Technical report on 'Exploring the impact of university-industry collaborations'

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Introduction

This technical report provides background information on the literature studied an analyses carried out in relation to chapter 3 on "Exploring the impact of university-industry collaboration" in the report *University-industry collaboration in Denmark. A comparative analysis with particular emphasis on Aalborg University* published as an Aalborg University Business School Working Paper in January 2021 (Drejer et al., 2021).

Academic literature on the impacts of university-industry collaboration

Table 1 provides an overview of relevant studies consulted in the literature review conducted for the study presented in the above-mentioned chapter. In addition to the academic papers listed in Table 1, grey literature on university-industry collaboration in Denmark was also consulted.

Table 1. Overview of academic literature on the impact of university-industry collaborations

Article	Methodology	Findings
Innovation input		
Lööf & Heshmati (2002)	Regression on sample of 619 Swedish manufacturing firms	Positive effect on R&D intensity
Scandura (2016)	Propensity score matching on a sample of 1887 British firms	Positive effect on R&D expenditures per employee and share of R&D employment
Innovation output		
Mansfield (1998)	Descriptive analysis based on a sample of 77 US firms	Collaboration helped firm develop new products and implement cost saving measures
Becker (2003)	Probit model with 2-step Heckman on sample of 2800 German manufacturing firms	Increased propensity of firms to engage in product and process innovation
Belderbos, Carree & Lokshin (2004)	Regression on sample of 2353 Dutch firms	Positive effect on innovative sales
Lööf & Broström (2008)	Matching analysis on a sample of 2071 Swedish firms	Positive effect on share of innovative sales only present for manufacturing firms with more than 100 employees. No effects on patenting.
Arvanitis, Sydow & Woerter (2008)	Three equation model with instrumental variables on a sample of 2428 Swiss firms	Positive effect on share of innovative sales
Eom & Lee (2010)	2-step probit model on a sample of 538 Korean firms	No significant impact on the innovation probability of firms. Positive impact on patenting
Robin & Schubert (2013)	Heckit model on a sample of 20,672 French and 5200 German firms	Increases product innovation, but has no effect on process innovation
Walsh, Lee & Nagaoka (2016)	(Ordered) logit models on a sample of 1919 US inventors	Collaboration leads to higher technical significance, but does not help with commercialization
Arant, Fornahl, Grashof, Hesse, & Söllner (2019)	Logistic regression on a sample of 8404 German firms	Collaboration with universities is associated with a higher probability of radical innovations, yet geographically distant universities are more likely to foster radical innovations than nearby universities

Firm performance		
Belderbos, Carree & Lokshin (2004)	Regression on a sample of 2353 Dutch firms	No effect on labour productivity
Medda, Piga & Siegel (2004)	Bivariate Probit Sample Selection model on a sample of 2222 Italian firms	No effect on labour productivity
Arvanitis, Sydow & Woerter (2008)	Three equation model with instrumental variables on a sample of 2428 Swiss firms	Positive effect on labour productivity
Eom & Lee (2010)	2-step probit model on a sample of 538 Korean firms	No effect on volume of sales or labour productivity

Sampling Strategy

The sampling strategy followed in the study presented in chapter 3 on "Exploring the impact of university-industry collaboration" in the report on *University-industry collaboration in Denmark* aggregates data from multiple waves of the Danish Research and Innovation Survey. This is done for three reasons:

- Prevalence of university-industry collaborations: the low prevalence of university-industry collaborations in general, and collaborations with specific universities in particular, makes sample size a major concern.
- Selection of covariates reduces sample size: for some co-variates, independent variables and dependent variables it is more appropriate to include lagged versions. This means that multiple survey waves (or in other cases, survey waves and employment data from earlier or later years) need to be combined for a given observation to remain in the data set.
- Year-specific effects: the impact of university-industry collaborations on firms cannot be seen in isolation from developments in the overall economy. Aggregating multiple years will provide a better and more general overview of the impacts, which is likely to be less affected by economic cycles.

For firms for which data is available for multiple years (or pairs of years), only one random observation is kept in the data set.

Balance statistics

As described in the main report, matching is applied as a means to address possible selection biases in the analyses of the likely causal firm-level impact of university-industry collaborations. Genetic Matching is applied to achieve the optimal balance in relevant covariates between the firms collaborating with a university and the non-collaborating firms (the latter being the control group). Tables 2 to 4 provide overviews of the balances achieved for the innovation input and output dimensions respectively.

Innovation input – impact of university collaboration on firms' hiring

Table 2 displays the balance achieved after matching for the innovation input analysis. The numbers allow comparing the average in the control vs the treatment group for each sample (the "general" sample for all university-industry collaborations, and the specific samples for collaborations with each university).

Table 2	Model 1 Share university graduate new		Model 2 Share graduate University X among university graduate hired									
Scope	*General*		*AAU*		*AU*		*KU*		*DTU*		*SDU*	
University-industry collaboration	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Share university graduates	0.21	0.21	0.26	0.25	0.33	0.30	0.33	0.37	0.23	0.25	0.31	0.30
Dummy PhD graduates prior	-	-	-	-	-	-	-	-	-	-	-	-
Share graduates University X in workforce	-	-	0.019	0.018	0.069	0.065	0.059	0.055	0.066	0.062	0.054	0.049
Square root (travel time)	-	-	13.0	13.2	9.69	10.07	3.30	3.33	7.67	6.92	4.08	4.16
Log firm size	4.07	4.06	5.12	5.05	5.16	5.12	4.85	4.75	5.00	4.90	5.15	5.03
Log firm age	2.90	2.88	3.13	3.26	2.98	3.10	3.00	2.94	3.13	3.14	3.11	3.12
Primary sector	0.00	0.00	0.03	0.03	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
High technology manufacturing	0.04	0.04	0.13	0.13	0.04	0.04	0.06	0.06	0.07	0.07	0.05	0.05
Medium-highmanufacturing	0.10	0.10	0.13	0.13	0.18	0.18	0.15	0.15	0.15	0.15	0.20	0.20
Medium-low manufacturing	0.06	0.06	0.11	0.11	0.09	0.09	0.02	0.02	0.11	0.11	0.05	0.05
Low technology manufacturing	0.07	0.07	0.10	0.10	0.14	0.14	0.13	0.13	0.15	0.15	0.09	0.09
Knowledge intensive services	0.39	0.39	0.29	0.29	0.39	0.39	0.51	0.51	0.26	0.26	0.43	0.43
Low-knowledge intensive services	0.30	0.30	0.17	0.17	0.13	0.13	0.06	0.06	0.17	0.17	0.11	0.11
Utilities	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.06
Construction	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.04	0.04	0.02	0.02

Innovation output – impact of collaboration on share innovative sales

Table 3 displays the balance achieved after matching for the innovation output analysis.

Table 3

Scope	*General*		*AAU*		*AU*		*KU*		*DTU*		*SDU*	
University-industry collaboration	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Propensity Score	0.25	0.24	0.42	0.41	0.42	0.40	0.43	0.41	0.41	0.40	0.38	0.37
Share university graduates	0.29	0.27	0.33	0.35	0.29	0.32	0.50	0.50	0.39	0.36	0.32	0.30
Log firm size	3.37	3.42	4.66	4.58	4.59	4.36	4.37	4.20	4.22	4.30	4.00	4.13
High technology manufacturing	0.03	0.03	0.08	0.08	0.09	0.10	0.10	0.08	0.08	0.11	0.11	0.11
Medium-high tech manufacturing	0.09	0.09	0.16	0.16	0.12	0.13	0.05	0.11	0.18	0.18	0.20	0.20
Medium-low tech manufacturing	0.08	0.07	0.11	0.11	0.04	0.03	0.01	0.03	0.08	0.08	0.04	0.04
Low technology manufacturing	0.08	0.07	0.11	0.11	0.22	0.19	0.15	0.13	0.13	0.10	0.17	0.17
Knowledge intensive services	0.41	0.44	0.38	0.38	0.36	0.36	0.62	0.58	0.32	0.38	0.22	0.22
Low-knowledge intensive services	0.31	0.30	0.16	0.16	0.17	0.17	0.08	0.08	0.22	0.15	0.26	0.26

Firm performance – impact of collaboration on turnover and employment

Table 4 displays the balance achieved after matching for the firm performance analysis.

Table 4

Scope	*General*		*AAU*		*AU*		*KU*		*DTU*		*SDU*	
University-industry collaboration	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Propensity Score	0.17	0.17	0.27	0.26	0.28	0.27	0.29	0.27	0.27	0.26	0.25	0.24
Share university graduates	0.25	0.24	0.36	0.35	0.48	0.47	0.45	0.43	0.39	0.37	0.39	0.37
Log firm size	2.86	2.96	3.50	3.60	3.28	3.36	3.43	3.50	3.48	3.58	3.04	3.11
High technology manufacturing	0.03	0.03	0.08	0.08	0.02	0.02	0.07	0.06	0.07	0.07	0.05	0.05
Medium-high tech manufacturing	0.09	0.09	0.17	0.16	0.09	0.08	0.08	0.08	0.22	0.22	0.22	0.21
Medium-low tech manufacturing	0.08	0.07	0.14	0.14	0.07	0.07	0.01	0.01	0.13	0.13	0.02	0.02
Low technology manufacturing	0.08	0.07	0.06	0.05	0.11	0.11	0.08	0.08	0.07	0.07	0.13	0.13
Knowledge intensive services	0.40	0.41	0.47	0.47	0.55	0.56	0.64	0.63	0.39	0.39	0.46	0.46
Low-knowledge intensive services	0.32	0.32	0.09	0.10	0.15	0.15	0.15	0.14	0.12	0.12	0.13	0.13

Additional analyses

In addition to the results reported in chapter 3 in the report *University-industry collaboration in Denmark. A comparative analysis with particular emphasis on Aalborg University*, several additional analyses have been carried out to investigate other innovation input and firm performance indicators.[1] The results of these analyses, which are summarised in the following, were either insignificant, not robust, or provided no clear insights in the direction of causality.

Innovation input

For the innovation input, we additionally looked into the following indicators:

- Impact on R&D spending:
  Some studies find that firms increase their R&D expenditures when collaborating with a universities. **The current data makes it difficult to confirm this claim directly**. A major concern is that the collaboration itself is often also incorporated into the R&D expenditures, and disentangling this from other R&D expenditures can be challenging and would reduce the sample size too much. Furthermore, R&D expenditures are often being spent on staff, which is also captured in the firm performance indicators.
- Impact on the location of R&D:
  There are arguments to be made about a potential effect of university-industry collaboration on a firm's choice between outsourcing R&D and conducting R&D in-house. However, the available empirics provide **no conclusive evidence** on this.
- Impact on the direction of R&D:
  Universities are often considered to be conducting research, which is further from the market compared to the R&D conducted by the private sector. It could be the case that firms engaged in collaborations with universities adjust the direction of their R&D activities towards more fundamental research. The empirical evidence on this was, however, **not conclusive.**

Firm performance

For firm performance, we additionally looked into the following indicator:

- Labour productivity:
  As discussed in the main report, using labour productivity as a firm-level performance measure involves several empirical challenges. Nevertheless, we did explore possible productivity effects, but **did not find robust significant results**.

[1] For innovation output no additional analyses have been run. Although there are some studies on the effects of university-industry collaboration on patenting behavior of the involved firms, we have not explored this because patenting behavior tends to be sector-specific, as patenting is not a relevant way to protect intellectual property in many sectors.

Robustness tests

Table 5 presents the robustness tests for the innovation output and firm performance models. For each year all university specific models and the general model (university-collaboration in general) are shown. The signs in Table 5 indicate the direction of the independent coefficient. Effects reported in black are significant at the 0.05 level. NA indicates models with a too small sample size. The aggregate of annual effects reported in the main report can differ slightly due to the sampling strategy followed to aggregate the annual samples (see also the section on sampling strategy in this technical report).

Table 5		General				AAU				AU				KU				DTU				SDU			
		2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012
Innovation output (see also table 4.1 and 4.2 in main report)																									
Share innovative sales	Zero	-	-	-	**-**	+	+	NA	-	-	-	+	+	-	-	-	+	+	+	-	-	-	-	**-**	-
	Count	-	-	-	-	+	+	NA	+	-	+	+	-	-	-	+	-	+	+	+	-	+	+	-	-
Share sales new to world	Zero	-	-	**+**	-	+	NA	+	NA	-	NA	+	NA	NA	NA	NA	+	+	NA	NA	-	+	NA	**+**	-
	Count	-	-	-	+	-	NA	-	NA	**-**	NA	-	NA	NA	NA	NA	+	+	NA	NA	+	+	NA	+	+
Share sales new to market	Zero	-	+	-	-	+	+	-	+	NA	NA	+	-	+	+	**-**	+	-	+	-	-	-	**-**	-	**-**
	Count	**-**	-	-	+	**+**	+	-	+	NA	NA	+	+	-	-	+	+	-	-	-	+	-	+	-	**-**
Share sales new to firm	Zero	-	+	**-**	**-**	NA	+	-	NA	NA	-	-	-	+	+	-	+	**-**	+	-	-	-	NA	**-**	-
	Count	+	+	+	+	NA	+	+	NA	NA	+	+	+	+	+	-	+	-	-	+	-	+	NA	+	+
Firm performance (see also table 4.3 and 4.4 in main report)																									
Employees		**+**	+	+	+	+	+	**+**	**-**	+	-	+	-	+	+	-	+	+	-	+	-	**-**	-	+	+
Turnover		**+**	**+**	**+**	+	+	**+**	+	+	**+**	+	**+**	**+**	-	-	-	**+**	+	+	**+**	+	-	-	-	+

Effects reported in black are significant at the 0.05 level, other effects are insignificant. NA indicates models with a too small sample size. Aggregate of annual effects can differ slightly due to the sampling strategy followed to aggregate the annual samples.

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