Supplementary information

THE MECHANISMS OF TECHNOLOGICAL INNOVATION IN SMEs: A BAYESIAN NETWORK ANALYSIS OF EU REGIONAL POLICY IMPACT ON POLISH FIRMS

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Appendix 1

The questionnaire

Questionnaire

The questionnaire is addressed to the enterprises who benefitted from the Technological Credit and for which they received a premium by the Bank Gospodarstwa Krajowego (BGK) since 2009. The survey's main objective is to get information on the types of realised investments and on their effects on the life of beneficiary enterprises during the period 2009–2015.

Questions should be answered by the enterprise **owner or managing director**, or in general **the entrepreneur (whatever his/her job description)** who is responsible for taking managerial, organisational and strategic decisions for the enterprise.

The survey is carried out by CSIL (Centre for Industrial Studies) in collaboration with CASE (Centre for Social and Economic Research) and BGK. It is implemented in the framework of an evaluation study of the publicly-funded initiatives to support the growth and innovation of European Small-Medium enterprises.

The compilation of the questionnaire requires about 10 minutes. Your answers will be treated confidentially, will be statistically processed and results will be presented at aggregate level only in a report for the European Commission due by the end of October 2015.

For any request of clarification you can contact XXX (<email address>, <phone number>).

Thanks for your cooperation![1]

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[1] The asterisk '*' indicates the mandatory questions.

Section A: GENERAL INFORMATION	
In this section we ask you some general information about your enterprise	

A1. Name of the enterprise	_____
A2. Position of the respondent	_____
A3. Year of establishment of the enterprise	_____
A4. Age of the entrepreneur today*	_____
A5. Education attainment of the entrepreneur*	☐ Primary education degree ☐ Secondary education degree ☐ Bachelor's degree or equivalent ☐ Master degree ☐ PhD ☐ Other – please specify: _____
A6. Is your enterprise part of a group?*	☐ Yes, it is the parent enterprise ☐ Yes, it is a subsidiary → Go to A6.1 ☐ No
If A6 = "Yes, it is a subsidiary" **A6.1 Where is the parent enterprise located?**	☐ Same province ☐ Same region ☐ Other regions in Poland ☐ Europe ☐ Outside Europe

Section B: ACCESS TO THE BGK TECHNOLOGICAL PREMIUM	
In this section we ask you how you got to know the BGK premium associated with the Technological Credit and whether you had previous experience with public support initiatives targeted to enterprises.	

B1. From whom did you first hear about the premium granted by BGK on Technological Credit?*	**More than one answer available, maximum three** ☐ BGK promotional activity ☐ From the lending bank, when requesting funds ☐ Newsletter/advertising materials from the lending bank ☐ Sectorial business associations ☐ Business consultant ☐ Word of mouth from other enterprises ☐ Research on the Internet ☐ Seminars/public meetings ☐ Friends ☐ Other – please specify: _____
B2. Did your enterprise ever benefitted from other public support measures before 2009?*	☐ Yes, at least once ☐ No ☐ I don't know

Section C: INVESTMENT PROJECT IMPLEMENTED

In this section we aim to collect some information about the investment project for which you have received the Technological Credit and signed an agreement with BGK. In case your enterprise signed more than one agreements with BGK since 2009, please select the types of costs funded by *all the agreements*

C1. What did the technological investment(s) for which you received BGK technological premium consist of?*	**more than one answer available** ☐ Purchase or lease of land, or rights of perpetual usufruct of land ☐ Purchase or lease of buildings and parts thereof ☐ Construction or expansion of existing buildings ☐ Purchase or lease of machinery and equipment ☐ Purchase or lease of means of transport ☐ Purchase or lease of informatics systems ☐ Purchase or lease of patents or licenses ☐ Expenditure on external consulting services necessary to implement the technological investment ☐ Other – please specify: _____
C2. For how many investment projects did your enterprise benefitted from BGK technological premium?*	☐ One → Go to C2.1 ☐ More than one → Go to C2.2
If C2. = "One" **C2.1 Have you received any interim payments by BGK?***	☐ Yes ☐ No, the whole contribution was paid in one tranche at the end of the investment project ☐ I don't know
If C2. = "More than one" **C2.2. Have you ever received any interim payments by BGK?***	☐ Yes, for *all the projects* for which my enterprise benefitted from BGK technological premiums ☐ Yes, for *some projects* for which my enterprise benefitted from BGK technological premiums ☐ No, never ☐ I don't know
C3. Did you start other investments for your enterprise development since 2009, different from those for which you received the BGK technological premium?*	☐ Yes → Go to C3.1 ☐ No
If C3. = "Yes" **C3.1. Have you received any public support to implement those investments (other than BGK technological premium)?**	☐ Yes ☐ No

Section D: INVESTMENT RESULTS

In this section we aim to understand the changes produced by the technological investment in your enterprise and the economic benefits ascribable to that investment.
In case your enterprise benefitted from more than one BGK technological premiums since 2009, please select all the changes generated in your enterprise thanks to
all the investment for which you received BGK support

D1. Did the implementation of the technological investment project(s) supported by BGK bring about any of the following changes to your enterprise?* *Select the most relevant change(s) in the following list (at least one)*	
D1.1. I have widened the range of offered products/services	☐
D1.2. I have improved the offered products/services	☐
D1.3. I have upgraded the existing production processes or introduced new production processes	☐
D1.4. I am able to sell products/services that did not exist in the market before	☐
D1.5. I have started selling in new foreign markets	☐
D1.6. My enterprise reputation improved	☐
D1.7. I have improved the overall work organisation	☐
D1.8. I have reduced the enterprise environmental impact (emissions, waste, water pollution…)	☐
D1.9. I have reduced the enterprise energy consumption	☐
D1.10. Personnel already working for the enterprise has gained new knowledge/skills	☐
D1.11. I hired new employees (full time or part time)	☐
D1.12. I could maintain the number of employees (full time o part time)	☐
D1.13. Other – please specify: _____	☐

D2. Did your enterprise own any patent before 2009?*	☐ Yes ☐ No
D3. Did your enterprise already registered a patent or does it expect to do so in the near future as a consequence of the technological investment project(s) implemented?*	☐ Yes ☐ No ☐ I don't know

D4. Which economic results has your enterprise already achieved thanks to the technological investment(s) supported by BGK?*	NOT AT ALL	LITTLE	ENO-UGH	APPRE-CIABLY	VERY MUCH	I DON'T KNOW
D4.1. I have increased sales	☐	☐	☐	☐	☐	☐
D4.2. I have increased the number of clients	☐	☐	☐	☐	☐	☐
D4.3. I have diversified the type of clients	☐	☐	☐	☐	☐	☐
D4.4. I have increased export (if you have never exported, select "Not at all")	☐	☐	☐	☐	☐	☐
D4.5. I have decreased total costs	☐	☐	☐	☐	☐	☐
D4.6. I have increased the enterprise's capacity to resist the effects of economic crisis	☐	☐	☐	☐	☐	☐
D4.7. Other – specify: _____	☐	☐	☐	☐	☐	☐
D5. Do you expect that these economic results will overall improve in the next 3–5 years?	☐ Yes, significantly ☐ Yes, to some extent ☐ No, they are likely to remain the same ☐ No, they may decrease to some extent (if no other investments or change is made) ☐ I don't know					

Section E: OPINION ON BGK TECHNOLOGICAL PREMIUM

In this section we ask you some questions to understand how you judge your experience with the Technological Credit and the associated Premium granted by BGK

E1. How important was the possibility of benefitting from the BGK aid for the decision of starting the technological investment(s)?*
Please select the most relevant option(s)

☐ Without BGK aid I would have faced more serious financial difficulties
☐ Without BGK aid I would have postponed the investment
☐ Without BGK aid I would have done the a smaller and less ambitious investment
☐ Without BGK aid I would have not realised the investment
☐ Other, please specify _____

E2. Please indicate your satisfaction on the following issues regarding your application to the BGK technological premium?*	NOT SATISFIED AT ALL	POORLY SATISFIED	INDIFFE-RENT	SATISFIED	VERY SATISFIED
E2.1 Simplicity of the application, selection and payment process to obtain the BGK premium	☐	☐	☐	☐	☐
E2.2. Time required to receive the BGK premium after the investment completion	☐	☐	☐	☐	☐
E2.3. The types of expenses eligible for BGK premium	☐	☐	☐	☐	☐
E3. To which extent do you agree with the following statements?*	STRONGLY DISAGREE	DISAGREE	DON'T KNOW	AGREE	STRONGLY AGREE
E3.1. I think that the combination between the BGK technological premium and the bank loan is effective to stimulate technological investments of firms	☐	☐	☐	☐	☐
E3.2. I wanted to apply for BGK technological premium even before, but rules were too complex or strict (*if you didn't want to apply earlier, but for other reasons, select "Don't know"*)	☐	☐	☐	☐	☐
E3.3. I think that the rules for obtaining the BGK technological premium should be further simplified	☐	☐	☐	☐	☐

E4. Would you apply again in future for other public initiatives supporting your technological investments?*

☐ I think so
☐ I don't think so
☐ I don't know

Section F: CHANGES IN YOUR ENTERPRISE LIFE
In this last section we want to understand what further changes, not necessarily economic ones, have been generated on your life and enterprise thanks to the experience with BGK technological premium

F1. How did you feel when you knew that your application for technological premium had been accepted by BGK?	☐ Worried ☐ I expected that ☐ I don't remember ☐ Happy ☐ Euphoric ☐ Other, please specify _____

F2. To which extent do you agree with the following statements?* **IF YOU DON'T NOTICE ANY OF THE FOLLOWING CHANGES IN YOUR WAY OF DOING BUSINESS OR ENTERPRISE LIFE, SELECT "STRONGLY DISAGREE"**	STRONGLY DISAGREE	DISAGREE	DON'T KNOW	AGREE	STRONGLY AGREE
F2.1. Thanks to BGK technological premium the relationship with my bank has improved	☐	☐	☐	☐	☐
F2.2. Thanks to BGK technological premium my opinion about public support for enterprises has improved	☐	☐	☐	☐	☐
F2.3. Thanks to BGK technological premium my opinion about initiatives financed by the European Union for small-medium enterprises has improved	☐	☐	☐	☐	☐
F2.4. After benefitting from BGK premium, I started to search more frequently news about public initiatives supporting enterprises in Poland	☐	☐	☐	☐	☐
F2.5. After benefitting from BGK premium, I started to consider new possible investments that I never considered before	☐	☐	☐	☐	☐
F2.6. After benefitting from BGK premium, I realized that my enterprise has more scope for expansion than I thought	☐	☐	☐	☐	☐
F2.7. After benefitting from BGK premium, I realised that it would be better to have more skilled employees	☐	☐	☐	☐	☐
F2.8. After benefitting from BGK premium I realised that it would be better to have more employees speaking foreign languages	☐	☐	☐	☐	☐
F2.9. After benefitting from BGK premium I realised that it would be better to have more younger employees	☐	☐	☐	☐	☐

F3. Space for open comments	

G1. Number of Full Time Equivalent Employees	In the year of application for BGK Technological Credit NOTE: SHOULD YOU HAVE REQUESTED BGK TECHNOLOGICAL CREDIT MORE THAN ONCE, PLEASE ANSWER WITH REFERENCE TO THE YEAR OF THE *FIRST* APPLICATION	At the end of 2014
	☐ 0–9 ☐ 10–49 ☐ 50–99 ☐ 100–249	☐ 0–9 ☐ 10–49 ☐ 50–99 ☐ 100–249 ☐ >249
G2. Amount of annual turnover (or annual sales), in Zloty	In the year of application for BGK Technological Credit NOTE: SHOULD YOU HAVE REQUESTED BGK TECHNOLOGICAL CREDIT MORE THAN ONCE, PLEASE ANSWER WITH REFERENCE TO THE YEAR OF THE *FIRST* APPLICATION	At the end of 2014
LESS THAN 4 MILLION	☐	☐
BETWEEN 4 AND 8 MILLION	☐	☐
BETWEEN 8 MILLION AND 20 MILLION	☐	☐
BETWEEN 20 MILLION AND 40 MILLION	☐	☐
BETWEEN 40 MILLION AND 80 MILLION	☐	☐
BETWEEN 80 MILLION AND 200 MILLION	☐	☐
MORE THAN 200 MILLION		☐
G3. Approximate share of exports out of total sales	In the year of application for BGK Technological Credit NOTE: SHOULD YOU HAVE REQUESTED BGK TECHNOLOGICAL CREDIT MORE THAN ONCE, PLEASE ANSWER WITH REFERENCE TO THE YEAR OF THE *FIRST* APPLICATION	At the end of 2014
NULL	☐	☐
LESS THAN 10%	☐	☐
BETWEEN 10% AND 30%	☐	☐
BETWEEN 30% AND 50%	☐	☐
MORE THAN 50%	☐	☐

Appendix 2

Methodological annex – the Bayesian search algorithm and DAG parameters

The graphical structure of the BN resulting from our analysis (see Figure 11) is determined by the application of a data-driven learning algorithm, the Bayesian Search Algorithm. The approach combines analysts' knowledge with statistical data (Cooper & Herkovitz, 1992; Heckerman et al., 1994): the causal relations revealed by the DAG are validated by an expert with prior knowledge of the issue. In our case, this means expertise gained from previous work on the functioning of SMEs and EU policy instruments for technological innovation (see EC, 2015a).

The algorithm produces a directed acyclic graph (DAG) that gives the maximum score following a hill-climbing procedure (guided by a scoring heuristic) with random restarts. The score is proportional to the probability of the data given the structure, which, assuming the same prior probability for any structure, is also proportional to the probability of the structure given the data. In other terms, applied to our set of data containing policy inputs and expected outcomes, the algorithm seeks the graphical structure that best explains the dependencies between them. This is based on three main parameters (we used the default):[2]

- Max Parent Count (default 8) limits the number of parents that a node can have. Because the size of conditional probability tables of a node grows exponentially in the number of parents, it is generally sensible to cap the number of parents in order to keep the construction of the network from exhausting the available computer memory.
- Iterations (default 20) sets the number of restarts of the algorithm. Generally, the algorithm is searching through a hyper-exponential search space – looking, one might say, for a needle in a haystack. Restarts allow for probing more areas of the search space and increase the chances of finding a structure that will fit the data better. The computing time is roughly linear in the number of iterations.
- Sample size (default 50) is a factor in the calculation of the Bayesian Dirichlet equivalent uniform score (BDeu), representing the inertia of the current parameters when introducing new data. In BN structure learning, the Dirichlet distribution is used to express the prior probability over the parameters. For example, for variable X the prior probability over the parameters $\theta = (\theta_x)$ is expressed as $\prod_x \theta_x^{\alpha(x)-1}$ multiplied by a constant, where θ_x is the probability of $X = x$ and $\alpha(x)$ is a positive constant associated with $X = x$. Therefore, the choice of the constant $\alpha(x)$ determines the solution of the Bayesian structure learning. In the (BDeu) score $\alpha(x) = \delta/\alpha$, α being the number of values that X takes and $\delta > 0$ a constant called an equivalent sample size.

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[2] For the remaining parameters, please see http://support.bayesfusion.com/docs/genie/structurelearning_bs.html.

Appendix 3

Descriptive statistics of the variables

Type of variable	Variable name	Definition	N	mean	sd	min	max
Type of change	D1.1 Larger range of products	See questionnaire	200	0.89	0.320	0	1
	D1.2 Improved products	See questionnaire	200	0.740	0.440	0	1
	D1.3 Upgraded production processes	See questionnaire	200	0.815	0.34	0	1
	D1.4 Innovative products	See questionnaire	200	0.505	0.501	0	1
	D1.5 Entered new foreign markets	See questionnaire	200	0.260	0.440	0	1
	D1.6 Improved reputation	See questionnaire	200	0.535	0.500	0	1
	D1.7 Improved work organisation	See questionnaire	200	0.450	0.499	0	1
	D1.8 Reduced environmental impact	See questionnaire	200	0.315	0.466	0	1
	D1.9 Reduced energy consumption	See questionnaire	200	0.200	0.401	0	1
	D1.10 Improved skills	See questionnaire	200	0.435	0.497	0	1
	D1.11 Hired new employees	See questionnaire	200	0.44	0.34	0	1
Economic Results	D4.1 Increased sales	See questionnaire	200	3.115	0.952	0	5
	D4.2 Increased number of clients	See questionnaire	200	2.860	1.056	0	5
	D4.3 Diversified types of clients	See questionnaire	200	2.480	1.08	0	5
	D4.4 Increased exports	See questionnaire	200	2.175	1.201	0	5
	D4.5 Decreased total costs	See questionnaire	200	2.30	1.090	0	5
	D4.6 Increased capacity to resist the crisis	See questionnaire	200	2.84	1.16	0	5
	D5 Future expected results	See questionnaire	200	4.155	0.857	1	5
Behavioural Changes	F2.2 Better opinion of public support	See questionnaire	200	3.865	0.670	1	5
	F2.4 More frequent search for public support initiatives	See questionnaire	200	4.180	1.120	1	5
	F2.5 Start to think about new possible investments	See questionnaire	200	4.225	1.167	1	5
	F2.6 Understood the company has more scope for expansion	See questionnaire	200	4.254	1.13	1	5
	F2.7 Understood importance of having more skilled employees	See questionnaire	200	3.78	1.38	1	5
	F2.8 Understood importance of having employees speaking foreign languages	See questionnaire	200	3.45	1.42	1	5
	F2.9 Understood importance of having younger employees	See questionnaire	200	2.67	1.21	1	5

Type of variable	Variable name	Definition	N	mean	sd	min	max
Opinion on application procedure	E2.1 Satisfaction for simplicity of application/payment process	See questionnaire	200	3.495	0.789	1	5
	E2.2 Satisfaction for time required to receive the premium	See questionnaire	200	3.930	0.818	1	5
	E2.3 Satisfaction for types of eligible expenses	See questionnaire	200	3.820	0.714	1	5
	E3.1 Opinion on the grant-loan combination	See questionnaire	200	3.810	0.593	1	5
	E4 Willingness to apply in the future	See questionnaire	200	1.110	0.359	0	2
Characteristics of the funded project	Public contribution	Logarithmic value of total public support received	200	13.27	0.820	9.857	14.87
	Project completion year	Year of project completion	200	2013		2011	2015
Characteristics of beneficiary firms	A5 Education	See questionnaire	200	3.615	0.794	2	5
	Sector of activity (NACE)	NACE sectors at 2 digit level	200	3.376	1.20	2	10
	Tech intensity level	Technological intensity class, defined as the ratio between business R&D expenditure and total value added in each 2 digits NACE sector	199	0.547	0.10	1	3
	Size	See questionnaire	200	2.84	0.719	1	4
	Region NUTS1	Polish region at NUTS 1 level where the beneficiary firm is located	200	3.410	1.633	1	6
	B2 Received public support before 2009	See questionnaire	200	0.635	0.611	0	2
	C3 Other simultaneous investment	See questionnaire	198	1.035	0.671	0	2
	G3 Initial export share	See questionnaire	170	2.565	1.380	1	5

Appendix 4

Correlations between the variables

	D1.1	D1.2	D1.3	D1.4	D1.5	D1.6	D1.7	D1.8	D1.9	D1.10	D1.11	D1.12	D4.1	D4.2	D4.3	D4.4	D4.5	D4.6	F2.1	F2.2	F2.3	F2.4	F2.5	F2.6	F2.7	F2.8	F2.9
D1.1	1.000																										
D1.2	0.108	1.000																									
D1.3	0.070	0.275	1.000																								
D1.4	0.082	0.006	0.018	1.000																							
D1.5	0.106	0.169	0.194	0.222	1.000																						
D1.6	0.167	0.270	0.175	0.240	0.347	1.000																					
D1.7	0.043	0.307	0.224	0.031	0.243	0.420	1.000																				
D1.8	0.109	0.107	0.157	0.198	0.212	0.222	0.166	1.000																			
D1.9	0.141	0.182	0.206	0.170	0.331	0.291	0.151	0.388	1.000																		
D1.10	0.158	0.152	0.210	0.223	0.147	0.353	0.281	0.143	0.166	1.000																	
D1.11	0.150	0.237	0.200	0.205	0.260	0.334	0.206	0.201	0.223	0.330	1.000																
D1.12	−0.019	0.128	0.097	0.203	0.093	0.233	0.196	0.126	−0.041	0.098	−0.077	1.000															
D4.1	0.064	0.028	0.046	−0.018	0.134	0.062	0.112	−0.090	0.065	0.000	0.030	0.004	1.000														
D4.2	0.016	0.136	0.008	0.070	0.218	0.241	0.194	0.007	0.072	0.067	0.064	0.071	0.516	1.000													
D4.3	0.034	0.053	0.063	0.180	0.267	0.157	0.136	0.128	0.100	0.108	0.028	0.075	0.313	0.578	1.000												
D4.4	0.128	0.123	0.038	0.074	0.391	0.067	0.183	0.164	0.215	0.001	0.095	0.026	0.388	0.358	0.329	1.000											
D4.5	−0.093	0.206	0.046	0.004	−0.009	0.093	0.187	0.143	0.118	−0.009	−0.067	0.126	0.166	0.274	0.257	0.208	1.000										
D4.6	0.010	0.135	−0.011	−0.003	0.179	0.124	0.152	0.048	0.196	0.110	0.034	0.099	0.367	0.334	0.322	0.177	0.299	1.000									
F2.1	−0.075	0.006	0.121	0.080	0.085	0.059	−0.009	0.112	−0.030	−0.019	0.018	0.120	−0.090	0.111	0.100	−0.008	0.047	0.081	1.000								
F2.2	0.105	0.061	0.081	0.073	0.096	0.072	0.110	0.142	0.076	−0.014	0.077	0.107	0.061	0.044	0.063	0.173	0.112	0.047	0.129	1.000							
F2.3	0.093	0.105	0.066	0.099	0.110	0.099	0.050	0.069	0.054	−0.072	0.083	0.153	0.077	0.050	0.036	0.134	0.127	0.113	0.126	0.777	1.000						
F2.4	−0.116	0.015	0.027	0.102	0.067	0.037	0.092	−0.030	−0.006	−0.021	0.049	0.094	0.169	0.168	0.244	0.128	0.022	0.135	0.078	0.406	0.382	1.000					
F2.5	0.106	0.035	0.113	0.209	0.128	0.194	0.054	0.185	0.150	0.183	0.114	0.098	0.018	0.133	0.279	0.112	0.082	0.201	0.113	0.365	0.341	0.436	1.000				
F2.6	0.054	0.041	0.124	0.146	0.173	0.157	0.108	0.205	0.076	0.044	0.158	0.176	0.082	0.127	0.216	0.137	0.129	0.097	0.170	0.439	0.444	0.408	0.454	1.000			
F2.7	0.050	0.085	0.126	0.171	0.007	0.120	0.121	0.106	0.188	0.219	0.107	0.104	0.076	0.140	0.123	0.125	0.040	0.098	0.049	0.233	0.177	0.269	0.257	0.388	1.000		
F2.8	0.085	0.118	0.083	0.101	0.087	0.105	0.063	0.209	0.135	0.233	0.145	0.127	0.033	0.092	0.084	0.077	0.037	0.088	0.181	0.261	0.171	0.132	0.334	0.289	0.492	1.000	
F2.9	0.038	0.086	0.044	0.066	0.102	0.102	0.072	0.123	0.106	0.113	0.039	0.027	0.026	0.071	0.084	0.102	−0.049	0.011	0.182	0.157	0.165	0.112	0.116	0.223	0.350	0.299	1.000

Note: the table reports correlation coefficients between: type of change (D1), economic results (D4) and behavioural changes (F2). For the description of variables see the questionnaire (Appendix 1). Variables D.4 and F2 have been recodified into binary response variables (where 1 = positive answer, e.g. agree/strongly agree). In grey correlations within variables' blocks.