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Cooperation and Innovative Performance of Firms: Panel Data Evidence from the Czech Republic, Norway and the UK

Martin Srholec

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Abstract Using panel micro data fro\m Community Innovation Survey in the Czech Republic, Norway and the UK, we estimate dynamic random effects models, in which the innovation output of firms is the function of their cooperative behaviour and other observed characteristics, while accounting for unobserved heterogeneity. The results indicate that the capacity of firms to build on external domestic linkages is what matters most for their innovation output and that external foreign cooperative linkages lead to superior innovative performance only if combined with the domestic ones. Hence, the findings support the take on globalization prevalent in innovation studies that the home base continues to matter and back up the arguments in geography of innovation on the importance of combining local and distant interactions.

Keywords Innovation · Cooperation · Performance · Micro data · Community Innovation Survey

Introduction

Traditionally, dynamic micro analyses of innovation focused on the relationship between R&D and patents on one hand and on the impact of these rather narrowly defined innovation activities on performance of firms on the other hand (Mairesse and

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M. Srholec (✉)
CERGE-EI, Economics Institute, Academy of Sciences of the Czech Republic, Politických vězňů 7,
111 21 Prague 1, Czech Republic
e-mail: martin.srholec@cerge-ei.cz

M. Srholec
Centre for Technology, Innovation and Culture (TIK), University of Oslo, Oslo, Norway

Mohnen 2010). But innovation may be conducted in many ways, by combining knowledge from diverse sources, with different productivity in terms of the firm performance (Fagerberg et al. 2004). Some of this knowledge is inside of the firm, while other elements need to be obtained externally (Nelson 1962; Richardson 1972; Lundvall 1988). Arrangements to cooperate on innovation with other organizations facilitate access to the external sources (Miotti and Sachwald 2003). But how much difference does this really make? Are cooperative firms more productive in selling innovated products? And what kind of linkages, at home or abroad, are more rewarding?

Over the last two decades, the so-called Community Innovation Survey (CIS) has been conducted in many countries offering new evidence on the innovative behaviour of firms. Availability of micro data from these surveys triggered a bourgeoning body of empirical literature, including research on the impact of cooperation on firm performance (Klomp and van Leeuwen 2001; Lööf and Heshmati 2002; Cincera et al. 2003; Janz et al. 2003; Miotti and Sachwald 2003; Okamuro 2007; Lööf 2009; Simonen and McCann 2008; Aschhoff and Schmidt 2008; Arvanitis and Bolli 2009), which is increasingly conducted by econometric methods. So far, this research has predominantly relied on cross-sectional data; however, evidence based on longitudinal datasets remains thin (Belderbos et al. 2004, 2006; Raymond et al. 2009; Arvanitis 2012).

The aim of the paper is to help in filling this gap. Using an unbalanced panel of micro data from several waves of CIS in the Czech Republic, Norway and the UK, we estimate dynamic random effects Tobit model, in which the innovation output of firms given by innovative sales is the function of cooperation and other observed characteristics of firms, while accounting for unobserved individual heterogeneity. The paper contributes to this line of research in four ways. First and foremost, we present new evidence in the dynamic panel design. Second, and a related point, is that using lagged predictors, including the lagged dependent variable, allows us to be more confident about causality. Third, we estimate the same model for multiple countries, which has been done before, but there is a need for more comparative research of this kind. Finally, the distinction between domestic and foreign cooperation is essential but seldom considered in literature on this topic.

The paper proceeds as follows. Section "Theory" discusses the theoretical background, derives the hypotheses to be tested and surveys the existing empirical evidence. Section "Data" presents the longitudinal panel datasets. Section "Econometric Model" outlines the dynamic Tobit model and explains the specification. Section "Econometric Results" gives results of the econometric estimates. Section "Conclusions" pulls the strands together.

Theory

Innovation as a new combination of productive means builds on diverse sources of knowledge (Fagerberg et al. 2004). Some of them are inside of the firm, while others need to be obtained externally. Firms have to decide on the combination of ways to organize their innovative efforts, either through building internal capabilities, arms-length acquisition of knowledge on the market or through cooperation with other organizations (Nelson 1962). But the purely "off-the shelf" purchase is often not efficient because transfer of knowledge requires interactive learning between users and producers (Lundvall 1988). Arrangements to cooperate on innovation facilitate access to these hard to transfer external sources of knowledge.

Already Richardson (1972) recognized the increasing trend in cooperation between firms. Firms are not islands separated by deep waters of market transactions, as he forcefully argued, but are linked together in patterns of cooperation, especially as far as the transfer, exchange or pooling of technology between firms with different capabilities for the purpose of developing new products is concerned. As the result, costs of developing these capabilities become spread across the cooperating firms, thereby permitting the exploitation of economies of scale and scope.

According to the knowledge-based extension of the "resource-based theory of the firm" by Nonaka and Takeuchi (1995), firms build on strategic capabilities, containing elements of tacit knowledge, which encourages them to pool resources with other organizations to access knowledge complementary to their own. Strategic motives for firms to cooperate on innovation have been further elaborated in the literature on alliances (Gulati 1998; Sachwald 1998; Miotti and Sachwald 2003). Innovation cooperation is seen as an organizational answer to increasing complexity of research, heightening global competition and rapid technology progress.

If agents are not fully able to appropriate benefits from their own innovative efforts, the problem of cooperation on innovation becomes intimately linked to the issue of knowledge spillovers (De Bondt 1996). Game-theoretic models of strategic investment in imperfect markets presume that cooperation allows firms to internalize knowledge spillovers through joint decisions on innovation (D'Aspremont and Jacquemin 1988). From the literature in this tradition follows that in situations like these, cooperative innovators should perform better and yield higher returns on their own innovative efforts.

Building on evolutionary perspectives, the interactive nature of innovation process has been elaborated in the literature on national innovation systems by Lundvall (1992), Nelson (1993) and Edquist (1997). The ability of firms to capitalize on external knowledge embedded in social networks is seen as crucial for successful innovation. Localized nature of interactive learning has been emphasized in the literature on regional innovation systems. The regional perspective highlights relationships among the internal organization of firms, their connections to one another and to the social structures and institutions of their particular localities (Asheim and Gertler 2004).

Cook (2004) even proposes the term "collaborative manufacturing" to capture the tendency to see value chains as the principal driver of new, more orchestrated relationships between customers and suppliers, which is increasingly important in industries with supply chains organized in value networks. Gertler (2004) points to the fact that systems of innovation and production have become more social in nature as production systems are increasingly characterized by a more finely articulated social division of labour, achieved through the process of vertical disintegration of large firms and the growing use of various forms of outsourcing.

Generally speaking, cooperation unlocks the internal constraints for innovation. Building partnerships facilitates access to external sources of knowledge, spreads costs and risks among the partners and allow firms to benefit from division of labour in innovation. More variety of knowledge at firm's disposal implies greater opportunity for innovation to arise. By networking, firms pool complementary resources with other organizations and make use of resources owned by others. From this follows the baseline hypothesis, according to which firms that cooperate on innovation are more productive in terms of their innovative performance.

Yet, cooperation on innovation is neither free nor easy. Running of cooperative projects entails extra resources, investments and costs. Selection of partners is particularly tricky and consumes time; thus, there are search costs. Travel and communication costs decreased but did not disappear because cooperation requires face-to-face interaction (Gertler 1995), at least at the beginning to establish the connection. The partners on both ends need to develop a platform for cooperation in order to engage in the interaction efficiently. Also, there are additional transaction costs for running joint projects in terms of increased management complexity, bridging barriers and conflict resolution.

Furthermore, cooperation on innovation requires conscious capability building. For firms to benefit from cooperation, they need capabilities to understand external knowledge, such as those usually grouped under the rubric of absorptive capacity coined by Cohen and Levinthal (1990). As shown vividly by Hildrum (2010), joint innovation projects require specific cooperative capabilities, managerial style and "open" sentiment of the participating organizations, which do not develop easily, but without which the venture does not operate properly. Accumulating "know-who" about the partners, the element of knowledge in terms of Lundvall and Johnson (1994), is another precious resource needed for engaging in cooperation.

So, not all cooperative projects necessarily pay off. Some of them partly or even completely fail. If cooperating on innovation involves too much hassle, if the extra costs associated to cooperating turn out to be steep and the resources consumed by cooperation are lacking elsewhere, the benefits in terms of better innovative performance may not materialize. Hence, the ultimate impact on performance depends on the balance between the presumed benefits and the extra costs of innovating in the cooperative manner, of which the former are generally expected to dominate, though there is likely to be a certain segment of the cooperative deals that do not deliver.

One important distinction in this respect, yet too little considered in the literature on innovation cooperation, is between domestic and foreign partners. Many of the perks outlined above are probably more significant in cooperation with foreigners. For instance, foreign cooperation offers particular benefits in terms of diversifying knowledge base in firm's disposal, hence helping firms to prevent from being locked into a possibly narrow location-specific technology path and hence boosting the potential for innovative solutions by the combination of local and distant sources of knowledge (Cantwell 1995; Narula 2002; Bathelt et al. 2004). From this follows the refinement of the baseline hypothesis, namely that the positive impact of foreign cooperation on performance is expected to be higher than domestic linkages.

On the other hand, however, most of the problems are also likely to be more daunting in cooperation with foreigners, which in turn appears relatively more prone to end up in a blunder. Selection of foreign partners surely entails much higher search costs. Foreign cooperation encompasses organizations embedded in different socio-institutional, legal and cultural environment. The partners need to develop shared institutions, which is taken for granted in the national context. They need to bridge additional cognitive barriers, and they need to find ways to "speak the same languages" in order to enable joint learning; not mentioning elevated travel and communication costs. Firms are expected to cooperate abroad, only if there are no relevant partners at home. From this follows the rival thesis, which in contrast postulates that due to these extra difficulties foreign cooperation is less beneficial for performance than engaging domestic partners.

Another logic conclusion that follows from this reasoning is that foreign cooperation is the more risky option with higher variability of outcomes. More unknowns chip in, promising big gains, but at the same time increasing the probability of a failure. Hence, the results should be more unstable, there is likely to be more diversity of the impact on performance among the firms cooperating abroad than those at home. And the results of foreign cooperation are also probably more varied between different settings, such as across countries and over time. As a consequence, the impact of foreign cooperation can be more difficult to pin down econometrically.

A large body of empirical research on the relationship between cooperation and innovative performance relies on cross-sectional data. Most of the existing papers, for instance Klomp and van Leeuwen (2001), Lööf and Heshmati (2002), Cincera et al. (2003), Miotti and Sachwald (2003), Lööf (2009), Simonen and McCann (2008) and Arvanitis and Bolli (2009), found a positive connection, while several others, namely by Janz et al. (2003), Okamuro (2007) and Aschhoff and Schmidt (2008), did not. Nevertheless, cooperation happens during the "search" phase of the innovation project, when commercially viable output may not exist yet, so the transformation to improved performance is likely to take some time and lags should be allowed in estimating this relationship.

To the best of our knowledge, the twin papers by Belderbos et al. (2004, 2006) based on two periods of CIS data in the Netherlands represent the first attempts to consider the impact of cooperation on performance in a dynamic framework. Belderbos et al. (2004) strongly backed up the contribution of cooperation to the growth in innovative sales and value added per employee. Belderbos et al. (2006) in a follow-up paper in which they focused on complementarity in cooperation strategies confirmed the positive impact on growth in labour productivity.

Using data derived from three CIS-like surveys in Switzerland, Arvanitis (2012) not only examines cooperation in general but also rather unique evidence on how different motives for cooperation affect firm performance. The results show that cooperation driven by each of the seven goals considered in the study has a positive impact on both firm innovativeness and productivity; however, technology-motivated projects turned out to have smaller impact on productivity than cost-motivated cooperation.

It should be further noted that Raymond et al. (2009) provide dynamic evidence on the link between innovation inputs, outputs and the performance of firms that takes into account the cooperative behaviour of firms based on date from five waves of CIS in the Netherlands. Yet, they only included the overall cooperation variable in the current period, not examining the time distribution. Although the impact of cooperation did not merit much of their attention, the estimated coefficient of this variable was not even reported; they hinted on the fact that cooperative firms incurred larger innovation expenditures and that cooperation had a significantly positive impact on innovation output.

Overall, hence, the existing evidence is largely in favour of the positive impact of cooperation on performance of firms. But most of this research is limited to cross-sectional evidence. Dynamic panel data literature on this topic is very thin and limited to evidence from a couple of countries. All too many relevant questions remain unanswered.

Data

The paper is based on panel data at the firm level obtained from merging several waves of CIS conducted by national statistical offices in the Czech Republic, Norway and the UK, namely the Czech Statistical Office, Statistics Norway and the Office of National Statists (ONS). Following the Oslo Manual (OECD 1997, 2005) a harmonized methodology has been used to collect the data. Yet, there are several differences in how the respective countries implement the survey and changes of the methodology over time that we need to kept in mind.

CIS by default collects information only on firms with ten and more employees. The data are collected on the base of a sample survey in the UK, while a combination of sampling small firms (from 10 to 249 employees) and a census of large firms (with at least 250 employees) is used in the Czech Republic and Norway. Answering is compulsory in the Czech Republic and Norway, but voluntary in the UK. Hence, the response rate edged up to 95 % in Norway, oscillated between 60 and 80 % in the Czech Republic and increased from around 40 to 60 % in the UK. This has consequences for the potential for creating a panel dataset.

Table 1 provides overview of the data. To create a panel, we merged four consecutive waves of CIS in each country. CISw1, CISw2, CISw3 and CISw4 shortcuts indicate the respective wave of the survey. CIS has a 3-year reference period. Even though there is 1-year overlap between some of the consecutive periods, this does not pose a problem in this paper because as further explained below, the dependent variable refers to outcomes in the final year of the period; thus, there is no period overlap with the lagged predictors.[1]

CIS in the earlier periods focused primarily on gathering data on industrial enterprises, whereas the coverage of firms operating in market services has improved only gradually over time. Some sectors have been covered erratically and therefore for the sake of harmonization excluded from the sample, namely the sectors of construction (45), repair, wholesale and retail trade (50–52) and hotels and restaurants (55) (NACE rev. 1.1 codes in the brackets). Because of the combined effect of extending the sectoral coverage and the general trend of improving response rates, the number of observations available for creating the panel dataset tends to increase over time.

Nevertheless, as a consequence of the random stratified sampling, i.e. of the fact that a somewhat different pool of respondents is drawn from the targeted population in each wave of the survey, a certain proportion of the firms appears in the data only once and

[1] Earlier surveys conducted in Norway and the UK, i.e. the so-called CIS1, provide data not sufficiently compatible with the subsequent evidence to be included in the panel. CISw2 in the Czech Republic is the only exception with 2-year reference period, but this should not lead to a serious bias, as the dependent variable is measured in a single year.

Table 1 Overview of the CIS data

Wave	Reference period			Number of observations		
	Czech Republic	Norway	UK	Czech Republic	Norway	UK
CISw1	1999–2001[a]	1995–1997[a]	1994–1996	2,841	2,933	2,109
CISw2	2002–2003[a]	1999–2001[a]	1998–2000	3,495	3,438	6,184
CISw3	2004–2006[a]	2002–2004[a]	2002–2004	6,235	3,732	4,906
CISw4	2006–2008[a]	2004–2006	2004–2006	6,583	5,120	4,876

[a] The questionnaire was filtered for innovatively inactive firms

therefore cannot be used in the dynamic analysis. Hence, an unbalanced panel, which includes firms that are present in at least two consecutive surveys, covers about 29, 34 and 46 % of the firms in the Czech Republic, Norway and the UK, respectively. Note that in the latter country, the last survey has been deliberately designed to collect data for the same firms that answered the preceding one, so most of the unbalanced panel comes from the last two periods.

Table 2 provides definition of the variables. TURNINN is the measure of innovation output, which refers to the proportion of products that were innovated during the reference period in total turnover in the final year. At the centre of the interest are the CO variables for cooperation, which are derived from the set of questions on whether the firm cooperated on innovation with other organizations during the reference period. Firms were asked to indicate whether the partner was domestic or foreign, from which we derive the “dom” and “for” abbreviations. In addition, several types of the partner have been distinguished, including other firms within the respondent’s group, suppliers, customers, competitors, commercial labs, universities and public research institutes, from which follows the basic distinction between internal cooperation within the group denoted by “GP” and external cooperation with the organizations unaffiliated to the same group given by “EXT”.

Hence, there are four dummy variables COforEXT, COdomEXT, COforGP and COdomGP for the respective location and type of partners. Next, because so many cooperating firms engage simultaneously with foreign and domestic partners, we create from these variables three mutually exclusive categories of firms that either cooperated only with partners abroad, only with partners at home or with both of them; these are delineated in the following by two more sets of shortcuts CObothEXT, COforEXTonly and COdomEXTonly for the external partners and CObothGP, COforGPonly and COdomGPonly for the within group cooperation. Finally, GPnonCO denotes the residual category of firms that are affiliated to a group but do not cooperate on innovation with the other members.[2]

Moreover, there is a battery of variables that account for resources, capabilities and structural features of the firms. R&DIN, R&DEX, MAC and ROEK stand for the

[2] Unfortunately, the GPnonCO variable lumps together firms affiliated to a group with headquarters in the same country and abroad because the location of headquarters is not possible to distinguish in the early surveys conducted in Norway and the UK.

Table 2 Definition of the variables

TURNINN	Sales of innovated products as the proportion of total turnover
COforEXT	Dummy variable with value 1 if the firm has a cooperation arrangement on innovation with a foreign non-affiliated partner
COdomEXT	Dummy variable with value 1 if the firm has a cooperation arrangement on innovation with a domestic non-affiliated partner
COforGP	Dummy variable with value 1 if the firm is affiliated to a group and cooperates on innovation with a foreign member of the group
COdomGP	Dummy variable with value 1 if the firm is affiliated to a group and cooperates on innovation with a domestic member of the group
GPnonCO	Dummy variable with value 1 if the firm is affiliated to a group but does not cooperate on innovation with the group members
R&DIN	Intramural R&D expenditure as percent of turnover
R&DEX	Extramural R&D expenditure as percent of turnover
MAC	Acquisition of machinery and equipment specifically purchased for the purpose of innovation as percent of turnover
ROEK	Acquisition of other external knowledge specifically purchased for the purpose of innovation as percent of turnover
PAT	Dummy variable with value 1 if the firm applies for a patent
EXPORT	Dummy variable with value 1 if the firm exports
SIZE	Log of employment
HT	Dummy variable with value 1 if the principal activity of the firm is classified in a high-tech (HT) manufacturing sector according to OECD (2003, p. 156)
MHT	Dummy variable with value 1 if the principal activity of the firm is classified in a medium-high-tech (MHT) manufacturing sector according to OECD (2003, p. 156)
MLT	Dummy variable with value 1 if the principal activity of the firm is classified in a medium-low-tech (MLT) manufacturing sector according to OECD (2003, p. 156)
LT	Dummy variable with value 1 if the principal activity of the firm is classified in a low-tech (LT) manufacturing sector according to OECD (2003, p. 156)
KIS	Dummy variable with value 1 if the principal activity of the firm is classified in a sector of knowledge-intensive services (KIS) according to OECD (2003, p. 140)
OTH	Dummy variable with value 1 if the principal activity of the firm is classified in other (OTH) residual sector not covered by OECD (2003, pp. 140 and 156)

intensity of the innovation process on different inputs given by the amount of expenditure on the respective innovation activity as the percentage of turnover in the final year. To curtail the influence of outliers, we exclude from the sample firms that reported more than 25 % intensity on any of these inputs.[3] PAT represents the appropriability conditions of the firms' knowledge base given by the fact whether the firm applied for a patent over the reference period. SIZE and EXPORT account for the structural features, namely the size of the firm represented by log of

[3] In fact, these extreme values were in many cases mere measurement errors caused by the fact that the firm mistakenly answered the question on turnover in thousands of the local currency units, but the questions on innovation expenditures in the full amount, generating exceptionally high ratios between them. Also note that the denominator is turnover, so the intensity in terms of value added is much higher and therefore generally not feasible beyond this threshold, except perhaps of special circumstances, which are not the concern of this paper.

employment in the final year and the exposure to foreign markets given by the fact whether the firm exports.[4]

Finally, we control for broad sectoral differences by dummy variables derived from the classification of firms in six groups of sectors following the OECD taxonomy of industries based on technology (OECD 2003, pp. 140 and 156). Manufacturing is divided into the so-called high-tech, medium-high-tech, medium-low-tech and low-tech industries, denoted by the HT, MHT, MLT and LT shortcuts. Only relatively recently this taxonomy has been extended to the service sector by specifying the category of so-called knowledge-intensive services, which is denoted by the KIS dummy. OTH refers to the mixed bag of other residual sectors not covered above, such as mining and quarrying, electricity, gas and water supply and transport.

Yet, there is one more difference in how the data is collected that needs to be explained. Oslo Manual (OECD 1997, 2005) defines the category of "innovation active" firms as those that responded positively at least to one of the questions asking them whether they introduced a new product, a new process and whether they had not yet completed (ongoing) or abandoned innovation activities. Accordingly, the harmonized CIS questionnaire devised by Eurostat uses this distinction to filter the way how the respondents are expected to fill in the survey, so only the innovation active firms are asked to report details on their innovation activity regarding the types of innovation expenditure, cooperation on innovation, etc. In other words, firms that do not report to innovate, not even claim to have ongoing or abandoned efforts, do not answer the more detailed questions.

But not every statistical office follows the suit. Table 1 indicates, with the asterisk, which of the surveys in fact adopted this recommendation. None of the questionnaires used in the UK did resort to the filtering. And in Norway, this is the case of the last version of the questionnaire only. As a result, in about half of the surveys, we have non-filtered data, but in the other half, there is missing information on the more detailed questions for those firms that have been spared from answering them, which needs to be harmonized. Since the firms that declared not having any innovation activity whatsoever, logically could not have reported a positive number on these missing figures, we impute zeros to these firms in the variables affected by the filtering. Alternatively, we could refrain from inferring the zeros and focus on the (persistently) innovation active firms only. But this would lead to a potential sample selection bias, which is quite computationally burdensome to handle in the panel data framework.

Table 3 compares averages of the variables in the total pooled dataset and the unbalanced panel subsample. After omitting observations with incomplete records, we arrive to an unbalanced panel of 3,079 firms with 8,218 observations in the Czech Republic, 2,905 firms with 7,986 observations in Norway and 5,013 firms with 10,550 observations in the UK. Hence, the individual firms on average appear in the sample 2.67, 2.75 and 2.10 times in the respective countries out of the maximum of four periods. To a large extent, the unbalanced sample accords with the overall dataset in the UK, while there is a certain bias in the Czech Republic and Norway, primarily

[4] It should be noted that definition of the EXPORT dummy has changed over time from the question on whether "the firm's most significant market is international with a distance of more than 50 km" used in (CIS3 and the earlier) surveys with reference periods ending before 2002 to the question whether "the firm sells goods or services to foreign markets" used in the more recent (CIS4 and later) surveys.

Table 3 Averages of the variable in the total sample and the unbalanced panel

	Czech Republic		Norway		UK	
	Total	Unbalanced panel	Total	Unbalanced panel	Total	Unbalanced panel
TURNINN	0.085	0.109	0.080	0.089	0.101	0.107
COforEXT	0.092	0.144	0.111	0.146	0.075	0.080
COdomEXT	0.144	0.218	0.179	0.225	0.135	0.152
COforGP	0.046	0.076	0.054	0.074	0.045	0.048
COdomGP	0.036	0.058	0.061	0.076	0.055	0.067
GPnonCO	0.253	0.328	0.465	0.510	0.434	0.369
R&DIN	0.004	0.013	0.011	0.026	0.005	0.006
R&DEX	0.001	0.002	0.002	0.005	0.001	0.001
MAC	0.007	0.017	0.004	0.007	0.011	0.014
ROEK	0.001	0.001	0.001	0.019	0.001	0.001
PAT	0.035	0.059	0.081	0.114	0.172	0.229
EXPORT	0.382	0.467	0.498	0.562	0.442	0.464
SIZE	4.328	5.078	3.820	4.183	4.169	4.288
HT	0.051	0.057	0.036	0.046	0.061	0.056
MHT	0.167	0.202	0.111	0.124	0.127	0.123
MLT	0.145	0.133	0.174	0.177	0.134	0.136
LT	0.222	0.194	0.289	0.271	0.209	0.200
KIS	0.240	0.226	0.191	0.186	0.292	0.313
OTH	0.175	0.188	0.209	0.197	0.177	0.172
Num. of obs.	16,013	8,218	9,357	7,986	16,131	10,550
Num. of firms	10,713	3,079	6,437	2,905	11,314	5,013

Number of observations available in the total sample differs by variable due to item non-response

because the data for large firms are collected by census in the latter, which naturally boosts their chances to appear in the sample repeatedly. Large firms are known to behave differently; thus, their oversampling is also reflected in the other variables. But the sectoral composition appears very similar, so there is no a bias along these lines.

Table 4 presents more detailed descriptive overview of the variables in the form as they appear in the econometric estimates, i.e. including their time distribution. For the purpose of this study, the most important insight is the dynamics of these variables. Between standard deviation refers to the variation "between" firms in a given period, while within standard deviation is the variation "within" the same firm over time. Most of the variables show higher variation between firms than within them over time, suggesting a great deal of persistence in firm's behaviour; however, the variables are far from being static. Now, the key question of our interest is whether there are statistically significant dynamic relationships between the cooperation and performance variables.[5]

[5] Note that the scope for variation over time increases with the number of periods; hence, the within variation appears particularly low in the UK, as for the majority of firms in this panel there is data only from the last two surveys.

Table 4 Descriptive statistics of the unbalanced panel data

	Czech Republic			Norway			UK		
	Mean	Between standard deviation	Within standard deviation	Mean	Between standard deviation	Within standard deviation	Mean	Between standard deviation	Within standard deviation
TURNINN	0.111	0.197	0.104	0.079	0.159	0.085	0.088	0.199	0.043
$TURNINN_{t-1}$	0.107	0.195	0.102	0.095	0.182	0.098	0.126	0.246	0.045
$COforEXT_{t-1}$	0.170	0.314	0.198	0.151	0.320	0.145	0.082	0.267	0.064
$COdomEXT_{t-1}$	0.250	0.376	0.213	0.223	0.368	0.212	0.161	0.359	0.088
$COforGP_{t-1}$	0.090	0.238	0.146	0.076	0.228	0.109	0.048	0.204	0.054
$COdomGP_{t-1}$	0.070	0.207	0.133	0.072	0.218	0.146	0.069	0.247	0.061
$CObothEXT_{t-1}$	0.122	0.272	0.187	0.138	0.294	0.187	0.072	0.251	0.061
$COforEXTonly_{t-1}$	0.017	0.109	0.080	0.019	0.113	0.087	0.010	0.096	0.031
$COdomEXTonly_{t-1}$	0.092	0.250	0.162	0.090	0.244	0.172	0.089	0.279	0.073
$CObothGP_{t-1}$	0.014	0.096	0.074	0.023	0.123	0.088	0.019	0.130	0.040
$COforGPonly_{t-1}$	0.056	0.194	0.124	0.058	0.185	0.133	0.029	0.160	0.044
$COdomGPonly_{t-1}$	0.040	0.162	0.108	0.053	0.189	0.133	0.049	0.213	0.051
$GPnonCO_{t-1}$	0.324	0.430	0.212	0.518	0.461	0.240	0.340	0.461	0.111
$R\&DIN_{t-1}$	0.006	0.022	0.008	0.014	0.036	0.013	0.006	0.021	0.004
$R\&DEX_{t-1}$	0.001	0.006	0.004	0.003	0.011	0.007	0.001	0.007	0.001
MAC_{t-1}	0.008	0.024	0.013	0.005	0.018	0.011	0.013	0.031	0.007
$ROEK_{t-1}$	0.001	0.006	0.004	0.001	0.009	0.004	0.001	0.006	0.002
PAT_{t-1}	0.064	0.196	0.127	0.116	0.280	0.152	0.215	0.405	0.089
$EXPORT_{t-1}$	0.529	0.479	0.184	0.580	0.469	0.203	0.449	0.494	0.073
$SIZE_{t-1}$	5.160	1.383	0.155	4.252	1.190	0.204	4.290	1.490	0.085
Num. of obs.	4,750			4,666			5,328		
Num. of firms	3,079			2,905			5,013		

Econometric Model

The aim of the analysis is to estimate the impact of past cooperative behaviour in the innovation process on the current innovation output. The econometric model predicts the output as follows:

$$Y_{it} = \alpha Y_{it-1} + \beta \mathrm{CO}_{it-1} + \gamma x_{it} + \delta_i + \varepsilon_{it} \tag{1}$$

where i is a firm and t is time, so the current innovation output (Y_{it}) is the function of the past innovation output (Y_{it-1}), past cooperation on innovation (CO_{it-1}), other observable characteristics of the firm (x_i), unobserved individual effects (δ_i) and other time-variant unobserved variables (ε_{it}). Since the model is estimated exclusively at the micro level, we suppress using i in the following.

If α turns out positive, there is persistence of innovation output. But the focal point of this study is the estimate of β, which indicates the impact of lagged cooperation.

Besides these predictors, however, there are other characteristics which affect the innovation output. If these other observables are persistent over time, they induce persistence in the outcome. Hence, it is essential to control for as many as possible of them. If in addition relevant persistent characteristics are unobserved, such as the entrepreneurial spirit, latent capabilities or risk profiles of firms, the results may still be biased because of picking up their effects. Hence, it is pertinent to account for these individual effects with the help of dynamic panel data analysis.

More specifically, TURNINN_t is the dependent variable of innovation output. On the right-hand side, the lagged dependent variable TURNINN_{t-1} accounts for the persistence and the square term $\text{TURNINNsquare}_{t-1}$ is included to control for potential non-linearity of this effect because of the upper boundary of the variable that cannot be trespassed by definition. Given the strategic, embedded and path-dependent decision process of firms to innovate and given the fact that existing papers on this topic detected persistence (Peters 2009; Raymond et al. 2009, 2010), the expectation is that the total impact of the lagged dependent variable comes out positive.

CO_{t-1} is in the spotlight. CO_{t-1} refers to the vector of lagged dummy variables for location and type of partners for cooperation on innovation, namely COforEXT_{t-1}, COdomEXT_{t-1}, COforGP_{t-1} and COdomGP_{t-1} and the combinations thereof as explained above. As far as the expected results are concerned, the baseline hypothesis is that their impact is positive; however, as discussed in more detail in the theoretical section, there are competing theses on the relative importance of domestic as compared to foreign cooperation. It will be therefore interesting to see which of them gets stronger support in the data.

Furthermore, the vector of other observed characteristics that we account for consists of the lagged firm-level predictors GPnonCO_{t-1}, $\text{R\&DIN}_{t-1}$, $\text{R\&DEX}_{t-1}$, MAC_{t-1}, ROEK_{t-1}, PAT_{t-1}, EXPORT_{t-1} and SIZE_{t-1}, the battery of sector dummies HT, MHT, MLT, LT, KIS and OTH in the current period, where the latter is the base category and a set of time dummies to control for cross-sectional dependence.

Because the dependent variable is truncated, we use maximum likelihood to estimate Tobit model, and because the number of periods in the sample is rather limited, and therefore some of the key predictors are time-invariant for many firms, we estimate a random effects model. Hence, the unobserved individual effects, i.e. the random effects δ_i, are conventionally assumed to be i.i.d. N(0, σ_δ^2) and the idiosyncratic errors ε_{it} are i.i.d. N(0, σ_ε^2) independently of δ_i (for more details on the estimator see, Stata (2009, pp. 511–522)).

Using lagged predictors, including the lagged dependent variable, allows us to be more confident about the arrow of causality, in the sense of Granger (1969), than the existing cross-sectional research on this topic has been able to do. So, even though it is fully acknowledged that endogeneity, such as the issue of self-selection into cooperation, remains to be a problem because we only partly mitigate the inherent endogeneity bias, this is a step in the right direction. It should be stressed that the estimates do not suffer from a serious problem of multicollinearity because the predictors are not excessively correlated to each other.

It should be noted that we do not tackle the potential problem of initial conditions described by Heckman (1981) that besets estimating dynamic non-linear models. Wooldridge (2005) proposed the so-called “simple solution” of this problem. Peters (2009) and Raymond et al. (2010) detected significant effects of the initial conditions, while Raymond et al. (2009) found a rather small bias. Unfortunately, a major limitation of this solution, however, is that the procedure has been developed for balanced panels with a reasonable number of periods. Since a majority of the firms are observed only in two consecutive periods, this solution is not suitable for us here, as for too many of them, the initial condition is identical to the lagged period. Hence, the initial conditions are assumed to be exogenous.

Econometric Results

The results are presented in four steps. First, we estimate a model with the basic set of CO_{t-1} predictors. Second, we consider the mutually exclusive categories of CO_{t-1}, in order to zoom on the impact of exclusively domestic and foreign cooperation, respectively. Third, we allow for interaction effects between the external and within the same group cooperation partners and hence examine whether they tend to reinforce each other. Finally, we run robustness checks.

To make easier the analysis of national differences, we report results of the same model by country with the Czech Republic in the first, Norway in the second and the UK in the third column of the regression tables.[6] Marginal effects for the expected value of the latent dependent variable unconditional on the censoring are reported; predictors are fixed at their means.[7] Stata 11 has been used to perform the estimates.

Table 5 gives the first set of results. In line with expectations, TURNINN_{t-1} comes out with positive and highly statistically significant coefficient, hence confirming the persistence of innovation output, and $\text{TURNINNsquare}_{t-1}$ turns out significantly negative, hence supporting the assumed non-linearity of this relationship. And this result holds regardless of the country, sample and model specification, as shown in the additional tests presented below, so we close the discussion on this issue by concluding that there is a strong support for the persistence of innovative output.

COdomEXT_{t-1} for the occurrence of linkages with external domestic partners is the only cooperation variable that comes out with highly statistically significant coefficient. Given the magnitude of the marginal effects, firms that cooperated with the external domestic partners are estimated to achieve by 1.3 to 2.8 percentage points higher share of innovative sales. At the first glance, this might not seem that much. But if compared to the sample mean that ranges from 7.9 to 11.1 percent, the estimated impact actually represents an increase by about one fourth to one sixth depending on the country, which is a sizeable boost. Hence, generally speaking, the baseline thesis is backed by the data.

[6] Since the confidential micro data from the Czech Republic and the UK could have been accessed only in the premises of the respective national statistical offices, and prohibited to take out from the terminal, we could not merge the national datasets together in order to perform the estimates on a combined cross-country sample.

[7] Just as there are three expected values of Tobit, i.e. the probability of being uncensored, the expected value of the dependent variable conditional on being uncensored and the unconditional expected value of the dependent variable, there are three corresponding marginal effects that can be possibly reported. But for the sake of space, only the latter marginal effects are reported because these combine the other two, and therefore, their values naturally lie in between of them. Results of the other marginal effects are available from the author upon request.

Table 5 Results for the basic cooperation variables

	Czech Republic	Norway	UK
$TURNINN_{t-1}$	0.368 (0.035)[a]	0.258 (0.026)[a]	0.350 (0.026)[a]
$TURNINNsquare_{t-1}$	−0.303 (0.040)[a]	−0.182 (0.030)[a]	−0.260 (0.029)[a]
$COforEXT_{t-1}$	0.002 (0.009)	0.007 (0.007)	−0.005 (0.009)
$COdomEXT_{t-1}$	0.028 (0.008)[a]	0.013 (0.006)[b]	0.021 (0.008)[b]
$COforGP_{t-1}$	0.015 (0.010)	−0.012 (0.008)	0.005 (0.011)
$COdomGP_{t-1}$	0.019 (0.010)[c]	0.002 (0.007)	−0.001 (0.009)
$GPnonCO_{t-1}$	0.025 (0.006)[a]	0.003 (0.004)	0.006 (0.005)
$R\&DIN_{t-1}$	0.632 (0.108)[a]	0.452 (0.055)[a]	0.479 (0.090)[a]
$R\&DEX_{t-1}$	0.304 (0.291)	−0.209 (0.136)	0.139 (0.255)
MAC_{t-1}	0.162 (0.093)[c]	0.161 (0.084)[c]	0.148 (0.062)[b]
$ROEK_{t-1}$	0.395 (0.325)	−0.375 (0.203)[c]	−0.019 (0.289)
PAT_{t-1}	0.019 (0.009)[b]	0.024 (0.006)[a]	0.022 (0.006)[a]
$EXPORT_{t-1}$	0.004 (0.006)	0.028 (0.004)[a]	0.027 (0.005)[a]
$SIZE_{t-1}$	0.018 (0.002)[a]	0.004 (0.002)[b]	0.003 (0.002)[c]
CISw3	0.043 (0.006)[a]	−0.016 (0.005)[a]	0.086 (0.018)[a]
CISw4	0.010 (0.006)[c]	−0.017 (0.005)[a]	0.025 (0.006)[a]
HT	0.091 (0.012)[a]	0.077 (0.010)[a]	0.066 (0.016)[a]
MHT	0.082 (0.009)[a]	0.072 (0.007)[a]	0.043 (0.011)[a]
MLT	0.063 (0.010)[a]	0.043 (0.007)[a]	0.036 (0.011)[a]
LT	0.061 (0.009)[a]	0.048 (0.006)[a]	0.040 (0.009)[a]
KIS	0.066 (0.009)[a]	0.061 (0.007)[a]	0.022 (0.008)[a]
Number of observations	4,750	4,666	5,328
Number of firms	3,079	2,905	5,013
$\sigma(\delta)$	0.134 (0.023)[a]	0.000 (0.000)	0.105 (0.093)
$\sigma(\varepsilon)$	0.349 (0.010)[a]	0.315 (0.006)[a]	0.469 (0.023)[a]
ρ	0.128[a]	3.67e-15	0.048
Wald χ^2	855.29	1,043.47	804.87
Log-likelihood	−2,204.287	3,798.430	−2,482.114

Marginal effects are reported. For binary variables, the marginal effects refer to discrete change from 0 to 1. Standard errors are in brackets

[a] Significance at 1 % level

[b] Significance at 5 % level

[c] Significance at 10 % level

Yet, the other modes of cooperation do not seem to make much difference. The only exceptions are within group linkages in the Czech Republic, which come out weakly statistically significant at 10 and 15 % levels for domestic and foreign partners, respectively. This needs to be interpreted together with the fact that another result in which the Czech sample stands out is the positively significant impact of $GPnonCO_{t-1}$. All three variables derived from group membership are therefore relevant, which generally indicates that in this country, affiliated firms tend to be more innovative, if compared to the base category of their non-affiliated counterparts. Arguably, this reflects the essential role of internal technology transfer, particularly in foreign affiliates, that was pivotal for restructuring of the Czech economy (Srholec 2003).[8]

The other predictors come out largely as expected. Appropriability of the firm's knowledge base represented by the PAT_{t-1} dummy helps. $R\&DIN_{t-1}$ has a highly positive impact, MAC_{t-1} contributes a bit too, but external sourcing of knowledge given by $R\&DEX_{t-1}$ and $ROEK_{t-1}$ is not important. $SIZE_{t-1}$ and $EXPORT_{t-1}$ are relevant control variables, except of the Czech Republic again, where the latter is not statistically significant, perhaps because most exporters from this country compete on the base of cost advantages, and they have not started to use innovation as the main source of comparative advantage so far.

To examine in more detail what is behind results of the cooperation variables, particularly the linkages with foreign partners, we change specification of the model by adding the mutually exclusive categories of CObothEXT, COforEXTonly and COdomEXTonly for the external partners and CObothGP, COforGPonly and COdomGPonly for the within group cooperation, instead. Because so many cooperating firms engage simultaneously with foreign and domestic partners, which somewhat blurs this distinction, using these exclusive categories helps us to zoom on the impact of links developed only with partners abroad on one hand and only with partners at home on the other hand.

Table 6 shows the results. $COdomEXTonly_{t-1}$ is the only category that comes out statistically significant across the board, albeit weakly in Norway. So, the capacity to build on exclusively domestic linkages is what matters everywhere. However, the exclusively external foreign cooperation, hence the $COforEXTonly_{t-1}$ category, has a negligible impact in Norway and the UK and a relatively large margin of error in the Czech Republic. Hence, the results are in favour of supporting the thesis that domestic cooperative linkages are more productive. In other words, the extra difficulties of venturing for cooperation abroad seem to offset the presumed benefits to the extent that the total impact tends to be largely inconclusive.

Admittedly, so far, the findings are in a stark contrast to cross-sectional evidence on this topic presented in the papers by Cincera et al. (2003), Miotti and Sachwald (2003), Lööf (2009) and Arvanitis and Bolli (2009), which in a static framework detected the opposite tendency, namely that innovative performance is positively affected by foreign cooperation, but not necessarily by domestic linkages. Of course, they estimated a somewhat different model on data from a different set of countries and over a different period, so the results are strictly speaking not comparable. It well also might be, however, that a dynamic analysis of this kind with the impact of cooperation distributed in time gives a different picture.

Most interestingly, furthermore, cooperation jointly with domestic and foreign partners, given by the $CObothEXT_{t-1}$ dummy, clearly leads to significantly superior innovative performance in the Czech and Norwegian economies as well as delivers a noticeably positive impact in the UK, though in the latter the coefficient is less precisely

[8] Unfortunately, we are not able to distinguish between foreign and domestic owners in the $GPnonCO_{t-1}$ variable in data from the UK; hence, for the sake of comparability, this distinction is not used in the model, but more detailed analysis of the Czech data reveals that the highly positive coefficient of this variable is primarily due to foreign affiliates.

Table 6 Results for the exclusive cooperation categories

	Czech Republic	Norway	UK
$TURNINN_{t-1}$	0.366 (0.035)[a]	0.259 (0.026)[a]	0.349 (0.026)[a]
$TURNINNsquare_{t-1}$	−0.301 (0.040)[a]	−0.183 (0.030)[a]	−0.259 (0.029)[a]
$CObothEXT_{t-1}$	0.029 (0.009)[a]	0.020 (0.006)[a]	0.016 (0.011)
$COforEXTonly_{t-1}$	0.030 (0.017)[c]	0.005 (0.012)	0.001 (0.019)
$COdomEXTonly_{t-1}$	0.035 (0.008)[a]	0.012 (0.007)[c]	0.025 (0.009)[a]
$CObothGP_{t-1}$	0.034 (0.019)[c]	−0.013 (0.012)	0.013 (0.017)
$COforGPonly_{t-1}$	0.013 (0.011)	−0.009 (0.009)	−0.004 (0.012)
$COdomGPonly_{t-1}$	0.020 (0.012)	0.006 (0.009)	−0.008 (0.010)
$GPnonCO_{t-1}$	0.026 (0.006)[a]	0.003 (0.004)	0.005 (0.005)
$R\&DIN_{t-1}$	0.623 (0.108)[a]	0.453 (0.055)[a]	0.484 (0.090)[a]
$R\&DEX_{t-1}$	0.314 (0.290)	−0.216 (0.137)	0.155 (0.255)
MAC_{t-1}	0.160 (0.093)[c]	0.161 (0.084)[c]	0.147 (0.062)[b]
$ROEK_{t-1}$	0.398 (0.325)	−0.374 (0.204)[c]	−0.037 (0.289)
PAT_{t-1}	0.019 (0.009)[b]	0.024 (0.006)[a]	0.022 (0.006)[a]
$EXPORT_{t-1}$	0.005 (0.006)	0.028 (0.004)[a]	0.027 (0.005)[a]
$SIZE_{t-1}$	0.018 (0.002)[a]	0.004 (0.002)[b]	0.003 (0.002)[c]
CISw3	0.044 (0.006)[a]	−0.016 (0.005)[a]	0.086 (0.018)[a]
CISw4	0.011 (0.006)[c]	−0.017 (0.005)[a]	0.025 (0.006)[a]
HT	0.090 (0.012)[a]	0.077 (0.010)[a]	0.066 (0.016)[a]
MHT	0.081 (0.009)[a]	0.072 (0.007)[a]	0.043 (0.011)[a]
MLT	0.063 (0.010)[a]	0.043 (0.007)[a]	0.036 (0.011)[a]
LT	0.061 (0.009)[a]	0.048 (0.006)[a]	0.040 (0.009)[a]
KIS	0.066 (0.009)[a]	0.061 (0.007)[a]	0.021 (0.008)[a]
Number of observations	4,750	4,666	5,328
Number of firms	3,079	2,905	5,013
$\sigma(\delta)$	0.131 (0.023)[a]	0.000 (0.000)	0.107 (0.092)
$\sigma(\varepsilon)$	0.350 (0.010)[a]	0.315 (0.006)[a]	0.468 (0.023)[a]
ρ	0.123 [a]	6.06e-15	0.049
Wald χ^2	858.50	1,043.97	806.15
Log-likelihood	−2,202.391	2,754.570	−2,481.208

Marginal effects are reported. For binary variables, the marginal effects refer to discrete change from 0 to 1. Standard errors are in brackets

[a] Significance at 1 % percent level

[b] Significance at 5 % percent level

[c] Significance at 10 % percent level

estimated, thus statistically significant at 15 % level only. The results support the proposition that firms gain from cooperation, if they are embedded in the domestic milieu and if they team up with foreign partners only to fill in knowledge that is missing at home. Combining foreign and domestic linkages works; however, relying solely on the foreign ones does not seem to pay off that much.

Likewise, Belderbos et al. (2013) based on data on technology transfer, not specifically cooperation, found that the largest impact on productivity is achieved, if firms combine international and domestic transfer strategies, suggesting that a diverse external technology sourcing strategy combining local know-how with know-how from abroad is the most effective.

Finally, we test for the possibility that the external and within group cooperative linkages interact with, hence reinforce, each other. In other words, for example, we test for the possibility that benefits from foreign external linkages are reinforced by cooperative innovation networks within the foreign group or vice versa. Table 7 gives the results of this exercise. Neither of the interaction terms appears highly significant. So, there does not seem to be a credible support for the connection between internal within group and external linkages, which suggests that these networks tend to operate separately, at least as far as their impact on innovative sales is concerned. Affiliated firms, including parts of multinational corporations, do not seem to capitalize on the opportunity for cross-fertilization of knowledge available in internal and external networks. This is in line with the finding by Veugelers and Cassiman (2004) that foreign multinationals tend to constrain local linkages in innovation of their affiliates in the host economy.

So far, we have not discussed the unobserved effects. At the bottom of the table are reported the estimated variance components $\sigma(\delta)$, $\sigma(\varepsilon)$ and consequently ρ, the latter of which is the proportion of the total variance attributed to the individual (i.e. firm level) component. If ρ is close to zero, the unobserved individual characteristics do not account for the outcome, and thus, the panel estimator is not different from a pooled estimator. A likelihood-ratio test has been performed whether ρ is different from zero, which formally compares the pooled and panel estimators.

The results indicate that the unobserved individual variance does not seem to be a serious matter for concern in the UK and Norway, where ρ is very small and virtually equal to zero, respectively, thus not statistically significant at the conventional levels. From this follows that for these countries the model can be estimated using ordinary pooled Tobit. A cursory look at the results of this estimator, not reported to save space, reveals that indeed there is a very little difference compared to random effects Tobit. Note that the insignificance of the individual variance component can be more than anything else the consequence of having a relatively short panel. It will be interesting to see whether this effect becomes more significant in future research based on longer time series.

Nevertheless, ρ is highly significantly different from zero in the Czech Republic. Hence, in this sample, the unobserved effects turn out to be relevant to control for in the dynamic panel data framework because, if not, the variables of interest may pick up the effect of these attributes. One way to interpret this result is that in the Czech context, the innovation process is intensive on capabilities, such as training, quality control and use of information technologies, which have been emphasized as particularly relevant in emerging countries but under-measured in the standard CIS data (OECD 2005, pp. 141–144), thus not properly accounted for here.

Since the unobserved individual effect is significant, however, there can be a bias with regards to the underlying orthogonality assumptions. Unfortunately, not much could have been done about this directly because valid instrumental variables are not available, which is admittedly a chronic problem for empirical research on innovation.

Table 7 Results for interactions terms

	Czech Republic	Norway	UK
TURNINN$_{t-1}$	0.366 (0.035)[a]	0.260 (0.026)[a]	0.351 (0.026)[a]
TURNINNsquare$_{t-1}$	−0.301 (0.040)[a]	−0.184 (0.030)[a]	−0.261 (0.029)[a]
CObothEXT$_{t-1}$	0.032 (0.010)[a]	0.024 (0.007)[a]	0.012 (0.014)
*CObothGP$_{t-1}$	0.035 (0.020)[c]	−0.021 (0.013)	0.021 (0.022)
*COforGPonly$_{t-1}$	−0.001 (0.015)	−0.017 (0.011)	−0.004 (0.017)
*COdomGPonly$_{t-1}$	0.016 (0.017)	−0.001 (0.012)	−0.001 (0.020)
COforEXTonly$_{t-1}$	0.030 (0.022)	0.015 (0.017)	0.011 (0.026)
*CObothGP$_{t-1}$	0.000 (0.000)	0.038 (0.061)	−0.012 (0.099)
*COforGPonly$_{t-1}$	0.010 (0.032)	−0.041 (0.025)[c]	−0.024 (0.029)
*COdomGPonly$_{t-1}$	0.033 (0.080)	0.013 (0.042)	−0.027 (0.041)
COdomEXTonly$_{t-1}$	0.036 (0.009)[a]	0.007 (0.007)	0.026 (0.010)[b]
*CObothGP$_{t-1}$	−0.012 (0.052)	−0.041 (0.039)	−0.022 (0.028)
*COforGPonly$_{t-1}$	0.017 (0.023)	0.006 (0.018)	0.002 (0.028)
*COdomGPonly$_{t-1}$	0.008 (0.019)	0.023 (0.014)[c]	−0.009 (0.012)
GPnonCO$_{t-1}$	0.024 (0.006)[a]	0.003 (0.004)	0.005 (0.005)
R&DIN$_{t-1}$	0.616 (0.108)[a]	0.446 (0.055)[a]	0.482 (0.090)[a]
R&DEX$_{t-1}$	0.328 (0.291)	−0.212 (0.137)	0.152 (0.256)
MAC$_{t-1}$	0.157 (0.093)[c]	0.150 (0.084)[c]	0.146 (0.062)[b]
ROEK$_{t-1}$	0.416 (0.324)	−0.378 (0.203)[c]	−0.036 (0.289)
PAT$_{t-1}$	0.018 (0.009)[b]	0.024 (0.006)[a]	0.021 (0.006)[a]
EXPORT$_{t-1}$	0.005 (0.006)	0.028 (0.004)[a]	0.027 (0.005)[a]
SIZE$_{t-1}$	0.018 (0.002)[a]	0.004 (0.002)[b]	0.003 (0.002)[c]
CISw3	0.044 (0.006)[a]	−0.016 (0.005)[a]	0.086 (0.018)[a]
CISw4	0.011 (0.006)[c]	−0.017 (0.005)[a]	0.025 (0.006)[a]
HT	0.091 (0.012)[a]	0.077 (0.010)[a]	0.067 (0.016)[a]
MHT	0.082 (0.009)[a]	0.072 (0.007)[a]	0.043 (0.011)[a]
MLT	0.063 (0.063)[a]	0.044 (0.007)[a]	0.036 (0.011)[a]
LT	0.061 (0.061)[a]	0.048 (0.006)[a]	0.040 (0.009)[a]
KIS	0.066 (0.066)[a]	0.061 (0.007)[a]	0.021 (0.008)[a]
Number of observations	4,750	4,666	5,328
Number of firms	3,079	2,905	5,013
$\sigma(\delta)$	0.132 (0.023)[a]	0.000 (0.000)	0.106 (0.093)
$\sigma(\varepsilon)$	0.350 (0.010)[a]	0.315 (0.006)[a]	0.468 (0.023)[a]
ρ	0.125 [a]	8.47e-15	0.048
Wald χ^2	856.76	1,051.77	806.72
Log-likelihood	−2,202.723	2,236.889	−2,480.567

Marginal effects are reported. For binary variables, the marginal effects refer to discrete change from 0 to 1. Standard errors are in brackets

[a] Significance at 1 % percent level

[b] Significance at 5 % percent level

[c] Significance at 10 % percent level

As a crude indication to which extent this is a problem, it is instructive to compare results of the pooled and panel estimators. If the difference is negligible, the bias is likely to be small and vice versa.

Table 8 provides results of the pooled estimator for the Czech sample in the first column. The main conclusions remain intact; the estimated coefficients come out very

Table 8 Robustness of results in the Czech Republic

	Excluding the random effect	Without imputing zeros for non-innovators	Large firms only
$TURNINN_{t-1}$	0.405 (0.032)[a]	0.352 (0.052)[a]	0.341 (0.057)[a]
$TURNINNsquare_{t-1}$	−0.322 (0.039)[a]	−0.266 (0.057)[a]	−0.269 (0.062)[a]
$CObothEXT_{t-1}$	0.030 (0.009)[a]	0.016 (0.012)	0.029 (0.013)[b]
$COforEXTonly_{t-1}$	0.034 (0.017)[b]	0.017 (0.023)	0.030 (0.024)
$COdomEXTonly_{t-1}$	0.036 (0.008)[a]	0.020 (0.012)[c]	0.037 (0.013)[a]
$CObothGP_{t-1}$	0.033 (0.019)[c]	0.044 (0.025)[c]	0.057 (0.026)[b]
$COforGPonly_{t-1}$	0.012 (0.011)	0.005 (0.015)	0.018 (0.016)
$COdomGPonly_{t-1}$	0.018 (0.012)	0.017 (0.017)	0.017 (0.018)
$GPnonCO_{t-1}$	0.025 (0.006)[a]	0.016 (0.010)	0.024 (0.009)[b]
$R\&DIN_{t-1}$	0.585 (0.106)[a]	0.878 (0.149)[a]	1.109 (0.249)[a]
$R\&DEX_{t-1}$	0.312 (0.287)	0.422 (0.394)	0.573 (0.536)
MAC_{t-1}	0.166 (0.092)[c]	−0.038 (0.129)	−0.034 (0.156)
$ROEK_{t-1}$	0.375 (0.326)	0.515 (0.439)	0.389 (0.581)
PAT_{t-1}	0.019 (0.009)[b]	0.023 (0.013)[c]	0.020 (0.013)
$EXPORT_{t-1}$	0.004 (0.006)	0.013 (0.010)	0.000 (0.011)
$SIZE_{t-1}$	0.018 (0.002)[a]	0.023 (0.004)[a]	0.025 (0.006)[a]
CISw3	0.045 (0.006)[a]	0.068 (0.010)[a]	0.067 (0.009)[a]
CISw4	0.010 (0.006)	0.040 (0.010)	0.028 (0.010)[a]
HT	0.085 (0.012)[a]	0.122 (0.022)[a]	0.124 (0.023)[a]
MHT	0.077 (0.009)[a]	0.118 (0.018)[a]	0.108 (0.017)[a]
MLT	0.061 (0.009)[a]	0.098 (0.018)[a]	0.097 (0.017)[a]
LT	0.060 (0.009)[a]	0.092 (0.018)[a]	0.100 (0.016)[a]
KIS	0.064 (0.009)[a]	0.089 (0.018)[a]	0.079 (0.020)[a]
Number of observations	4,750	2,434	2,277
Number of firms	3,079	1,652	1,220
$\sigma(\delta)$	–	0.129 (0.020)[a]	0.152 (0.018)[a]
$\sigma(\varepsilon)$	–	0.286 (0.009)[a]	0.286 (0.010)[a]
ρ	–	0.169[a]	0.221[a]
Wald χ^2	–	367.86	337.98
LR χ^2	1,243.46	–	–
Log-likelihood	−2,206.629	−1,055.085	−994.467

Marginal effects are reported. For binary variables, the marginal effects refer to discrete change from 0 to 1. Standard errors are in brackets

[a] Significance at 1 % percent level

[b] Significance at 5 % percent level

[c] Significance at 10 % percent level

similar and the levels of statistical significance are nearly identical, if compared to results of the random effects estimator. Hence, this source of endogeneity seems to be largely inconsequential, at least in a relatively short panel like this one.

Some of the surveys included filtering questions to establish whether the firm had any innovation activity, as already explained above, which in turn we used to impute zeros, wherever they logically belong to. Yet, another approach is to use only on the observations with full information in the raw data, without using the imputation procedure, which in the framework of this panel model implies restricting the analysis to firms that were innovation active in the lagged period. By focusing on this part of the sample, however, the inferences can be influenced by a sample selection bias, which arises when the analysis is limited to a non-randomly restricted sample, and about which little can be done due to the lack of credible instruments to identify the restriction. In other words, we are moving in a vicious circle here.

Table 8 gives results for the sub-sample in which the zeros were not imputed in the second column. Since the filtering was most prevalent in the Czech sample, we use data from this country to demonstrate the impact of this potential problem again. Overall, the estimated signs of the variables of interest are the same, hence the grand picture holds, but some of the estimated coefficients are noticeably smaller, while the estimated standard errors increased for a vast majority of them, resulting in less statistically significant results. But the lower precision of the estimates is not surprising given the fact that the number of observations halved due to this restriction.

Finally, we test robustness of the results to estimating the model on large firms only. As also already explained above, the Czech surveys are based on the combination of a stratified sample of small and medium firms and a census of large firms. As a consequence, large firms have higher likelihood to appear in the sample repeatedly, and in turn for them, the panel data is more "balanced". So, besides testing sensitivity of the results to size of the firm, this also reveals the extent to which the quality of panel influences the estimated coefficients, which is a valuable insight in its own right.

Table 8 shows results for the sub-sample of large firms in the third column. Since the average number of observations per firm increased from 1.5 to 1.9, the supposedly more balanced sample has been confirmed, although this is arguably not a major improvement. The main outcome is that the results are remarkably similar to the benchmark estimate conducted on the full sample, and hence, the findings are strongly robust to the sample composition. Two discrepancies perhaps deserve to be mentioned, namely that the estimated impacts of GPbothGP_{t-1} and $\text{R\&DIN}_{t-1}$ nearly doubled; indicating that these predictors are more intimately linked to the innovation output of large firms, which indeed is feasible. Likewise, the results are largely robust to this restriction in Norway and UK, too.

Conclusions

Overall, the main finding is that the capacity of firms to build on domestic linkages is what affects most their innovation output. Admittedly, this confirms the notion that international business does not undermine the role of domestic innovation systems. Quite the contrary in fact, as argued by Maskell and Malmberg (1999) and Rugman and D'Cruz (2003), this tends to be the outcome of deepening globalization of production and innovation. The results largely confirm the fact highlighted already by Chesnais (1992) and Cantwell (1995) that even if firms invest and cooperate abroad to tap into foreign sources of tacit knowledge, their strategic capabilities remain embedded in indigenous innovation systems. Patel and Pavitt's (1991) and Patel and Vega's (1999) conclusions on "non-globalization" of core technological competencies appear as relevant as ever.

Nevertheless, cooperation on innovation jointly with domestic and foreign partners, in other words combining local and global linkages, has been shown to lead to superior innovation performance as well. Here, the results concord with the arguments aired in the literature on geography of innovation by Bathelt et al. (2004) on the key role of interactions between learning processes taking place among actors embedded in the "local buzz" and knowledge obtained by building "global pipelines" to sources outside of the local milieu because exactly the co-existence of high levels of buzz and many pipelines provides firms with a string of particular advantages not available to outsiders. Hence, foreign external linkages are valuable, but only in combination with the domestic ones.

A major limitation of this study that needs to be acknowledged is that the data allows us only to test for the occurrence of a cooperative agreement, but not for the intensity or quality of the technology transfer involved. Ideally, we would like to use more information on these deals, including the amount of resources devoted to them, which can be perhaps collected in the forthcoming waves of the survey. Further, it would have been of interest to analyse the impact on productivity growth, in terms of value added per worker, but this requires merging innovation surveys with balance sheet data, which unfortunately was not possible. Finally, there are inherent endogeneity problems that have been only partially tackled by including the lagged predictors, so we have been able to show that cooperation is Granger-causing innovative performance, but one needs to be careful to infer on causality beyond this point. It remains a challenge for future research to address these caveats as soon as more extensive data become available in the future.

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