level of analysis, specification of the model and estimation procedure.

First and foremost, the results indicate that foreign cooperation is more prevalent in countries with less developed research infrastructure, thus supporting the diaspora thesis that a major reason why firms cooperate abroad is a lack of relevant partners at home. In underdeveloped conditions, firms often resort to foreign cooperation out of necessity, because they are desperate for help from abroad. Instead of the virtuous “local buzz and global pipelines” interactions in terms of Bathelt et al. (2004), which is a relevant view in the context of frontier countries, foreign cooperative linkages in less advanced countries can be perhaps more accurately understood as situations of “local wreck and global lifelines”.

Of course, this does not imply that foreign cooperative links are en masse futile nor that policy-makers should frown on foreign cooperation on innovation. However, a cautionary note that firms cooperate with foreign partners, in particular exclusively with the foreign ones, more frequently in underdeveloped innovation systems, and that this can actually be a symptom of weakness rather than strength, should be taken. So the question that policy-makers need to ask themselves is exactly what proportion of the foreign linkages are diasporic in the particular country, how many of them would not materialize, if the national innovation system provides better opportunities for cooperation.

If the diaspora thesis holds, the potential for domestic interactions is unsatisfactory, the necessity to venture abroad for cooperation on innovation represents a competitive disadvantage for the local producers. Hence, the diasporic perspective on foreign linkages gives support to the line of policy interventions directly aimed at facilitating learning between organizations as advocated by Lundvall and Borrás (2005) and mitigating “systemic failures” in terms of Chaminade and Edquist (2006), which highlight the problem of deficient linkages in the national innovation system.

Surprisingly, however, the heterogeneity of firm-level relationships appears limited across countries. In other words, the general tendency to cooperation, the frequency of cooperative linkages, considerably differs by country, but the characteristics of firms that explain cooperation do not. Firms seem to follow a similar model of cooperation regardless of the national framework conditions. Arguably, particularly this finding deserves further examination on datasets with even more cross-country variability, including preferably evidence from developing countries outside of Europe, in order to establish more convincingly that indeed this is the case.

In terms of methods, the paper demonstrates benefits of doing cross-country comparative research based on data directly at the firm-level. Analysis of the multi-country micro dataset gave us a unique opportunity to systematically compare results of the very same model in countries with different framework conditions. And we have shown that this approach can yield relevant insights on the nature of cooperation on innovation in different settings. As new micro datasets with data harmonized across many countries become increasingly available for research purposes, it becomes a major opportunity for future study to put forward more comparisons of this kind.

A major limitation of this study that needs to be acknowledged is that the data reveal only whether a firm cooperated or not, but there is no information in the survey about the intensity of these linkages. Ideally, we should be able to distinguish between the motives for cooperation on innovation using more detailed evidence on what the firms directly reported about these deals. Another limitation given by the dataset in hand is the cross-sectional nature of the analysis, because the data could not be connected to the previous vintages of this survey or other surveys by that matter due to confidentiality of the respondents. It remains an important challenge for future research to address these caveats.

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Appendix Table A1: Macro variable definitions and sources

Indicator	Unit	Source of data
Scientific articles: The number of articles published in journals classified and covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI); fractional assignments.	Per million working-age population	National Science Foundation
PCT patents: The number of PCT patent applications; fractional counts; by inventor(s)'s country(ies) of residence and by the priority date	Per million working-age population	OECD Patent Database
Business sector R&D : Expenditures on R&D performed by the business sector	% of GDP	Eurostat
Public sector R&D : Expenditures on R&D performed by the government, higher education and non-profit sectors	% of GDP	Eurostat
Protection of intellectual property: Adherence to protection of intellectual property rights.	Index	Gwartney and Lawson (2005)
Imports of goods and services: The value of all goods and market services received from the rest of the world.	% of GDP	Eurostat
Inward foreign direct investment stock: A received investment that involves a long-term relationship between a resident entity in one economy and an enterprise resident in a different economy.	% of GDP	UNCTAD FDI Statistics
Debit licence payments: Payments between residents and non-residents for the authorized use of intangible assets, proprietary rights and produced originals.	% of GDP	Eurostat
Population: The number of inhabitants aged 15-64 (working-age population)	People	Eurostat

Appendix Table A2: Descriptive statistics of the macro variables

Country	COtotal	COdom	COforEU	COforOTH	COforONLY	INFRA	OPEN	SIZE
Austria	17.4	15.2	9.9	3.0	2.2	0.9	-0.4	0.1
Belgium	35.7	30.9	24.0	10.9	4.8	0.8	1.5	0.2
Bulgaria	22.0	17.9	12.0	6.3	4.1	-1.3	-0.1	0.1
Cyprus	37.0	27.5	18.3	4.0	9.5	-0.9	0.4	-1.6
Czech Rep.	38.4	34.1	24.5	6.2	4.2	-0.3	0.4	0.3
Denmark	42.8	38.7	27.8	9.6	4.1	1.4	0.2	-0.2
Estonia	34.8	28.8	24.5	9.6	6.1	-0.2	1.0	-1.2
Finland	44.4	44.0	30.0	13.7	0.4	1.5	-0.5	-0.2
France	39.5	36.9	16.3	9.6	2.6	0.9	-0.7	1.5
Germany	16.0	15.3	4.7	2.6	0.6	1.1	-1.2	1.7
Greece	24.0	19.7	11.9	6.1	4.4	-0.4	-1.6	0.3
Hungary	36.8	34.2	17.7	5.0	2.6	-0.2	1.0	0.2
Italy	13.0	12.4	2.5	1.1	0.5	0.2	-1.9	1.4
Latvia	38.8	36.0	22.6	17.4	2.9	-1.2	-0.3	-0.8
Lithuania	56.1	50.9	30.8	13.7	5.2	-1.2	-0.4	-0.5
Luxembourg	30.5	22.0	27.3	10.5	8.5	0.0	2.4	-1.9
Malta	31.9	16.0	22.9	18.1	16.0	-1.2	1.1	-2.0
Netherlands	39.4	35.7	20.5	9.4	3.7	1.2	1.2	0.6
Norway	33.2	30.9	19.3	9.7	2.4	1.0	-1.0	-0.3
Poland	42.2	36.1	17.6	5.1	6.1	-1.0	-0.5	1.2
Portugal	19.4	17.9	10.6	3.6	1.5	-0.4	-0.3	0.3
Romania	17.5	13.3	7.5	1.7	4.2	-1.8	-0.8	0.8
Slovakia	37.7	33.5	29.7	7.7	4.1	-0.8	0.7	-0.2
Slovenia	37.2	34.7	22.9	7.6	2.6	0.3	-0.4	-0.9
Spain	18.2	17.2	4.3	1.3	1.1	0.1	-0.4	1.2
Sweden	42.8	40.2	21.2	6.9	2.6	1.5	0.2	0.1

Note: COtotal = enterprise engaged in any type of innovation cooperation (% of innovative enterprises); COdom = enterprise engaged in innovation cooperation with any type of a domestic partner (% of innovative enterprises); COforEU = enterprise engaged in innovation cooperation with any type of a partner in other European Union (EU) countries, EFTA, or EU candidate countries (% of innovative enterprises); COforOTH = enterprise engaged in innovation cooperation with any type of a partner in other countries (% of innovative enterprises); COforONLY = COtotal – COdom.
Source: Appendix A1

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