



INNOVATION &
RESEARCH
CAUCUS

ECONOMIC BENEFITS OF INTERNATIONAL RDI COLLABORATION:

Evidence on Product and Process Innovation
(phase 2)

IRC Report No. 063

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Executive Summary

This report presents an econometric analysis of the additionality of international Research, Development, and Innovation (RDI) collaboration for UK businesses focusing on both Business-to-Business (B2B) and Business-to-University (B2U) collaborations. Specifically, the study examines the innovation benefits of collaboration by comparing firms that engage in partnerships with businesses and universities against those that do not collaborate. Additionally, it assesses whether collaborating with international partners provides greater innovation benefits compared to working exclusively with domestic counterparts. By contrasting firms that collaborate versus those that do not, and firms that collaborate internationally versus domestically, this analysis provides valuable insights into the added value of engaging with international partners on self-reported innovation outcomes. Building on the evidence review conducted by Ozusaglam et al. (2024) in Phase 1 of this project, this research addresses key gaps in the literature by evaluating the innovation benefits of international collaboration relative to domestic-only collaborations in the UK context.

Data and Approach

The analysis is based on data from the UK Innovation Survey (UKIS), which provides a representative sample of innovative businesses in the UK. As the UKIS is conducted biennially, the dataset covers seven observation periods between 2009 and 2021 with each wave covering a three-year period. The study focuses on key innovation outcomes, including process innovation, new-to-market (N2M) product innovations, and new-to-business (N2B) product innovations. To estimate the causal effect of collaboration versus no collaboration, and international collaboration versus domestic collaboration in B2B and B2U contexts, we employ a Propensity Score Matching approach combined with a staggered Difference-in-Differences (DiD) estimator proposed by Callaway and Sant'Anna (2021). Together, these approaches mitigate concerns of endogeneity, self-selection and omitted variable bias. In particular, the staggered DiD estimator is suitable for this econometric analysis since businesses are treated at different point in time.

Key findings

- » RDI collaborations matter for product and process innovations. UK businesses engaging in RDI collaborations with other businesses (B2B collaboration) are 21 percentage points

more likely to introduce process innovations and 9 percentage points more likely to introduce new-to-market (N2M) product innovations in respect to businesses who do not collaborate. Those collaborating with universities (B2U collaboration) are 11 percentage points more likely to introduce process innovations. However, B2U collaborations do not significantly increase the likelihood of introducing new-to-market (N2M) or new-to-business (N2B) product innovations.

- » International collaborations are even more important than domestic ones. Compared to UK businesses that exclusively engage in domestic RDI collaborations with other UK businesses, those that collaborate with foreign businesses (international B2B collaborations) are 13 percentage points more likely to introduce process innovations and 7.3 percentage points more likely to introduce new-to-market product innovations. Similarly, those that engage in collaboration with foreign universities (international B2U collaborations) are 11 percentage points more likely to introduce process innovations. However, international B2U collaborations do not significantly increase the likelihood of introducing new-to-market or new-to-business product innovations.

Actionable insights

- » The findings suggest that collaboration with other businesses, regardless of their origin, is likely to improve business innovation outcomes by enabling UK businesses to engage in radical innovations and enhance business processes.
- » In addition, the findings also suggest that business innovation outcome benefits gained through international collaboration with foreign businesses exceed those from purely domestic collaborations.
- » Similarly, collaboration with universities, regardless of their origin, is likely to enable businesses to adopt better processes. However, despite a marginal difference, the potential innovation benefits gained through international university collaboration is similar to that from purely domestic university collaborations. This highlights a potential value of domestic B2U collaborations for enhancing business efficiency.
- » Collaborating with foreign universities is unlikely to yield additional benefits over collaborating with domestic university in terms of enabling businesses to introduce new or significantly improved products and services.

Limitations

- » **Collaboration measures:** The analysis only considers collaborations with businesses and universities; it excludes collaborations with other organisations such as third sector organisations, and government or public research institutes which may have a distinct influence on business innovation.
- » **Innovation measures:** While we consider innovation of different types and of different degrees of novelty, our innovation measures are self-reported outcomes based on businesses' own assessments of their innovation activities.
- » **Mechanisms and moderating effects:** Our data does not allow us to analyse the mechanisms through which the effects identified occur. In addition, we do not observe the characteristics of collaborating partners, such as technological or cognitive proximity to UK businesses. Although these may influence the extent of impact, due to heterogeneity in innovation types and their commercial potentials, it is difficult to provide an estimate of monetary value of innovations at an aggregate level.
- » **Timing of collaboration and innovation:** The UK Innovation Survey (UKIS) is carried out every two years, with each survey covering the previous three years. For example, UKIS 2021 collected information on innovation activities from 2018 to 2020. Because of this setup, we cannot tell exactly when a business introduced an innovation or started collaborating during the three-year period. However, we employ appropriate econometric methods to address this limitation as far as possible, although it cannot be entirely resolved due to the structure of the data.

Next Steps

This econometric analysis serves as an initial step in a broader research agenda aimed at deepening our understanding of the role of RDI collaboration in delivering economic impact for the UK. Future analyses will seek to address the limitations of this study by incorporating additional datasets and methodologies:

- » A parallel study uses a matched dataset linking Gateway to Research (GtR¹) data with UK Intellectual Property Office (IPO) data to assess the economic benefits of public funding for RDI collaborations, with a particular focus on intellectual property (IP) outcomes. This provides a complementary view of innovation outcomes using more objective measures.
- » A further iteration of the empirical analysis will integrate Gateway to Research (GtR) data with the Business Structure Database (BSD) to capture broader business performance metrics and introduce a wider set of control variables, providing a more comprehensive evaluation of the impact of international collaboration.
- » A third strand of this study will involve collecting qualitative data through interviews with businesses that have received public support for international collaboration. These interviews will offer valuable insights into the benefits of international partnerships between universities and businesses. They will also explore the various pathways through which UK university-led international collaborations contribute to economic impact in the UK, examining how and why these mechanisms' function. This qualitative analysis will complement and enrich the quantitative findings.

¹ GtR is an online platform managed by UK Research and Innovation (UKRI) that provides open access to information about publicly funded research projects in the UK.

1. Introduction and Objectives

This report presents an econometric analysis of the additionality of international Business-to-Business (B2B) and Business-to-University (B2U) collaborations for UK businesses, with a specific focus on their impact on innovation outcomes. It builds on Phase 1 of this project, which reviewed existing evidence on the economic benefits of international RDI collaboration. The first phase identified key benefits of international partnerships, such as better bibliometric research outputs, talent development, improved business innovation and sales outcomes, and higher individual and organisational productivity. The review also identified wider benefits such as knowledge spillovers, societal and reputational benefits, national competitiveness and economic growth.

However, it also highlighted significant gaps in the literature regarding the additional value of international collaborations over domestic collaborations, the mechanisms driving these benefits, and the lack of monetised assessments of their economic impact. This study addresses these gaps by employing econometric techniques to examine the causal effects of collaborating with business and university partners versus not collaborating, and collaborating with international business and university partners compared to collaborating solely with domestic partners.

Using data from the UK Innovation Survey (UKIS), the analysis estimates the impact of different types of collaborations on key innovation outcomes, namely process innovation, new-to-market (N2M) product innovations and new-to-business (N2B) product innovations.

1.1. Research objectives

The primary objective of this report is to strengthen the evidence base on the additional economic and business benefits that international RDI collaboration offers to UK businesses, beyond those derived from not collaborating or collaborating only with domestic partners. To achieve this, the analysis explores whether B2B and B2U collaborations as well as international B2B and B2U collaborations have distinct effects on process innovations, N2M and N2B product innovations.

This report forms part of a wider research agenda, with future studies set to integrate additional datasets and methodologies to assess the broader economic impact of international RDI collaboration more comprehensively. By contributing to the growing body of research on

international RDI partnerships, this study aims to inform policy and funding strategies that support cross-border collaborations as a means of driving innovation and strengthening the UK's global competitiveness.

The analysis is based on data from the UK Innovation Survey (UKIS), providing a statistically representative sample of UK regions, industries and of firms of all sizes (Becker et al., 2023). As the UKIS is conducted biennially, the dataset covers seven observation periods between 2009 and 2021. The self-reported innovation outcomes in the UKIS are: process innovation, new-to-market (N2M) product innovations, and new-to-business (N2B) product innovations. These measures capture different dimensions of firms' innovation activities, which may be influenced by international collaboration:

- » Process innovation encompasses changes in business processes used to produce or supply goods and services, regardless of their origin.
- » New-to-market product innovations represent entirely novel products introduced to the market before competitors.
- » New-to-business innovations involve the adoption of innovations that are new to a firm but may already exist elsewhere.

This distinction helps assess whether B2B and B2U collaborations—both overall and specifically at the international level—foster radical, market-defining innovations or facilitate knowledge transfer and incremental improvements within firms.

To estimate the causal effect of collaboration vs no collaboration, as well as the effects of involving international collaboration partners in B2B and B2U contexts—compared to collaborating only with domestic partners—we employ the staggered Difference-in-Differences (DiD) estimator proposed by Callaway and Sant'Anna (2021) in combination with a Propensity Score Matching procedure to mitigate concerns of endogeneity, self-selection and omitted variable bias.

The rest of this report is organized as follows. Section 2 provides a brief overview of the literature that examines the relationship between international B2B and B2U collaboration and business innovation outcomes, focussing on the gaps in the evidence base which this study attempts to fill. Readers should refer to the Phase 1 evidence review in [Ozusaglam et al. \(2024\)](#) for a more detailed exposition of the evidence base. Section 3 describes our data and

approach, including the limitations of our analysis. Section 4 presents the empirical results and Section 5 provides a discussion of these results, highlighting our contribution to the existing literature.

2. Evidence Review and Gaps in the Evidence Base

This study presents evidence on the benefits of international B2B and B2U collaboration for self-reported business innovation outcomes². The Phase 1 evidence review found a growing body of research comparing the innovation benefits of domestic and international collaborations, particularly in B2U and B2B contexts, but none of these are within the UK context (Ozusaglam et al, 2024).

In the B2U collaboration context, existing literature highlights the benefits of international collaboration over domestic on various measures of innovation. Fu and Li (2016) analysed the international collaboration of Chinese firms and found that collaborations with foreign universities were associated with at least an 8% increase in sales from novel innovation. Meanwhile, Fitjar et al. (2016) examined evidence from Norway and found that collaboration between businesses and foreign research partners boosts the likelihood of introducing product and process innovation by between 39% and 45%, while increasing the likelihood of introducing new-to-the market product innovation by 50% compared to domestic collaborations. Based on these studies, one may expect to find strong additional benefits of international B2U collaboration on both product and process innovations, particularly for novel or new-to-market product innovations.

While most studies suggest that international collaboration leads to higher innovation-related performance outcomes compared to domestic collaboration (e.g., Miotti and Sachwald, 2003; Fitjar et al., 2016), findings from studies in B2B contexts are more mixed. For instance, using France's version of the second European community innovation survey, Miotti and Sachwald (2003) found that collaboration with international partners increase the share of innovative products in turnover by 0.37% (with an American partner) and 0.28% (with a European partner). However, Rodríguez et al. (2018) found that the effects of international B2B collaboration in the Spanish context had lesser impact on innovation than domestic collaboration. Based on

² While these business innovation outcomes are measurable, they cannot be monetized in aggregate terms

these studies, therefore, it is unclear whether international B2B collaborations will yield better outcomes than domestic collaborations. The analysis conducted in this study addresses this gap for the UK context and explores additionality in both B2B and B2U scenarios.

3. Data and Approach

3.1. Data

The empirical analysis is based on data from the UK Innovation Survey (UKIS), an official representative survey administered by the Office for National Statistics (ONS) and part of the European Community Innovation Survey (CIS). Its methodology follows the OECD's Oslo Manual (OECD, 1997).

UKIS collects data on firms' innovation activities, R&D, and collaboration for innovation, alongside key economic indicators such as employment, sector, and geographic location. The survey's reliability and validity were assessed through extensive pilot testing by ONS statisticians and economists, as well as the European Commission, before its adoption across multiple European countries (DBEIS, 2019). The UKIS questionnaire is typically completed by a Director, CEO, or R&D manager, following the approach of the Yale survey (Cohen & Levinthal, 1989)³. Each wave of the survey samples approximately 30,000 businesses and achieves an average response rate of 50% (circa 15,000 respondents in each wave). This study constructs an unbalanced panel dataset using responses from seven waves of the survey collected between 2009 and 2021. In total, the dataset includes approximately 98,000 observations collected from 53,000 UK businesses observed at least once across this period. For the purposes of empirical analysis, we limit the sample to firms that participated in at least two waves of the survey during the specified period. As a result, the final dataset includes approximately 66,000 observations from around 22,000 UK businesses. Restricting the sample in this way is important for creating a pseudo panel dataset, which allows us to make direct comparisons across observation periods and identify businesses that engaged in B2B and B2U collaborations, and those that did not.

³ UKIS data are drawn from the ONS Inter-Departmental Business Register (IDBR) using a stratified random sampling method, ensuring representativeness of UK firms with 10 or more employees.

3.2. Approach

To analyse the additionality of engaging in collaboration (treatment) compared to no collaboration (control), as well as international collaboration (treatment) compared to domestic collaboration only (control) on innovation outcomes, we first employ a Propensity Score Matching (PSM) method. This approach creates balanced groups of treated and control observations which are as similar as possible to each other before the treatment takes place. As such, the PSM allows us to obtain a sample of treated businesses by matching firms engaged in collaboration with similar control firms that have not engaged in collaboration. Accordingly, to achieve the best match between the groups we included a set of control variables (see table 1 for detailed descriptions) such as business size, engagement in internal R&D and external R&D, exporting, networking as well as region, sector and time fixed effects. This helps to mitigate endogeneity, self-selection and omitted variable bias⁴ arising from observable factors, which reduces any systematic differences between the treatment and control groups.

We then use the matched sample of observations for the second step of the analysis - the Callaway-Sant'Anna (2021) staggered Difference-in-Difference (DiD) estimator. The DiD estimators are typically used to examine the impact of an intervention (or a 'treatment') by comparing changes in outcomes between observations that received the treatment and those that did not. The Callaway-Sant'Anna (2021) DiD estimator is different than the standard DiD estimation and particularly well-suited for this analysis, as it provides robust estimates in cases where data includes multiple time periods and variation in treatment timing—that is, firms may begin collaboration at different points in time. In addition, the DiD controls for unobserved factors which do not differ significantly over time. This approach enables us to account for time-invariant firm-specific differences (e.g., industry or location) and common time-related trends (e.g., Brexit and the COVID-19 pandemic). The model also allows us to estimate an aggregate impact of B2B and B2U collaboration, as well as the heterogeneous and dynamic (staggered) impact across different time dimensions. Combining PSM and DiD techniques leads to a

⁴ DiD relies on within-group changes over time, therefore it removes bias from omitted variables as long as they do not vary over time differently across groups.

Maryland Scientific Methods Scale score of 3⁵.

In this study, we consider four ‘treatment’ variables relating to:

- i) the first instance of collaboration with another business (B2B collaboration), regardless of their origin.
- ii) the first instance of collaboration with another university (B2U collaboration), regardless of their origin.
- iii) the first instance of collaboration with a foreign business (B2B international collaboration).
- iv) the first instance of collaboration with a foreign university (B2U international collaboration).

We compare firms engaged in collaboration with those that have not, as well as firms collaborating only domestically with those collaborating internationally. We then estimate the impact of these collaborations (treatment) on innovation outcomes in the years following the collaboration. It is important to note that the UK Innovation Survey (UKIS) is conducted biennially, with each wave covering a three-year period. For instance, the UKIS 2021 collected data on innovation activities from 2018 to 2020. Therefore, the treatment time refers to three years and due to this structure, it is not possible to determine the exact timing of when a business introduced an innovation or when it began collaborating within the 3-years window. However, the use of an event study analysis mitigates any issues related to contemporaneity between treatment and outcome, as it allows us to check for the presence of potential pre-treatment trends in the outcome variables, and the evolution in the years following the treatment.

Additionally, given the wide range of collaboration partners available in the UKIS, businesses often engage with multiple types of partners simultaneously. If not accounted for the potential overlaps between B2B and B2U collaborations could bias the results. To account for this, the empirical analysis controls for B2U collaboration when constructing matched control and

⁵ <https://whatworksgrowth.org/resource-library/the-maryland-scientific-methods-scale-sms/>

treatment samples for B2B analysis, and vice versa which helps ensuring a more accurate assessment of each collaboration type's impact.

3.3. Limitations

Our approach has three limitations relating to the completeness of our collaboration and innovation measures:

- » **Collaboration measures:** The analysis only considers collaborations with businesses and universities; it excludes collaborations with other organisations such as third sector organisations, and government or public research institutes which may have a distinct influence on business innovation.
- » **Innovation measures:** While we consider innovation of different types and of different degrees of novelty, our innovation measures are self-reported outcomes based on businesses' own assessments of their innovation activities.
- » **Mechanisms and moderating effects:** Our data does not allow us to analyse the mechanisms through which the effects identified occur. In addition, we do not observe the characteristics of collaborating partners, such as technological or cognitive proximity to UK businesses. This may influence the extent of impact.
- » **Timing of collaboration and innovation:** The UK Innovation Survey (UKIS) is carried out every two years, with each survey covering the previous three years. For example, UKIS 2021 collected information on innovation activities from 2018 to 2020. Because of this setup, we cannot tell exactly when a business introduced an innovation or started collaborating during the three-year period. However, we employ appropriate econometric methods to address this limitation as far as possible, although it cannot be entirely resolved due to the structure of the data.

4. Empirical results

4.1. Descriptive Analysis

This section presents descriptive statistics pertaining to innovation outcomes, as well as the type and geography of collaboration activities that businesses engaged in between 2009 - 2021.

It is important to note that the B2B and B2U collaboration indicators are not mutually exclusive. Businesses that collaborate with UK or international firms may also collaborate with domestic and/or international universities—or they may not. The reverse is also true: collaboration with universities does not necessarily imply collaboration with other businesses. In other words, participation in one type of collaboration does not imply or exclude participation in the other. The two forms of collaboration can overlap, but they are independent. For example, 75% of the sample (around 59,000 businesses) reported no engagement in B2B collaboration while about 90% of the sample (around 71,000 businesses) reported no engagement in B2U collaboration. In addition, about 13% (around 10,400 businesses) participated in domestic B2B collaboration, and 7.5% (approximately 5,800 businesses) engaged in domestic B2U collaboration. In contrast, roughly 12% (around 9,000 businesses) reported engaging in international B2B collaboration, while only 2% (roughly 1,500 businesses) reported international B2U collaboration.

Looking more closely at the type of collaboration, among businesses that collaborated with other domestic businesses, 77% did not collaborate with universities, while the remaining 23% collaborated with domestic universities; none collaborated with foreign universities. Finally, among businesses that collaborated with international businesses, 59% did not collaborate with universities, 26% collaborated with domestic universities and 15% with international universities.

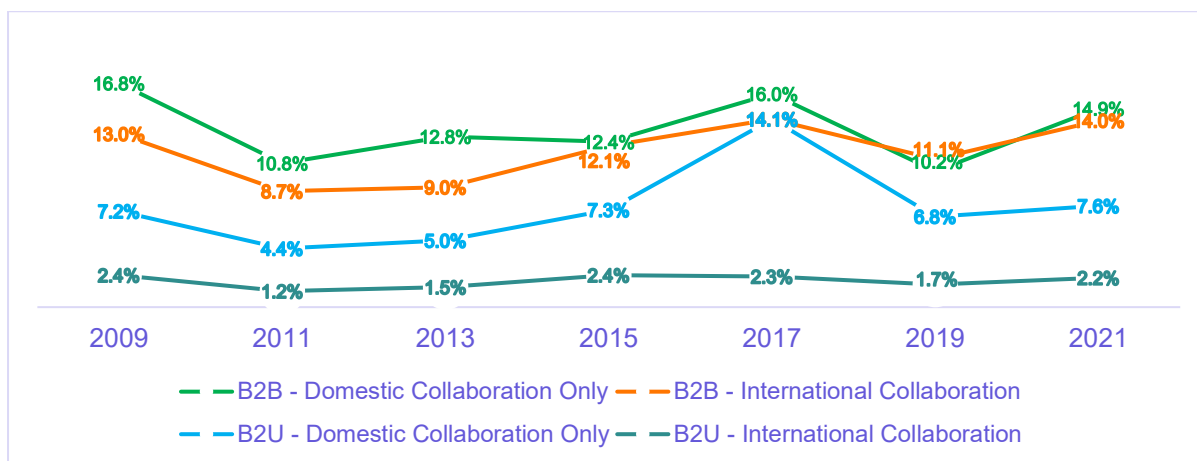


Figure 1: Percentage of business engaging in domestic and international B2B and B2U collaboration by years of observation

Note: Sample size (N) for B2B collaboration = 78,593; B2U collaboration = 78,923.

Figure 1 shows that in 2009, 16.8% of UK businesses engaged in exclusively domestic B2B collaboration and 13% engaged in international B2B collaborations. These figures remained relatively stable across the observation periods. For example, in 2021 these figures were about 14.9% and 14%, respectively. Additionally, in 2009, 7.2% UK businesses collaborated exclusively with domestic universities while only 2.4% UK businesses collaborated with international universities. As before, these figures remained comparable across observation periods, however in 2017, we observe a significant increase in the share of businesses engaging exclusively in domestic B2U collaboration (14%).

4.2. Business-to-Business (B2B) Collaborations and Innovation Outcomes

Figures 2 - 4 illustrate the percentage of businesses that did not engage in B2B collaboration, engaged in domestic-only B2B collaboration and international B2B collaboration, and reported introducing process innovations, new-to-market (N2M) product innovations, and new-to-business (N2B) product innovations over the observation period.

Accordingly, **Figure 2** shows that businesses that engaged exclusively in domestic B2B collaboration generally reported higher rates of process innovation compared to those that did not collaborate or collaborated internationally. For example, in 2009, only 7.7% of UK businesses that did not engage in B2B collaboration reported introducing process innovation compared to 54% of businesses that engaged exclusively in domestic B2B collaboration and 50% of businesses that engaged in international B2B collaboration. Although these percentages remained comparable across observation periods, in 2015 and 2017, the share of process innovators among businesses that did not engage in B2B collaboration increased to 11% in both years. In addition, by 2021, the percentage of process innovators increased to around 60% among those engaged in exclusively domestic B2B collaboration and international B2B collaboration, respectively.

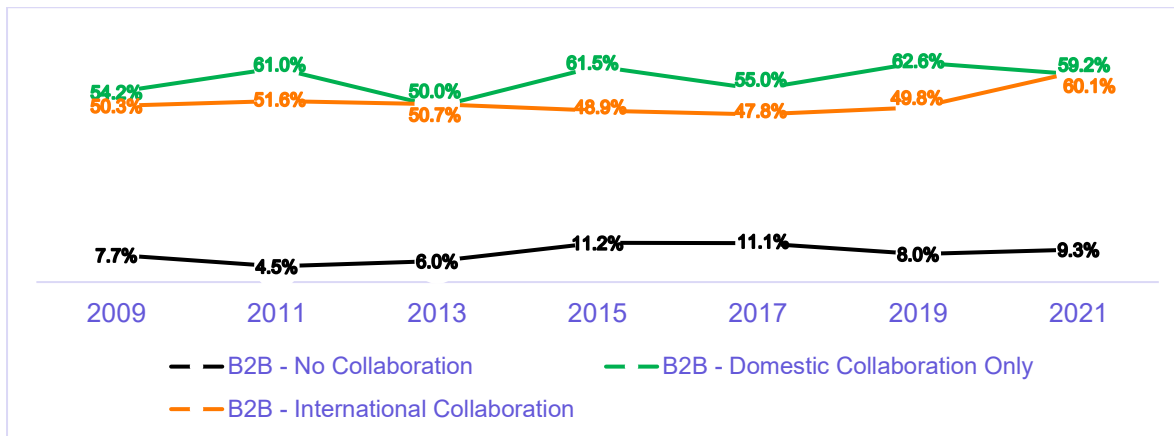


Figure 2: Percentage of business engaged in B2B collaboration reporting process innovation

Note: Sample size (N) for B2B collaboration =78,593.

Similarly, **Figure 3** illustrates that the share of UK businesses reporting N2M innovations is significantly higher amongst those collaborated with domestic and international businesses compared to those did not collaborate. For example, in 2009, only about 6% of UK businesses that did not engage in B2B collaboration reported introducing product innovations that are new-to-market. The figures were 42% for those engaged in domestic B2B collaboration and 51% for those engaged in international B2B collaboration. However, since 2009, the share of businesses has been declining among those engaged exclusively in domestic B2B collaboration and the figures remained below 30% after 2015.

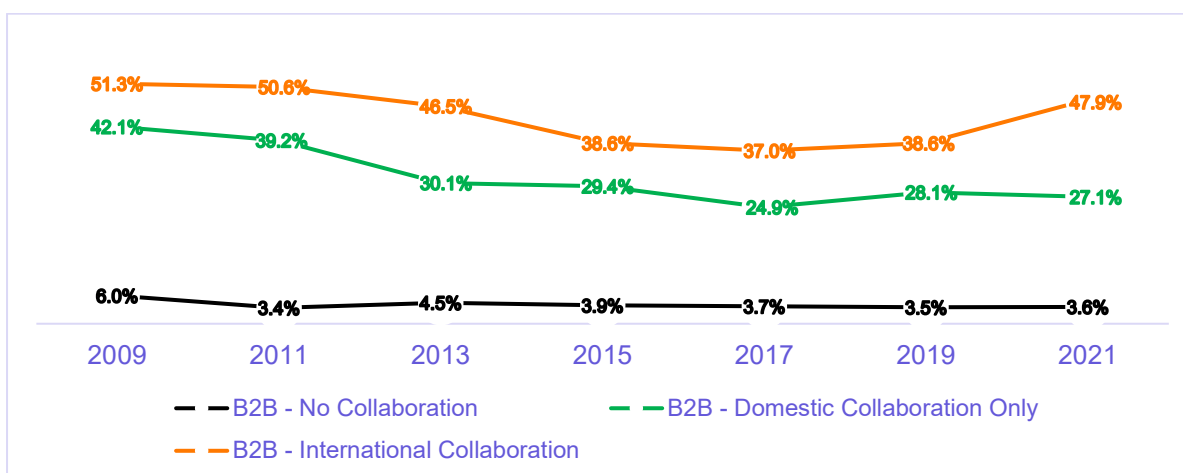


Figure 3: Percentage of businesses engaged in B2B collaboration reporting product innovation N2M

Note: Sample size (N) for B2B collaboration = 77,770.

Figure 4 illustrates that UK businesses that did not engage in B2B collaboration consistently reported lower percentages of N2B product innovations compared to those that collaborated with domestic or international business partners. In addition, UK businesses collaborating only with domestic partners tend to report higher rates of N2B product innovation across the observation periods except in 2021. In 2021, about 8% of non-collaborating businesses, 54% of those collaborated only with domestic partners and 57% of those engaged in international B2B collaboration reported introducing N2B product innovations.

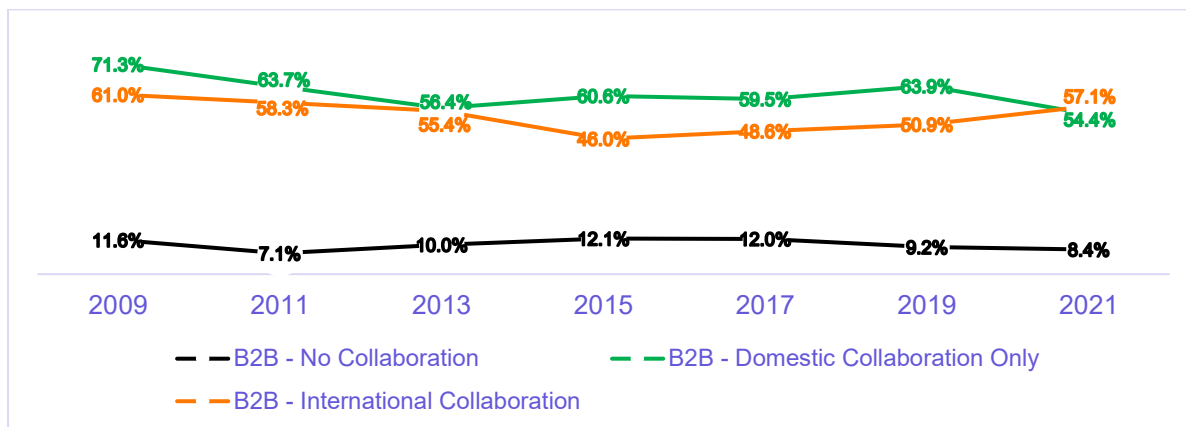


Figure 4: Percentage of businesses engaged in B2B collaboration reporting product innovation N2B

Note: Sample size (N) for B2B collaboration = 77,842.

4.3. Business-to-University (B2U) Collaborations and Innovation Outcomes

Figures 5-7 illustrate the percentage of businesses that did not engage in B2U collaboration, those collaborated only domestically, and those engaged in international B2U collaboration that reported introducing process, N2M and N2B product innovations across the observation period. As observed in the B2B case, businesses that did not engage in B2U collaboration consistently reported lower share of innovation outcomes compared to those that collaborated only with domestic or international universities.

Figure 5 shows that in 2009, around 19% of UK businesses that did not engage in B2U collaboration, 47% of those engaged in exclusively domestic B2U collaboration and 36% of those engaged in international B2U collaboration reported process innovation. Although the share of businesses reporting process innovation varied across the observation periods,

particularly in 2021 we observe a significant increase in the levels of UK businesses reporting process innovation, 20%, 61% and 62%, respectively.

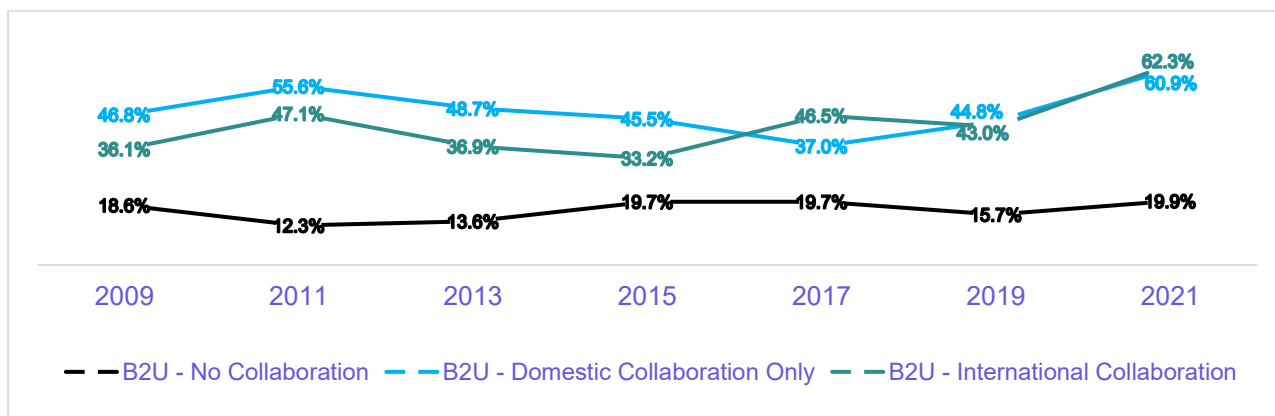


Figure 5: Percentage of businesses engaged in B2U collaboration reporting process innovation

Note: Sample size (N) for B2U collaboration = 78,923.

Figure 6 illustrates that, between 2009 and 2013, businesses collaborating with domestic universities reported higher rates of N2M product innovation than those engaged in international B2U collaboration. However, this trend reversed between 2017 and 2021, with businesses collaborating internationally reporting higher share of N2M innovation. For example, in 2009, 15% of UK businesses that did not collaborate with universities, 48% of those collaborating exclusively with domestic universities, and 36% of those collaborating with international universities reported introducing N2M product innovations. By 2021, these rates were approximately 10%, 45% and 55%, respectively.

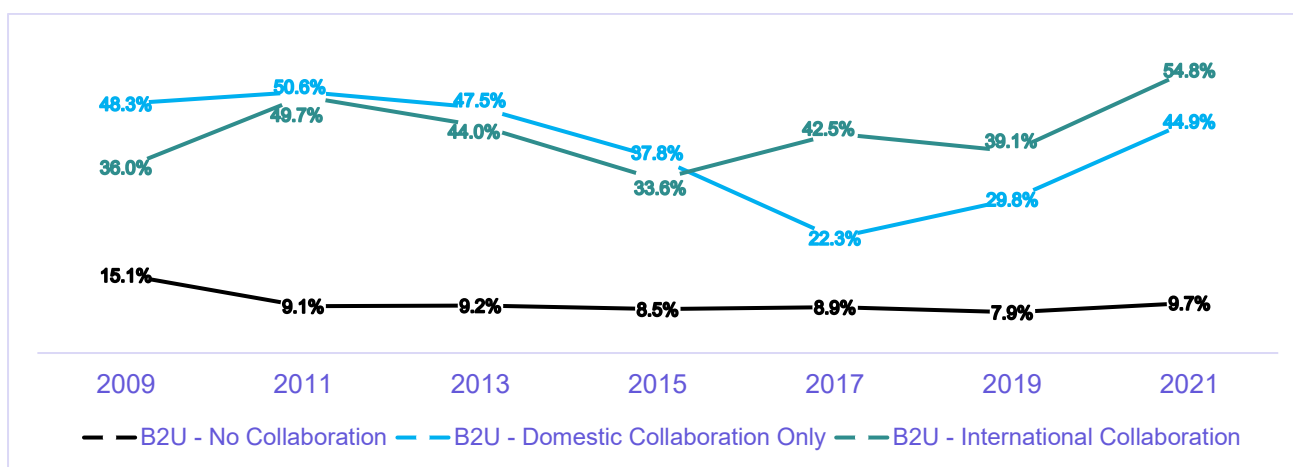


Figure 6: Percentage of businesses engaged in B2U collaboration reporting product innovation N2M

Note: Sample size (N) for B2U collaboration = 78,100.

Figure 7 illustrates that in 2009 approximately 25% of UK businesses that did not collaborate with universities introduced N2B product innovations, compared to 60% of those engaged in domestic B2U collaboration and 39% of those engaged in international B2U collaboration. We also observe that the share of businesses reporting N2B product innovation amongst those engaging in international B2U collaboration has decreased significantly from 47% in 2013 to 25% in 2015. However, this decrease seems only temporary as the figures have adjusted in 2017 and even very slightly exceeded the rates reported by those engage only in domestic B2U collaboration, 39% and 38%, respectively. Nevertheless, on average, the share of businesses reporting introducing N2B product innovations is slightly higher amongst those engaged exclusively in domestic B2U collaboration compared to those engaged in international B2U collaboration and those that do not engage in B2U collaboration.

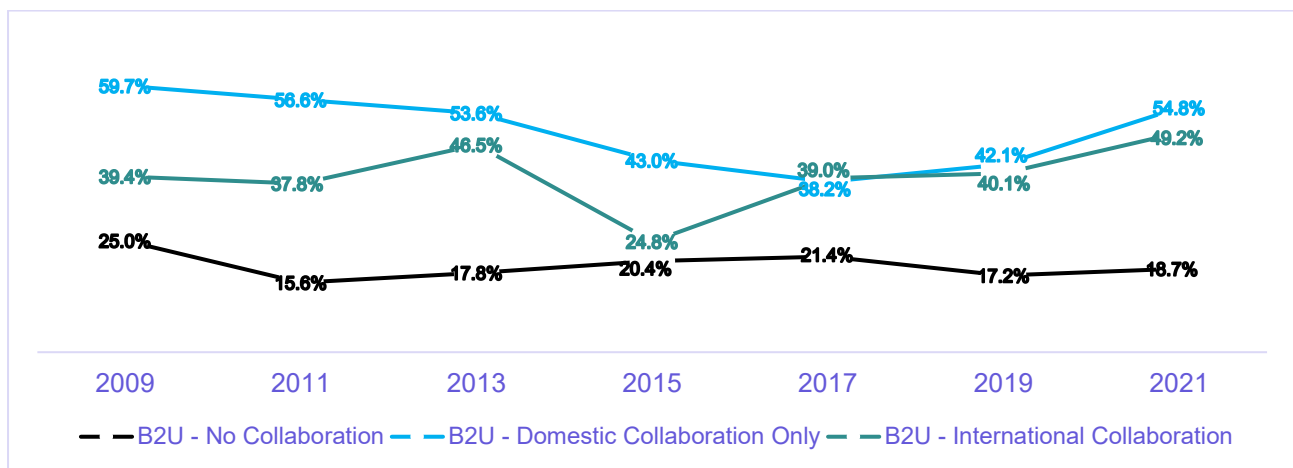


Figure 7: Percentage of businesses engaged in B2U collaboration reporting product innovation N2B

Note: Sample size (N) for B2U collaboration = 78,172.

5. Results from Econometric Analysis

The Callaway and Sant’Anna (2021) staggered DiD approach produces a robust DiD estimator where data, like ours, is characterised by multiple time periods and variation in the timing at which different firms may start collaborating internationally. The model estimates of the aggregate impact of RDI collaborations for each innovation outcome are presented in Table 2.

Table 2: Effects of B2B and B2U Collaboration: Results presents the ATT obtained from Staggered Difference-in-Difference analysis

	Process Innovation	Product Innovation New to Market	Product Innovation New to Business
Business to Business (B2B)			
Collaboration vs No Collaboration	0.21***	0.087**	-0.004
	(0.015)	(0.041)	(0.039)
N	8,459	1,539	1,569
Business to University (B2U)			
Collaboration vs No Collaboration	0.11***	-0.01	0.025
	(0.023)	(0.033)	(0.033)
N	5,666	2,438	2,427
International collaboration vs UK collaboration only	0.107**	0.012	-0.037
	(0.049)	(0.059)	(0.06)
N	1,436	779	784
*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses.			

5.1. Process Innovations

The results indicate a positive and statistically significant impact of collaborating with other businesses (B2B collaboration), regardless of whether the partners are domestic or international, on the likelihood of introducing process innovations. Specifically, businesses engaging in B2B collaboration are 21 percentage points more likely to introduce process innovations compared to those do not engage in B2B collaboration. In addition, businesses engaging in B2B collaboration with foreign business partners are about 13% percentage points more likely to introduce process innovations compared to those engaged in exclusively domestic B2B collaboration. Taken together, these findings indicate that, while any form of B2B collaboration significantly increases the likelihood of introducing process innovation,

businesses that engage in international partnerships are in a particularly strong position to benefit.

The results also indicate a positive and statistically significant effect of collaborating with universities (B2U collaboration) on the likelihood of introducing process innovations. Accordingly, compared to businesses that do not engage in B2U collaboration, engaging in B2U collaboration increases the likelihood of introducing process innovation by 11%. In addition, we also observe that collaborating with foreign universities has a positive and statistically significant effect on the likelihood of introducing process innovations compared to collaborating exclusively with domestic universities. Accordingly, businesses engaging in international B2U collaborations are 11 percentage points more likely to introduce process innovations compared to those engaged exclusively with domestic universities. These results indicate that both international B2B and B2U collaborations play a critical role in enhancing operational efficiency.

5.2. New-to-Market product innovations

Results pertaining to new-to-market (N2M) product innovation also indicate a positive and statistically significant effect of B2B collaboration over no-collaboration, and of international B2B collaboration over domestic B2B collaboration. Specifically, the results indicate that UK businesses that collaborate with other businesses are 8.7% more likely to introduce new-to-market (N2M) product innovations compared to those which do not collaborate. In addition, we also observe that businesses engaging in international B2B collaborations are 7.3 percentage points more likely to introduce N2M product innovations, compared to businesses collaborating with only UK partners. However, we find that, on average, neither collaborating with universities—compared to not collaborating—nor collaborating with international universities over domestic ones has a statistically significant effect on the likelihood of introducing new-to-market (N2M) product innovations.

5.3. New-to-Business product innovations

The results indicate that neither collaborating with businesses or universities—compared to not collaborating—nor engaging with international partners over domestic ones has a statistically significant effect on the likelihood of introducing new-to-business (N2B) product innovations. This indicates that while collaboration may offer other benefits, such as

knowledge exchange and access to new more radical forms of innovations, it does not necessarily translate into a higher probability of adopting product innovations that are new to the business.

5.4. Dynamic effects of international collaboration on business innovation

5.4.1. The effects of international B2B collaborations

This section examines the dynamic effects of business collaboration on innovation outcomes, comparing firms that collaborate with other businesses to those that do not, and firms that engage in international partnerships to those that collaborate exclusively with domestic businesses (**Figure 8–10**). The figures show average treatment effects with 95% confidence intervals.

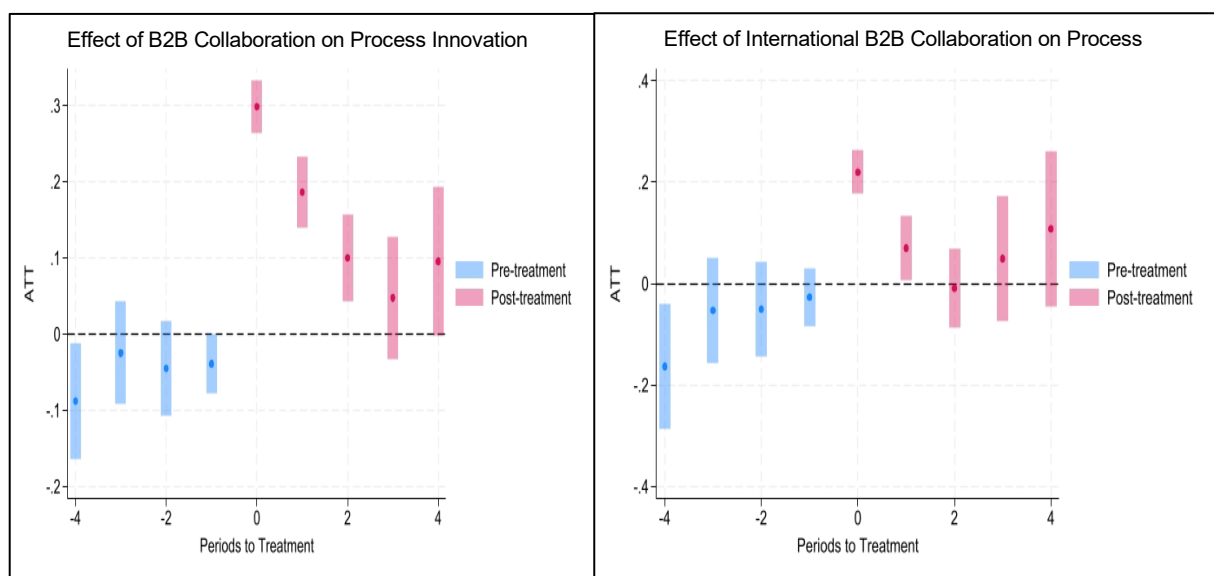


Figure 8: Dynamic Effect of Business-to-Business Collaboration on Process Innovation

Note: N = 8,459 for collaboration vs no collaboration (left pane) and N = 5,879 international vs domestic collaboration (right pane).

Accordingly, **Figure 8** presents the effects of collaborating with businesses—compared to not collaborating (left panel) and collaborating with international businesses—over collaborating exclusively with domestic businesses (right panel), on the likelihood of introducing process innovations.

The left panel figure illustrates that, before the treatment (B2B collaboration) there is no significant difference between treated and control group in terms of the likelihood of introducing process innovation. However, in the treatment year (t_0), the coefficients turn positive, which indicates that collaboration has a significant and positive effect on the likelihood of introducing process innovations. This positive effect remains statistically significant for up to two periods after the collaboration begins ($t+1$ and $t+2$) although the magnitude of this effect decreases gradually over time. Since each treatment period corresponds to three years, the benefits of B2B collaboration persist for up to nine years after the initial collaboration. This highlights the long-term advantages of engaging with businesses to drive process innovation.

Additionally, the right panel figure indicates that compared to collaborating exclusively with domestic businesses, UK firms that engaged in international B2B collaborations were more likely to introduce process innovations for up to one period after the collaboration begins ($t+1$) which is equivalent to up to 6 years. The positive impact in the period following the treatment year is much smaller in magnitude, but nevertheless positive and statistically significant.

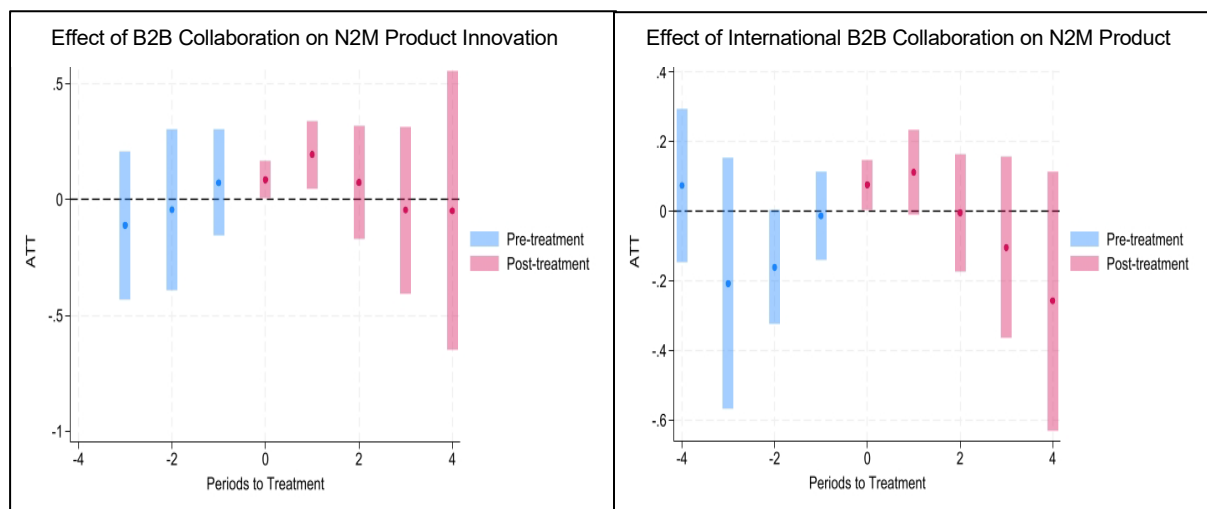


Figure 9: Dynamic Effect of Business-to-Business Collaboration on N2M Product Innovation

Note: $N = 1,539$ for collaboration vs no collaboration (left pane) and $N = 2,300$ international vs domestic collaboration (right pane).

Figure 9 presents the effects of collaborating with businesses—compared to not collaborating (left panel) and collaborating with international businesses—over collaborating exclusively

with domestic businesses (right panel) on the likelihood of introducing new-to-market product innovations.

Accordingly, the left panel in Figure 9 shows that collaborating with business partners has statistically significant positive impact on the likelihood of introducing N2M product innovations in the period of the treatment (t_0) and one period after the collaboration begins ($t+1$). More importantly, we also observe that the positive impact in the period following the treatment year is slightly larger in magnitude than in the treatment period. This indicates that while B2B collaboration have shorter term positive impact, the medium-term (up to six years) impact of B2B collaboration is equally important to introduce new products.

The right panel in **Figure 9** shows that collaborating with international business partners has statistically significant positive impact on the likelihood of introducing N2M product innovations in the period of the treatment (t_0). However, the positive impact is rather short lived as we did not find a statistically significant relationship between international B2B collaboration and the likelihood of introducing N2M product innovations in the period after the treatment (t_0).

5.4.2. The effects of international B2U collaborations

Figure 10 presents the effects of collaborating with universities—compared to not collaborating (left panel) and collaborating with international universities —over collaborating exclusively with domestic universities (right panel) on the likelihood of introducing process innovations.

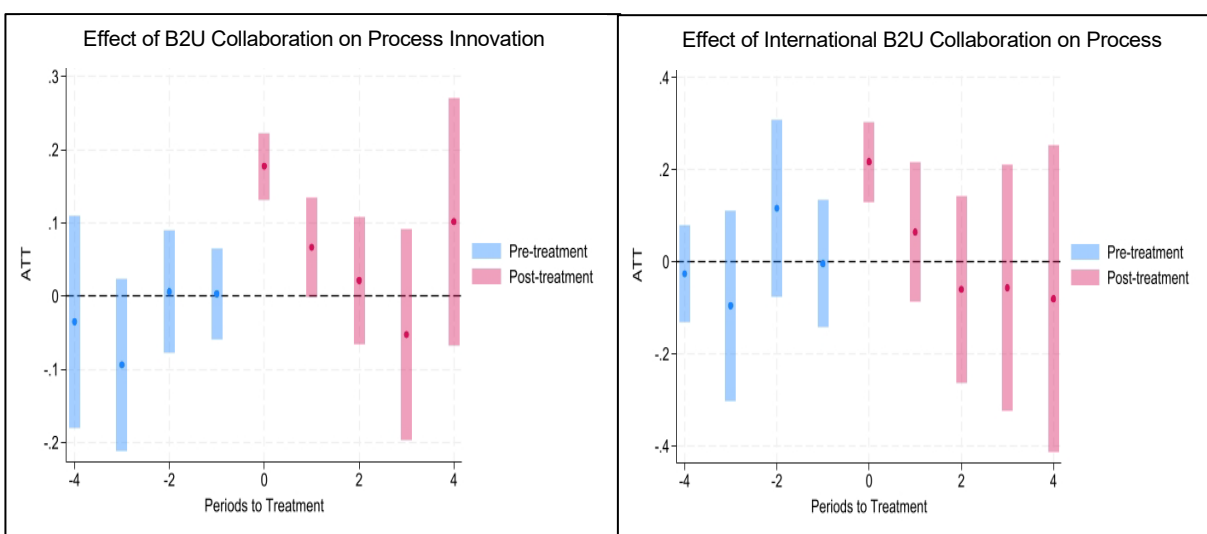


Figure 10: Dynamic Effect of Business-to-University Collaboration on Process Innovation

Note: N = 5,666 for collaboration vs no collaboration (left pane) and N = 1,436 international vs domestic collaboration (right pane).

The left panel figure illustrates that in the treatment year (t_0), compared to those who did not collaborate, there is a significant increase in the likelihood of introducing process innovations for UK businesses that collaborated with universities. Moreover, this positive effect remains statistically significant one period after the collaboration begins ($t+1$) although the magnitude of this effect seems to be halved.

Additionally, the right panel figure indicates that compared to collaborating exclusively with domestic universities, UK firms that engaged in international B2U collaboration were more likely to introduce process innovations for up to one period after the collaboration begins ($t+1$). Although the positive impact in the period following the treatment year is smaller in magnitude, the estimated coefficient nevertheless remained positive.

6. Discussion

The analysis of the UKIS highlights the significance of B2B and B2U collaboration in firms' innovation activities and underscores the differential impacts of collaboration vs no-collaboration, and international vs domestic collaboration on innovation outcomes.

Accordingly, the findings indicate a positive relationship between B2B collaboration and process innovation and new-to-market (N2M) product innovation. Similarly, the results indicate a significant positive relationship between international B2B collaboration and process innovation and new-to-market (N2M) product innovation. Combined, these findings suggest that engaging in international B2B collaborations helps firms introduce or adopt new or significantly improved methods for the production or supply of goods and services and access cutting-edge technological knowledge. This exposure, therefore, seems to support businesses in developing not only new processes but also more radical forms of product innovations (N2M).

Furthermore, a more detailed look at the dynamic effects of B2B collaboration patterns indicate that the innovation benefits of international B2B collaboration appear to be short-lived compared to collaboration with any business partners, whether they are domestic or international partners. For example, in the case of process innovation, the positive effect of B2B collaboration remains statistically significant for up to two periods after the collaboration

begins. Accounting for the treatment year and two periods after the treatment, this is equivalent to up to 9 years. In contrast, the positive effect of international B2B collaboration is statistically significant only up to one period after the collaboration begins. Accounting for the treatment year, this is equivalent to six years. This finding is particularly important as it suggests that UK businesses engaging in B2B collaboration are more likely to achieve longer-term process innovation gains, compared to those engaging in collaboration with international businesses. Nevertheless, it is important to note that due to data limitations, we are unable to investigate the precise mechanisms through which these effects occur. Evidence from the first phase of this project suggests possible pathways to impact, such as firms gaining access to diverse and distant knowledge bases, as well as technological expertise that may not be available in their domestic markets (Ozusaglam et al., 2024).

By comparison, the results of our empirical analysis indicate that the innovation benefits of B2U and international B2U collaborations for UK businesses are, on average, more limited. The positive effects of these collaborations are statistically significant only for process innovation and the dynamic effects of these collaborations tend to be short-lived. Specifically, while partnerships with universities—whether domestic or international—may initially support the introduction of process innovations, this impact tends to diminish after just one period following the start of collaboration. This contrasts with international B2B collaborations, whose benefits tend to persist over time. One possible explanation for this pattern lies in the nature of B2U collaborations, which are often structured as short-term, project-specific engagements, frequently supported by time-limited public funding. Even when not publicly funded, such collaborations are often designed to address narrowly defined technical or innovation challenges, after which the partnership concludes. While these arrangements can deliver targeted and timely benefits, particularly at the early stages of innovation, they may not facilitate the continuous or iterative knowledge exchange required for longer-term innovation outcomes. Accordingly, while B2U collaborations may provide firms with access to advanced research and specialised expertise that support the introduction of process innovations, these benefits appear to diminish quickly. Due to data limitations, however, we are unable to directly assess the duration, structure, or funding sources of these collaborations. Further research is therefore needed to better understand how these factors influence the persistence and scope of innovation outcomes in B2U settings.

Although understanding the mechanisms driving these effects is important, it falls beyond the scope of this study. Nonetheless, evidence from the first phase of this project suggests potential pathways, including firms leveraging university collaborations to access frontier research, specialised technical expertise, and novel scientific knowledge that may not be readily available through domestic partnerships (Ozusaglam et al., 2024). Indeed, the empirical evidence stemming from the analysis in the report indicates that collaborating with international universities provide additional innovation benefits compared to collaborating exclusively with domestic ones. However, the relatively short-lived impact on process innovation, and non-significant impact on N2M and N2B product innovations, may reflect difficulties in translating academic research into innovative product offerings. This could be due to differences in the pace of academic research compared to the development of commercialisable product and process innovations, firms' capacity to absorb and apply new knowledge, or a lack of continued collaboration beyond the initial engagement.

Importantly, our findings are different in some dimensions to other country-specific analysis presented in the existing literature which largely suggests that international collaborations, particularly in B2U contexts, offer greater innovation benefits than domestic collaborations. For example, studies from China and Norway indicate that firms collaborating with foreign universities and businesses experience significant boosts in innovation outcomes (Fu & Li, 2016; Fitjar et al., 2016). In particular, Fitjar et al. (2016) found much stronger effects of international collaboration on various dimensions of innovation in the Norwegian context, where B2U collaboration increased innovation propensity by between 30%-50%. Our results suggest a much weaker effect in the UK context and relating mainly to process innovations. However, it is important to acknowledge the differences between the data and the methodologies used in both of studies. For example, Fu & Li, 2016 employed a national innovation survey dataset of 1,408 manufacturing firms in China which was collected in 2008, and applied cross section data analysis methods. Similarly, Fitjar et al., 2016 used self-collected web-based survey data from 542 firms and applied ordinal logit regression models (a probability model). Accordingly, unlike the findings of these studies, which are based on simple correlations and do not establish causal relationships, our study makes a significant contribution by identifying causal effects.

Prior evidence from international B2B collaborations is more mixed, with some studies finding stronger effects for international partnerships (Miotti & Sachwald, 2003), while others suggest

domestic collaborations can be more beneficial in certain contexts (Rodríguez et al., 2018). Importantly, these studies do not focus on the UK and are limited to specific sectors. For example, Miotti and Sachwald (2003) examine French manufacturing firms, whereas Rodríguez et al. (2018) study knowledge-intensive business services in Spain. As such, there remains a gap in understanding how international collaborations influence innovation within the UK's distinct economic and institutional context.

Our findings address this gap and suggest that the UK's innovation landscape may moderate the expected benefits of both international B2U and B2B collaborations. Country-specific differences, such as industrial composition, policy frameworks, and the nature of domestic university-business ties, are likely to influence the effectiveness of these collaborations. China's manufacturing-driven and state-supported innovation model provides firms with structured government incentives to engage in international partnerships, which facilitates stronger spillovers from foreign university collaborations (Fu, 2015). Meanwhile, Norway's research-intensive economy benefits from long-standing policies that foster close university-industry ties, particularly in strategic sectors like energy and maritime industries (Aslesen & Freel, 2012). In contrast, the UK's innovation ecosystem is more commercially oriented, with a stronger emphasis on business-driven R&D, commercialisation, and market-led innovation (Hughes & Mina, 2012). These structural differences may explain why the benefits of international university collaborations in the UK appear more limited and, in some cases, short-lived.

However, our study is not without limitations. First, the analysis focuses only on collaboration with businesses and universities and excludes other organizations, such as third sector organisations, and government or public research institutes which may have a distinct influence on business innovation. Second, our innovation measures are based on self-reported outcomes, which may lead to potential bias. Third, the data does not allow for an exploration of the specific mechanisms through which the effects identified occur, nor does it account for the characteristics of collaborating partners, such as social or cognitive proximity to UK businesses, which could influence the extent of impact.

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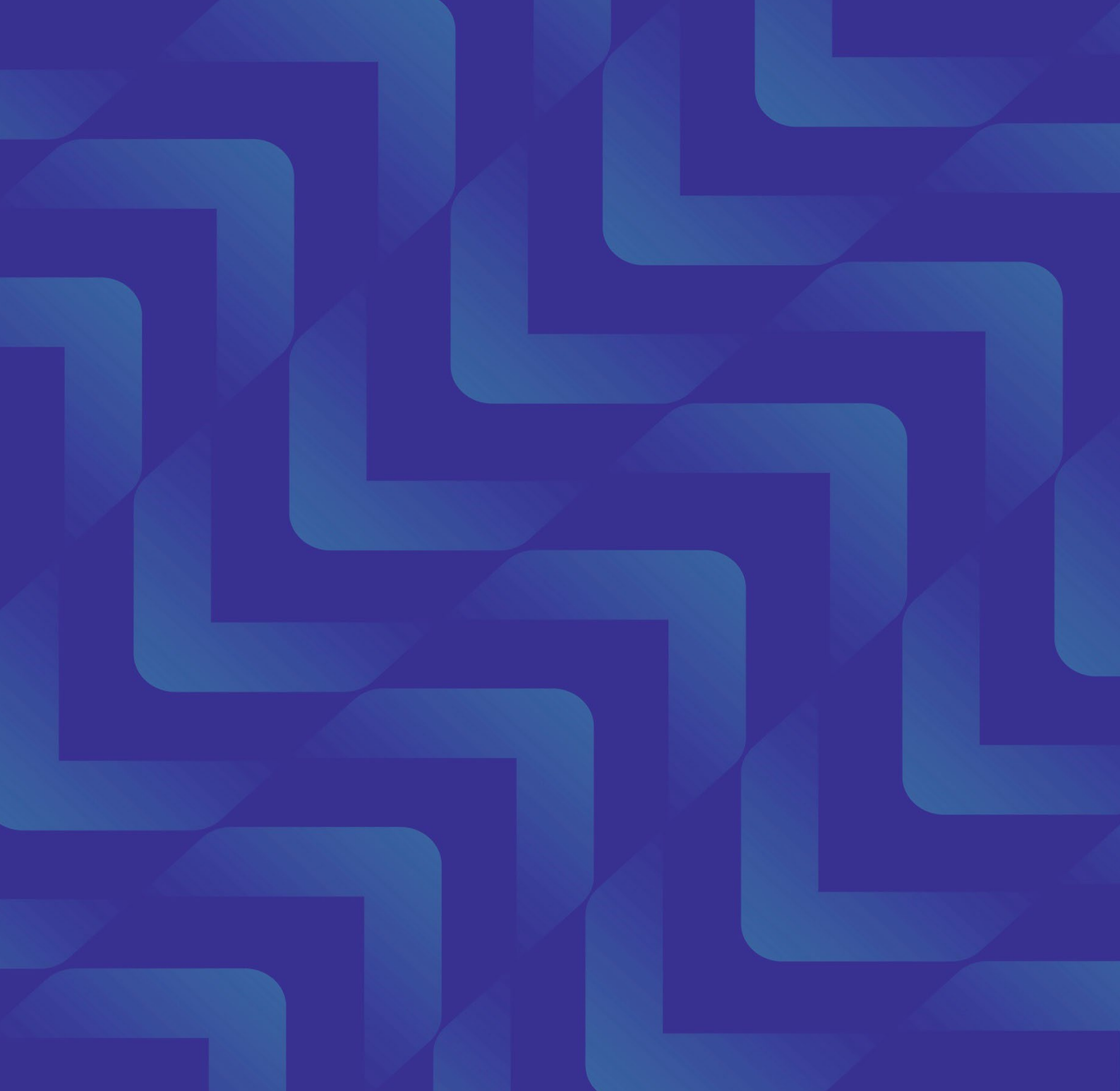
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Appendices

Table 1 provides an overview of the variables used in the analysis, along with their descriptive statistics.

Table 1: Description of variables

Variable	Description of variable	Obs.	Mean	Std. dev.
Process Innovation (0/1)	Binary variable taking the value of 1 if business introduced new or significantly improved methods for the production or supply of goods or services, and 0 otherwise. The innovation, although new to the business, does not need to be new to the industry and includes all process innovations, regardless of their origin.	97,900	0.16	0.36
Product Innovation (0/1)	Binary variable taking the value of 1 if business introduced new or significantly improved goods or services e.g. improvement in quality or distinct user benefits, and 0 otherwise. The innovation, although new to this business, does not need to be new to the market and includes all product innovations, regardless of their origin.	97,900	0.23	0.42
Product Innovation - New to Market (0/1)	Binary variable taking the value of 1 if product innovation is new to market.	97,077	0.10	0.30
Product Innovation - New to Business (0/1)	Binary variable taking the value of 1 if product innovation is new to business.	97,149	0.17	0.38
Business to Business (B2B) Collaboration (0/2)	Categorical variable taking the value of 0 if a business has not engaged in B2B collaboration, 1 if engaged in domestic B2B collaboration only and 2 if engaged in domestic and international B2B collaboration.	78,593	0.36	0.68
Business to University (B2U) Collaboration (0/2)	Categorical variable taking the value of 0 if a business has not engaged in B2U collaboration, 1 if engaged in domestic B2U collaboration only and 2 if engaged in domestic and international B2U collaboration.	78,923	0.11	0.37
Internal R&D (continuous)	Continuous variable indicating the amount spent for internal R&D expenditure (in £ thousand).	38,794	662.76	11043.51
External R&D (continuous)	Continuous variable indicating the amount spent for external R&D expenditure (in £ thousand).	29,247	223.54	8742.57
Exporter (0/1)	Binary variable taking the value of 1 if business is an exporter.	84,302	0.31	0.46
Networking (0/1)	Binary variable taking the value of 1 if business introduced new methods of organising external relationships with other firms or public institutions, and 0 otherwise.	92,735	0.11	0.31
Employment (log)	Natural logarithm of business's average number of employees.	97,900	4.20	1.47



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