THE ROLE OF EU POLICY IN SUPPORTING TECHNOLOGICAL INNOVATION IN SMES - A BAYESIAN NETWORK ANALYSIS OF FIRM-LEVEL DATA FROM POLAND

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The role of EU policy in supporting technological innovation in SMEs - a Bayesian Network Analysis of firm-level data from Poland

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Abstract

We study the effectiveness of the 'Technological Credit' (TC) instrument in supporting innovation in Polish SMEs. Our research question is: to what extent does providing credit to SMEs tied to technological investment affect capital expenditure and how does this change the innovativeness of firms? So far, the evidence on the impact of this policy instrument is unsystematic. To answer the question, we use an approach which is novel in innovation policy studies: we perform a Bayesian Network Analysis of survey data. Our data include a unique sample of 200 Polish firms that received TC support during the 2007-2013 programming period. Our findings confirm short-term positive effects (i.e. a wider range of products/services offered and increased sales and exports) and we also have many interesting results related to behavioural changes in firms (which are not necessarily quantifiable economically). We also find that only more financially solid and more internationalized firms were able to take advantage of the policy. These findings suggest that schemes based on technological credits are not appropriate for promoting innovation in all types of SME and should be designed to shift the technological frontier rather than to sustain a catching up process for firms lagging behind the frontier.

JEL: O31, O33, R11, C11

Keywords: technological innovation; innovation policy; ex-post evaluation; Bayesian Network Analysis

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1 Introduction

Technology-driven growth has become a key aspect of development strategies considering innovation to be one of the main drivers of economic growth[1] (Cox and Rigby, 2013; Dolfsma and Seo, 2013; EC, 2010; OECD, 2015). The recently revised OECD innovation strategy (OECD, 2015) acknowledges the role of innovation in driving growth through technology embodied in fixed capital (e.g. ICT), investment in knowledge-based capital, productivity growth due to innovation and its impact on creative destruction and business dynamism. Innovation activity and knowledge spillovers are considered to be among the key factors in the survival, growth and development of firms (Acs and Audretsch, 1990; Audretsch and Lehmann, 2016; Acs et al., 2009; Cohen and Levinthal, 1990; Mazzarol and Reboud, 2009). Of course, innovative activity is not costless, and the role of financial constraints in firm development has traditionally been at the top of the research agenda on the barriers which firms (especially SMEs) have to face (among others, see Carpenter and Petersen, 2002; Beck and Demirguc-Kunt, 2006; Czanitzki and Hottenrott, 2011). In particular, a lack of financial resources is among the main factors hampering innovation capacity (Hadjimanolis, 1999; Madrid-Guijarro et al., 2009).[2] Consequently, many policy instruments have been developed, including those by the EU, to support the innovation performance of SMEs and to help them overcome their financial constraints.[3]

In this paper, we focus on technological innovation and the role played by innovation policy in affecting firm performance. Our research question is simple: to what extent does providing credit to enterprises (here, SMEs) tied to technological investment change the volume and quality of capital expenditure and to what extent does this change the innovativeness of firms? The question is important because this type of policy instrument may be an ingredient of innovation policy in many countries, but the evidence on its impact is unsystematic.

[1] Theoretical contributions highlighting the role of innovation in economic growth include, among others: Grossman and Helpman (1993); Romer (1986); Romer (1990); Segerstrom (1991).

[2] Hueske and Guenther (2015) in their meta-analysis of 188 empirical studies provide a comprehensive description of a variety of factors which hamper, delay or block innovation. The list of barriers they identify includes those manifested at the levels of: the external environment (external stakeholders: investors, potential employees, suppliers, competitors, customers, the state, society), the organization (managerial dynamic capability levers: strategy, structure, size, resources, organizational learning, organizational culture), the group (team structure, team climate, team processes, composition of members depending on their characteristics, leadership style), and the individual (managers' attitudes and abilities, employees' attitudes and abilities).

[3] A review of ERDF measures supporting SMEs at the EU level can be found in EC (2015a). These include instruments designed to stimulate business creation and support R&D projects, the commercialisation of innovative products, access to and the diffusion of ICT services for SMEs, the development of infrastructure targeting the business sector (e.g. incubator facilities, logistic centres, congress venues, technology parks, etc.), capacity building, networking and other activities aimed at helping SMEs go international, such as participation in fairs. In many cases, SMEs are provided with repayable financial support without any indication or condition on the use of the capital.

In order to address this issue, we study in depth the effectiveness of a specific measure called Technological Credit (TC) in supporting innovation in Polish SMEs. TC was included in the 'Innovative Economy' Operational Programme (OP) [4] and was delivered in Poland in the 2007-2013 programming period. The main goal of Technological Credit was to promote technological change in SMEs in order to increase their competitiveness through a partial waiving of credit. The Polish case is unique because of the large number of enterprises involved (the public contribution allocated to the instrument amounted to approximately €430 million and 586 Polish micro, small and medium enterprises benefited), the common legal framework, the variability of sectors and regions, and the timeframe spanning several years. Our analysis allows us to shed some new light on technological innovation from the perspective of a country whose technological backwardness is considerable (e.g. the share of innovative enterprises in Poland is half the EU average[5]) and thus has much need of innovation policy measures.

An important contribution of this paper lies in the methodology we employ to answer the research question. We use an approach which is novel in innovation policy studies: the application of Bayesian Network statistical analysis to survey data. In particular, we match theory-based impact evaluation (Mole et al., 2009; Weiss, 1997a; Weiss, 1997b; Carvalho and White, 2004; Astbury and Leeuw, 2010) with Bayesian Network Analysis (BNA hereafter – Daly et al., 2011; Nielsen and Jensen, 2009). In a first step, we restructure the logic of intervention of the policy instrument as designed by policymakers according to the Realist Evaluation paradigm (Pawson and Tilley, 1997; Astbury, 2013) and in a second step we test the theory: BNA is used to uncover the mechanisms of change and the outcomes generated by the innovation policy instrument. To the best of our knowledge, this is the first attempt at adopting BNA to assess the effectiveness of EU innovation policies supporting technological innovation.

The BNA approach allows us to open the black box (Brown and Mason, 2014) linked to the effects of technological innovation support. We thus address the important issue of a potential mismatch between the policymakers' view and the participating firms' view of EU policy measures designed to support companies (Massa and Testa, 2008).[6] The two-step methodology adopted in our analysis allows for a direct comparison between the theoretical expectations of policymakers and the ex-ante views expressed by the beneficiaries, which may

[4] 2007PL161PO001. The choice of this particular OP is based on a previous examination of 50 operational programmes to show the variety of EU instruments supporting SMEs (see EC, 2015a for a detailed description of the 50 OPs under examination and the rationale for their selection).

[5] Nieć (2015, p.12); see also section 2.1.

[6] In this context, Bach et al. (2014) use the example of the European Framework Programmes for Research and Technological Development to analyse the extent to which participation in public programmes meets the goals pursued by policymakers when setting up such instruments. Faber et al. (2015) list a set of incentives and barriers that influence the likelihood of participation in European research programmes by Dutch science-based SMEs.

help understanding of the reasons for the success or failure of innovation policy support for SMEs. It should be underlined that such a deep level of analysis involving ex-post evaluation of innovation policies designed to support firms is not very common as it requires access to micro-level data gathered through tailored time-consuming and costly surveys (as in Lewandowska et al., 2015; Sanopoulos et al., 2015; Moral-Arce and Paniagua, 2015; Equinox Consulting, 2016). Individual data on the performance of Polish firms is extremely scarce[7] so our ex-post policy evaluation study of Technological Credit is based on micro level data gathered through direct surveys. The sample encompasses 200 Polish firms receiving TC support all over the country. Importantly, overall it represents an unbiased approximation of the population of firms receiving Technological Credit, which is a pre-condition for performing a correct inference, and thus guarantees the external validity of our results.

The rest of the paper is structured as follows. In Section 2 we describe the context of our analysis. We describe the main features of Polish SMEs in terms of their innovation performance and technological backwardness, and present the EU policy instrument (Technological Credit) which we assess. In Section 3 we describe the Bayesian Network methodology used to assess the effectiveness of the instrument and describe the survey-based data on Polish firms. In Section 4 we present our results and explore how theory was effectively put into practice and whether the causal chain of effects expected to result from Technological Credit actually took place. The paper concludes with some policy recommendations in Section 5.

Our main findings can be summarised as follows. The case of Polish firms shows that the EU policy instrument analysed succeeded in producing the desired effects for the beneficiary SMEs. Importantly, thanks to the innovative methodology based on BNA (which proves to be a valuable tool with which to assess the outcomes of policy intervention) we are able to identify the mechanisms which explain how these effects are produced. We find that there are short-term positive effects of the policy instrument. The Polish SMEs that benefitted from Technological Credit actually used it to modernise their production technologies, which allowed them to increase their sales and exports. However, the most interesting results are related to behavioural

[7] The effectiveness of EU policies has often been analysed from the perspective of uneven regional development in Europe, convergence and cohesion problems (e.g.: Armstrong, 2002; McCann and Ortega-Argiles, 2015) – topics which, however, go beyond the scope of our analysis. Then, there are numerous studies on the effectiveness of innovation policy (or R&D support) from the perspective of enterprises in well-developed countries (among others: Foreman-Peck, 2013 and Mole et al., 2009 on firms in the UK; Bérubé and Mohnen, 2009 and Czarnitzki et al., 2011 on companies in Canada; Bronzini and Iachini, 2014 on Italy; Clausen, 2009 on Norway). Venturini et al. (2016) provide a recent analysis of the effectiveness of R&D subsidies during the crisis using firm-leve data for: France, Germany, Italy, Spain, and the UK. The existing papers on Poland compare the general features of various innovation policies for Polish firms or the allocation of EU funds across firms in selected Polish regions (Golejewska and Garda, 2015; Duda, 2012; Jasinski, 2014, Lewandowska et al., 2015). They are typically based on small samples; the recent paper by Lewandowska et al. (2015) studying 394 Polish firms is among the very few which are based on wider surveys.

changes which can lead to additional positive economic results in the future. There are, however, some preconditions determining the effectiveness of the EU support analysed: only more financially solid and more internationalized firms were able to take advantage of the policy. These findings suggest that schemes based on technological credits are not appropriate to promote innovation in all types of SMEs and should be designed to shift the technological frontier rather than to sustain a catching up process for firms lagging behind the frontier.

2 The context

2.1 Innovation in Polish firms and constraints on technological investment

In order to understand the specificity of technological innovation support in the Polish case we need to put it in a wider historical and political context. Poland's transformation from a centrally planned economy to a market system was painful and resulted in massive unemployment, closures of large companies and difficult restructuring, accompanied by investment and credit constraints (Konings et al., 2003). According to the survey presented in Baruk (1997), in the initial period of system transformation in Poland (early 1990s) innovativeness in the private sector was less than in the public sector and a lack of company financial resources was the main obstacle to innovation (indicated by 52.5% of the companies investigated). National policies aimed at fostering innovation did not turn out to be particularly successful. Jasinski (2003) analyses Polish innovation performance in the period 1989-2000 and concludes that it is hard to find correlations between national innovation activity and innovation policy. Consequently, the turning point linked to EU accession (in 2004) and the prospect of having access to EU policies designed to support innovation was very attractive for Polish firms.

According to the data reported in Kelley et al. (2016), Poland can still be classified as an efficiency-driven economy[8] and is ranked 25th (out of 189) in the World Bank Doing Business Ranking. Moving to an innovation-driven economy which is able to maintain high wages and high living standards is only possible if enterprises are able to compete on the basis of new and specialized products and other innovative solutions (Węcławska et al., 2015, p. 11). Polish SMEs contribute approximately 50% of overall GDP (Kelley et al., 2016; data refer to 2014) so their role in upgrading the Polish economy is not trivial. However, the share of innovative enterprises

[8] Based on a classification of economic development phases where countries are grouped into: factor-driven, efficiency-driven and innovation-driven (Porter et al., 2001). In Europe, Bulgaria, Croatia, Estonia, Hungary, Latvia, Poland, Romania and Macedonia are among the efficiency-driven economies while the other European countries belong to the innovation-driven group (Kelley et al., 2016, p. 7).

in Poland is very low (23% in 2012 compared to an EU average of 49%)[9] and has been declining in recent years (Nieć, 2015). R&D spending in Poland is low (0.94% of GDP in 2014, Eurostat). As a result of low public and private R&D expenditure (0.23% and 0.44% of GDP respectively,[10] Eurostat), and of the weak ability of Polish companies and institutions to translate investment into innovation, Poland has a poor rating in the European Innovation Scorebord 2016 (ranked 22nd among the 28 EU countries, with no significant improvement since 2008) and is performing below the EU average for all dimensions of innovation (EC, 2016). Hence, the backwardness of Polish companies with respect to the technological frontier is significant and the question is to what extent this bad record is determined by financial constraints.

Nowadays, Poland is a country with relatively difficult credit conditions where 34 percent of firms that need a loan are credit-constrained (EBRD, 2015a, p. 31).[11] According to a recent BEEPS survey (EBRD, 2015b)[12] the three largest obstacles to conducting business indicated by Polish firms were still tax administration, competitors' practices in the informal sector and access to finance. This is a sign that financial limitations still hamper the development and innovative capacity of Polish firms and there is a great need for effective use of the support available.

2.2 Technological Credit as an EU policy instrument fostering technological innovation in SMEs

The EU offers several instruments supporting SMEs (EC, 2015a).[13] We focus on the role played by an EU policy instrument called Technological Credit. This was implemented as part of OP Innovative Economy (2007PL161PO001) – the widest public programme aimed at supporting innovation in Poland during the 2007-2013 programming period.[14] More than 90% of total OP spending was dedicated to R&D, innovation and ICT. Measures supporting innovation (among them, measure 4.3: Technological Credit) mainly concerned capital investment for technological improvement and absorption. Technological Credit consisted of a grant to Polish

[9] Poland, Latvia, Romania and Bulgaria fall into the category of EU countries with the lowest shares of innovative enterprises (below 30% in 2012). Germany was the leader with 67% of its enterprises being categorised as innovative in 2012 (Nieć, 2015, p. 12).

[10] The data refer to R&D spending by the government sector and by business enterprises.

[11] The percentage of credit-constrained firms (those that needed a loan, but either decided not to apply for it or were rejected when applying) in 2013-14. The data are based on the Business Environment and Enterprise Performance Survey (BEEPS) conducted by the EBRD and the World Bank (details can be found at http://ebrd-beeps.com/).

[12] Business Environment and Enterprise Performance Survey, BEEPS 5th edition (http://ebrd-beeps.com/countries/poland/).

[13] See some examples in footnote 3 above.

[14] For a complete analysis of the OP strategy, see the case study conducted under the same evaluation contract: (contract number 2014CE16BAT002) described in EC (2015b).

SMEs planning to invest in technology which had already obtained the promise of a bank loan to finance such an investment. The grant was meant to cover part of the credit provided by the commercial bank.

The initial public allocation of funds provided by Technological Credit amounted to €409.85 million, but after reprogramming the total allocated funds increased to €432.6 million. The instrument was managed by Bank Gospodarstwa Krajowego (BGK), the Polish National Bank of the Economy, which was selected as the implementing body by the Polish Ministry of Infrastructure and Development.

The instrument was launched in 2009 and was initially designed to support the purchase and leasing of fixed assets (needed to achieve the objective stated in the contract for Technological Credit) and intangible assets (such as patents and licenses). From 2011 it also supported other types of expenditure, such as the construction and expansion of existing fixed assets (structures, buildings, machinery, equipment), the purchase of land (up to 10% of eligible spending) and the acquisition of external advisory services needed to implement new technology. All Polish SMEs (enterprises employing less than 250 people) were eligible to apply for Technological Credit, independently of their location or sector of activity. There were no limits (neither lower nor upper) set on the total value of the technological investment.

There were five calls (between July 2009 and October 2012) and 1,528 applications for Technological Credit were received, most of them in the 4th and 5th calls (see Figure 1, left-hand panel). Almost half of them (45%) were rejected after assessment by the BGK (see Figure 1, right-hand panel) and in the end agreements for 717 projects (to be realised in 586 different Polish SMEs[15]) were signed. In terms of sector of activity, 83% of the beneficiaries belonged to the manufacturing sector (of which more than 60% were producers of metal, plastic, other non-metallic mineral products and machinery). Regarding geographical distribution, 17% of the beneficiaries were in the Wielkopolskie region (in western Poland and one of the most important industrial centres) followed by Śląskie (10%) and Podkarpackie (10%). In Figure 2 we show the relation between the geographical distribution of expenditure and regional statistics on GDP growth and the unemployment rate: rather more developed areas generally absorbed more funds.

[Figure 1 about here]

[Figure 2 about here]

The total financial volume of investment projects supported amounted to €822.7 million, with €415.6 million of public contributions from the OP and €353 million of EU financing. The

[15] Most of the beneficiaries (86%) carried out one investment project and 14% implemented more than one project (12% – 2 projects, 2% – more than 2 projects).

average aid intensity (the share of the public contribution in the total value of the investment) was 54% (ranging from 18% to 70%). The average beneficiary SME received a public contribution amounting to €584,000. In Table 1 we show financial accounting data for the beneficiary enterprises divided by firm class. Medium-sized enterprises represented 48% of the SMEs receiving support and realised the largest investment projects.

[Table 1 about here]

3 Methodology and data

3.1 The two-step evaluation strategy adopted – expected outcomes of the EU policy instrument

We divide our analysis into two main steps: (1) a reconstruction of the theory and the logic of intervention behind the policy instrument analysed; and (2) an ex-post test of the theory underlying the policy intervention by means of BNA to understand the reasons for the success or failure of its support for SMEs.

Concerning the first step, among various theory-based methods, we identify the Realist Evaluation paradigm (Pawson and Tilley, 1997) as the one that best suits the specificities of our analysis, mainly because of the important role played by context variables (Astbury, 2013) in policies supporting SME innovation and development. By using this paradigm, we are able to answer three main questions: (i) What works for whom? (ii) In which contexts does the policy instrument work/not work? (iii) Which are the mechanisms activated by the policy instrument in given contexts that determine its effectiveness? A thorough analysis of programming documents[16] and interviews with policymakers served as a basis for defining detailed context-mechanism-outcome (CMO) configurations. These identify and explain the logic of the instrument and the underlying theory of change, and they describe the effects that are expected to be created by the decision-maker.

The expected logic of intervention must be rooted in economic theory. The role of innovation and technological progress in supporting economic growth is at the core of influential growth models, for example Romer's (1990) endogenous growth model and Aghion and Howitt's (1992) model of growth through creative destruction. The Schumpeterian approach (surveyed in Scherer, 1986) of creative destruction, the process by which new innovations replace older technologies, still remains the main reference. Over the years it has developed into an integrated

[16] See a publication accompanying this paper (First Intermediate Report - EC 2015a) for a detailed analysis concerning 50 OPs (Operational Programmes) delivered during the 2007-2013 programming period. This scrutiny of OPs was performed to show how many forms EU policy instruments to support SMEs can take and to provide a preliminary assessment of their effectiveness.

framework for understanding the role of innovation in macroeconomic growth and in many microeconomic issues regarding incentives, policies and the organization of innovation activity (Aghion et al., 2013).[17]

The two sets of outcomes expected as a result of the TC policy instrument are associated with two CMO configurations showing the logic of intervention. Figure 3 illustrates the expected economic effects of Technological Credit directed at Polish SMEs. The main objective of Technological Credit is to incentivise SMEs to realise investments associated with the adoption of new production technologies. It is expected that the premium for SMEs that realise technological change (i.e. replace their fixed tangible assets with more modern ones thanks to access to bank credit) will help them to improve their production processes and, as a result, to introduce new or improved products on the market. This is the logic of the expected mechanism (in blue) and it leads to expected outcomes (in green). At the firm level, two main results are expected: (i) an improvement in the economic performance of SMEs benefiting from the policy instrument; and (ii) a decrease in SMEs' debt burden (which in turn affects their economic performance). These firm-level effects are supported by expected context changes affecting the external conditions in which SMEs operate (in red). For instance, the economic performance of supported SMEs improves if there is sufficient market demand for the new/improved products introduced. All of these mechanisms, providing they are matched with other favourable context features (successful adoption of other policy instruments supporting SMEs and a large participation of SMEs), should lead to a desired outcome observed at the aggregate level: the instrument is intended to (indirectly) raise the overall competitiveness of Polish industry.

[Figure 3 about here]

Figure 4 refers to the secondary goal of the TC policy instrument: a change in the perception of financial instruments and new forms of support initiatives. The initial mechanism is the same as in CMO 1 (Figure 3). One expected outcome concerns commercial banks and their attitude to new forms of support initiatives. Then, if SMEs that use the policy instrument are satisfied with the rules and procedures on the one hand and with the economic results achieved on the other, it should lead to the desired result: that SME involvement with Technological Credit (which is not a proper financial instrument itself) will create awareness and experience in the delivery and use of financial instruments,[18] which are intended to replace the traditional grant support during the

[17] A recent generation of Schumpeterian growth models focuses on firm-level innovation, firm dynamics and the reallocation of resources among incumbents and new entrants (e.g. Acemoglu et al., 2013).

[18] Financial instruments are defined as "measures of financial support provided on a complementary basis from the budget in order to address one or more specific policy objectives of the Union. Such instruments may take the form of equity or quasi-equity investments, loans or guarantees, or other risk-sharing instruments, and may, where appropriate, be combined with grants." Source: Art. 2(p) of (EU, EURATOM) 966/2012, Financial Regulation.

next programming period (2014-2020). At the aggregate level, all these expected outcomes will imply more efficient use of public resources (in line with the aim of a best use of EU funds: European Parliament and Council, 2013). Additionally, a greater incentive for better performance on the part of the final recipients who need to repay funds is also desired.

[Figure 4 about here]

The two CMO configurations represented in Figure 3 and Figure 4 determine our main research questions and guide our analysis of the responses from the enterprises. The key questions are:

- Was the policy instrument successful in enhancing the positive economic performance of the SMEs supported?
- Was the policy instrument successful in increasing the awareness and ability of SMEs to use public support in the form of financial instruments?
- Are the changes observed in line with the theory behind the intervention, and, if not, what are the reasons for deviations from the theory?
- Did the policy instrument produce any other types of behavioural change in the beneficiary SMEs?

3.2 Bayesian Network Analysis as a tool of ex-post policy evaluation

In the second step, we test the above theory: theoretical CMO configurations are re-examined to discover whether the expected links between mechanisms, outcomes and context variables actually occurred and, additionally, to check *ex-post* if any other (unexpected *ex-ante*) mechanisms materialised. The theory test is performed on the basis of data collected from the firms benefitting from the EU policy instrument being evaluated (here, Technological Credit) and involves Bayesian Network Analysis to discover *ex-post* the mechanisms of change.

Bayesian Network Analysis (BNA – among others, see Nadkarni and Shenoy, 2001; Neapolitan, 2004; Gelman et al., 2014) is an advanced but at the same time intuitive method which combines statistical analysis with graphical representation of the links between variables. A Bayesian Network (BN) illustrates the probabilistic relationship between a set of variables and their conditional interdependences. The resulting directed acyclic graph (DAG) shows the network structure which reflects the conditional independence relationships between the variables (represented by nodes). A BN thus provides a useful compact representation of a joint probability distribution. The DAG represents a hierarchical arrangement of variables – the nodes which are linked are called 'parent' or 'child' and if the arrow goes from 'parent' to 'child' it means that the former is correlated with (depends on) the latter. The hierarchical arrangement of

the variables (i.e. the arrow links between the nodes) can serve as a basis for inference on the causality (direct and indirect) between variables. The causal relations are then validated by an expert with prior knowledge of the problem investigated. In our case this involves expertise on the functioning of SMEs and EU policy instruments supporting technological innovation gained through previous work (see EC 2015a for details).

A formal explanation of the construction of a BNA and details of its statistical properties can be found in Lauritzen and Spiegelhalter (1988), Spiegelhalter et al. (1993) and Heckerman et al. (1995) and is summarised in EC (2015c). Given the applied nature of our paper we focus on the innovative application of the method for the purpose of ex-post policy evaluation. In practice, we construct a BN corresponding to the ex-post evaluation of Technological Credit by Polish firms by taking the following steps: (1) we sketch the theory of intervention behind Technological Credit, which allows us to determine the variables of interest and to design the survey questionnaires; (2) we gather microdata from Polish firms benefitting from the policy instrument, asking them several questions linked to their performance before and after the adoption of the instrument; (3) we elaborate the responses for the purpose of BNA;[19] (4) we use the survey data to calculate the local probability distributions between the variables and construct a DAG showing the complex network between several aspects of SMEs performance and the outcomes of Technological Credit;[20] and (5) we reassess the theory using the outcomes of the BNA.

Figure 5 shows a schematic example of a BN graph (obtained using the GeNIe software). It is composed of eight nodes (variables). The tables under each node (variable) show the conditional probabilities obtained on the basis of the survey (e.g. 31% of the interviewees experienced low value – state 0 – of variable 1). The arrows between the nodes indicate the dependence between the variables and the thickness of the arcs between the nodes shows the degree of influence of one variable upon another (ranging between 0 – the weakest influence – and 1 – the strongest influence). In Section 4 we show the graph resulting from our analysis.

[Figure 5 about here]

We choose to adopt BNA because it has several properties proven to be useful in the context of ex-post policy evaluation. First, the flexibility of BNA is crucial to test the theory of intervention and to find hidden or unexpected mechanisms of change associated with the instrument assessed (even ones not visible in ex-ante CMO configurations). Traditionally, the

[19] We use discrete Bayesian Networks, where all the variables are defined to be either categorical ('yes' or 'no') or ordinal (e.g. from 'very low effect' to 'very high effect'). Consequently, we use a hierarchical model to obtain the classes and to transform continuous variables into discrete variables.

[20] The algorithms of network learning are described in, among others, Anthony and Barlett (2009). In particular, in order to avoid imposing an arbitrary structure on the network we use the automatic learning approach, which lets the software freely learn from the data, estimate the probability distribution and set up the corresponding network.

links between various variables of interest are assessed through regression analysis where the dependent variable (outcome) is regressed on its potential determinants (called independent or explanatory variables). We use regression analysis as a supporting tool.[21] Instead of assessing the statistical significance of correlations between dependent and independent variables (as in regression analysis), BNA has the advantage of revealing the underlying and, at least partially, unknown causal system by verifying the existence of confounders in the data (i.e. variables which can be both dependent and independent variables in the statistical model) and estimating the conditional probabilities for all the variables in the model.

Moreover, a BN can be used for two types of reasoning: predictive ('top-down') and diagnostic ('bottom-up'). The 'top-down' approach involves extracting evidence on 'parent' variables and using it to predict the posterior conditional probability distribution of their 'children'. The 'bottom-up' approach works in the opposite direction: based on evidence on 'child' variables, the BN is used to analyse the distribution of a 'parent' variable. Assuming that each parent-child relationship in the network represents a stable mechanism of change, the possibility of carrying out top-down or bottom-up reasoning allows us to perform simulations and assess various scenarios (similar to counterfactual analysis). We can thus verify the response of a parent or child variable to a change in the value of a particular variable of interest. In our case, this means, for instance, the possibility of drawing conclusions on the two-way link between the size of a firm and its export performance once a Technological Credit has been adopted. BNA can therefore be used as an innovative tool to support strategic decisions (Pearl, 2000; Glymour and Cooper, 1999), which is very important in a policy-design setting.

3.3 The data

The data on Polish firms used in this study was collected through a survey launched between the end of July and mid-September 2015. The aim was to reach SMEs that had benefitted from the Technological Credit measure targeted at Polish firms.[22] The survey was carried out by the CSIL in collaboration with the CASE (Centre for Social and Economic Research) and the BGK (Bank Gospodarstwa Krajowego).

[21] The results are obtainable upon request.

[22] In parallel, two other surveys were launched, in Italy and Spain, to analyse the effectiveness of other policy instruments: aid to investment projects in micro and small enterprises operating in the craft, commerce and low-tech manufacturing sectors (the so-called 'Title II') included in the OP of the Italian region Apulia (2007IT161PO010); and grants for research and development (R&D) projects undertaken by enterprises of all sizes in the Spanish region of Castile and León (2007ES162PO009). Details of the data collection and evidence emerging from the surveys performed in Italy and Spain are provided in EC (2015c).

Overall, enterprise owners, managing directors or entrepreneurs responsible for taking managerial, organisational and strategic decisions for enterprises were asked 28 multiple choice questions.[23] Firms were interviewed about: access to the BGK technological premium; the investment project for which they received Technological Credit and signed an agreement with the BGK; the results of the investment (changes produced by the technological investment in the enterprise), their opinion on Technological Credit and the associated premium granted by the BGK; and further changes (not necessarily economic ones) made as a result of their experience with the BGK technological premium.

In the end, the sample consists of 200 enterprises in Poland which completed the questionnaire, out of a total number of 586 beneficiaries to which the questionnaire was circulated (response rate: 34.1% which is very high in this type of surveys).

In order to ensure the representativeness of our sample we compared the distribution of enterprises in the sample and in the population, taking into account their size, sector of activity, geographical location, the value of the investment project and of the public support received. The sample represents an overall unbiased approximation of the targeted population quite well, which is very important for the conclusions drawn on the basis of a BNA run with survey data. In terms of size (Figure 6), the group analysed is mainly composed of medium-sized enterprises (48.5% vis-à-vis 48.5% in the population), small enterprises account for 37% of the respondents (36.9% in the population) and micro enterprises for 14.5% (14.8% in the population). Most of the firms interviewed are in the following regions (Figure 7): Wielkopolskie – PL41 (17%), Śląskie – PL22 (11%) and Podkarpackie PL32 (10%). In terms of sector, (Figure 8) approximately a fifth of the firms belong to 'Manufacture of basic metals and fabricated metal products except machinery and equipment' (22%). These are followed by 'Manufacture of rubber and plastic products' (16%). These characteristics, as well as the value of the investment project and the support received (Table 2), seem to be very similar in the sample and in the population, which means that the sample provides us with the necessary information for sound statistical analysis.

[Figure 6 about here]

[Figure 7 about here]

[Figure 8 about here]

[Table 2 about here]

[23] The questionnaire can be found in EC (2015c) (Volume II).

4 Ex-post assessment of investment policy effectiveness – results of the empirical test of the theory

4.1 Descriptive statistics of the results of TC[24]

Most of the firms which answered the questionnaire were founded after 1990 and the majority of the entrepreneurs interviewed are currently relatively young (52% are 30-45 years old, while 64% are 26-50) and well educated (72% have a master's degree). Half of the enterprises benefited from other public support measures before 2009, so they already had some experience of the system of public support for enterprises. The enterprises used the Technological Credit to finance the purchase or lease of new production technologies (machinery, equipment) or of intangible assets (patents and licenses). In half of the cases, the enterprises accompanied the purchase of machinery with other types of expense, such as construction costs to expand or open new production areas, and/or external consulting services. 84% of the firms used Technological Credit to carry out only one investment project.

Some crucial questions were related to the results of the investment. As shown in Figure 9, implementation of the technological projects supported by TC brought different effects, especially in terms of products/services offered and operational improvements. In particular, the main effect – indicated by 88% of the respondents – is related to a widening of the range of products/services offered, while 81% of the firms acknowledged upgrading of their existing production process or introduction of a new production process. Figure 10 plots the responses of firms with respect to six different economic outcomes. Note that these effects are entirely in line with the theory behind the intervention (CMO configuration 1 – Figure 3).

[Figure 9 about here]

[Figure 10 about here]

4.2 BNA results[25]

In order to find the variables which are most correlated with the expected results observed by the firms (increased sales or exports, reduced costs), in the first instance we use the answers from the questionnaire to run standard regression analyses (logit and ordered logit models).[26] However, the main objective is to uncover the hidden patterns behind the responses of the firms without setting one specific dependent variable. The search for other possible correlations among the

[24] Full descriptive statistics emerging from the survey can be found in EC (2015c) (Volume II).

[25] This section draws upon EC (2015c, 30-51).

[26] Available in EC (2015c) (Volume II).

variables was done by means of Bayesian Network Analysis (BNA).[27] BNA has been employed in a variety of fields such as finance, banking, medicine, robotics, civil engineering, geology, geography, genetics, forensic science, ecology and industry for the purposes of analysis, simulation, prediction and diagnosis. Nevertheless, the application of BNA in the context of EU policy evaluation is missing[28] and our results are novel in the context of innovation policy studies.

The resulting Directed Acyclic Graph (DAG) is presented in Figure 11. It shows the Bayesian Network of variables related to economic performance outcomes (variables from D4.1 to D4.6) and other behavioural changes (from F2.4 to F2.9) associated with Technological Credit. Variables D1.1-D1.11 indicate changes triggered by the investment project supported by the public contribution.

[Figure 11 about here]

The main results concerning changes in the economic performance of firms resulting from the Technological Credit and revealed by the DAG are as follows.[29] First, the main changes generated by the policy instrument refer to: a widening of the range of products offered by SMEs (D1.1); upgrading of production processes (D1.3); and possibilities of selling products that did not previously exist on the market (D1.4). These outcomes were expected *ex-ante* and refer to pure economically measurable outcomes of the support. Thanks to their enhanced access to funding, firms were able to expand their ranges of production, upgrade their production and sell products on the market. Increasing sales (D4.1) are associated with an increase in the number (D4.2) and types of clients (D4.3), and with an improvement in the firm's capacity to resist the effects of the economic crisis (D4.6). It is interesting to note that increases in sales do not derive from any specific change within the SME's production function. Instead, the economic effect on sales is channelled through increases in exports. It is mainly by increasing exports that SMEs obtain an increase in sales. Other causes are certainly at work, but they play a much weaker role, which is the reason why they are not highlighted in the Bayesian Network

Importantly, there are also other relationships between changes generated by the policy instrument which are revealed in the Bayesian Network, e.g. a link between a reduction in energy consumption and an improvement in personnel skills (D1.10) and a link between an improved

[27] In order to build the Bayesian Network, we used the Graphical Network Interface (GeNIe). This is a development environment for building graphical decision-theoretic models and was developed at the Decision Systems Laboratory, University of Pittsburgh. The documentation can be found at: https://dslpitt.org/genie/wiki/GeNIe_Documentation.

[28] There are, however, studies employing BNA for the purpose of analysis of SME performance (e.g. Lee et al., 2016 on R&D cooperation).

[29] The robustness of the main results stemming from the network has been addressed by changing some of the variables, for example by substituting sets of variables with their principal components to reduce the dimensionality of the model.

reputation of the enterprise (D1.6), enhanced employees skills, the hiring of new employees (D1.11) and improvement in the work organisation (D1.7). This is a sign that the policy instrument indirectly stimulated many factors benefiting the activities of firms which could not have been discovered using standard assessment methodology. Thanks to BNA, we can find relationships between different types of change which demonstrate the many different but interconnected ways in which the policy instrument stimulates changes in the basic activities of firms.

Concerning export activity, starting selling in new foreign markets (D1.5) is correlated with an increase in exports (D4.4) more than with other changes in SME production functions. The decision to enter new markets and the effects of export performance are, however, strongly determined by the initial export share. The network clearly indicates that the policy instrument affects the export patterns of companies which are already operating in foreign markets. Put differently, the higher the SME's export share in the year of application for the instrument, the more probable it is that it will use the investment to sell into new foreign markets and to achieve an increase in exports. This is an important result showing that some initial preconditions (here, already being present in the international market) must have been met in order to guarantee the success of the policy instrument.

Finally, expectations of future economic results (D5) do not depend on the type and degree of results already achieved, but instead on the year of project completion (recent projects correspond with higher expectations) and the technology intensity level of SMEs (with firms from low-tech sectors being less optimistic).

The DAG also reveals important behavioural changes with respect to the use of financial instruments. The SMEs surveyed are generally satisfied with the support received and the delivery procedures related to Technological Credit. Almost 80% of them agree that the combination of the BGK premium and the bank loan is an effective instrument to stimulate technological investment by firms. It is therefore reasonable to think that these enterprises will be ready to access financial instruments in the future rather than grant schemes. In this respect, it is important to note that only 28% of respondents maintain that without BGK aid they would have faced serious financial difficulties. This suggests that access to credit was probably not a barrier for enterprises that benefitted from Technological Credit, and this could further justify the use of financial instruments. When looking at the results of the BNA, behavioural change is linked to neither the economic results already achieved by the beneficiaries (question D4) nor to any specific change occurring within an SME (question D1).

The various possible behavioural changes tested in the questionnaire are strongly related to each other, implying that a behavioural change, when it occurs, is diffuse and affects the SME's life in various ways. For instance, it is more probable that SMEs that have made a change will seek to have more skilled employees (F2.7) and also that they believe that it would be better to have more employees speaking foreign languages (F2.8). In turn, if foreign languages are considered important, it is probable that reducing the age of employees (F2.9) is considered more valuable too, even if, as mentioned above, the number of entrepreneurs which attach greater value to having younger employees is still rather small. Realising that the enterprise has more scope for expansion than previously thought (F2.6) and considering the possibility of new possible investments (F2.5) are also strongly interlinked.

Involvement in the TC scheme also changed firms' perspectives on public support initiatives. The results of BNA reflect that more than 80% of enterprises recognise that their opinion about national and European public support initiatives for SMEs improved thanks to the policy instrument (F2.2 and F2.3). This variable is an important 'node' in the network, as it is linked to all the other behavioural changes, including the willingness expressed by 86% of SMEs to apply for other public initiatives supporting technological investment (E4).

4.3 Ex-post test of the theory behind the intervention

The BNA results obtained allow us to go back to the expected theory behind the intervention and to perform an ex-post reassessment of CMOs. The results of this exercise are shown in Figure 12 (they correspond to the ex-ante CMOs depicted in Figure 3 and Figure 4). The graph schematically shows which of the expected links between mechanism, context and outcome variables actually took place as a result of the Technological Credit adoption according to the survey results.

[Figure 12 about here]

The policy instrument enhanced technological progress among Polish SMEs, increasing the technological intensity of their products and making them more competitive on the market. The instrument particularly benefitted financially solid enterprises and SMEs which were already operating in the international market. Interestingly, these effects were not explicitly pursued by the policy instrument but we have been able to discover them through the use of non-standard BNA methodology.

The survey and BNA also reveal that beneficiary SMEs experienced other types of behavioural change which are not made explicit in the intervention theory behind the policy instrument and not necessarily related to quantifiable economic results. Nevertheless, they may

lead to relevant outcomes in the future. After benefitting from the policy instrument, almost 80% of entrepreneurs acknowledge that they have started searching for news about pubic initiatives supporting SMEs more frequently, that they are considering the idea of venturing into new investments which they had never considered before, that they realise that their enterprise has more scope for expansion than they previously believed, and that they recognise the importance of having more skilled employees. Thanks to the positive results gained with Technological Credit, opinions about public support initiatives for enterprises financed by Poland and the European Union have improved for around 85% of the SMEs surveyed. These changes be considered intermediate effects along a longer-term path of economic performance improvement.

Some of the expected links (e.g. those referring to the impact of Technological Credit on the overall economic performance of the country) could not be checked. To this end, the scope of future evaluations should be broader so as to include other policy instruments delivered to support Polish SMEs over the same period.

5 Conclusions and policy implications

This paper has contributed to the literature on public policies aimed at promoting technological progress in SMEs by means of an empirical analysis of a specific tool, Technological Credit, as experimented within Poland. We asked a simple research question concerning the impact of the policy instrument: does providing Technological Credit to SMEs change the volume and quality of investment and to what extent do these changes have an effect on the innovativeness of firms?

The research method was, for the first time in the literature on innovation, the use of a Bayesian Network Analysis in the framework of a theory-based ex-post evaluation. The main advantage of this approach is to directly test if the effects observed are consistent with the hypotheses of the intervention's logic. This is different from simply observing a statistical effect 'after' a policy has been adopted because it is based on evidence of behavioural changes in firms as revealed by survey respondents. In our case-study on Poland, 200 firms responded, i.e. a third of all the firms involved in the policy – a very high response rate.

To sum up, we have been able to find the following:

a) There is clear evidence that Technological Credit shifted the investment pattern of firms, at least in terms of accelerating the acquisition of machinery and equipment, and was instrumental in widening the range of products offered by the beneficiary SMEs, improving production processes, and increasing sales to a greater number and more types of clients. This even happened in a period when there was recession in some

markets. The core driver of the process is a link between technology adoption and wider market penetration abroad.

b) More specifically, the changes associated with the adoption of new technologies increased energy efficiency and improved personnel skills and the overall organisation of work.

c) Bayesian Network Analysis reveals the path dependency of export effects. Technological credit is particularly beneficial to firms which were already exporters, but is much less beneficial to domestic-oriented firms.

d) Future economic results correlate with the level of technology intensity of SMEs, with low tech firms being less optimistic – another form of path dependency, which is confirmed by an association between positive expectations of economic results from the investment and an understanding of the need to accompany fixed investment with increasing the human capital endowment of the firm, including skills in foreign languages.

The logic of the policy intervention is confirmed to a certain extent, as technological intensity increased, but, perhaps unexpectedly, the main beneficiaries of the instrument were financially solid enterprises and SMEs which were already operating in international markets.

Our findings have some broader policy implications that go beyond our case study on Poland. Technological Credit targeted at SMEs in the form that we have studied in this paper will not change the behaviour of firms which are locked into existing market patterns, typically in the domestic market. Effects will be felt by firms in terms of the linkage between adopting new technology and the discovery of new markets, typically abroad. As going abroad needs some previous experience, there will be path dependency. Hence, credit for innovative technologies does not seem to be the most effective instrument to support investment by SMEs which simply need to expand their production capacity, while it should be considered an effective policy instrument for firms that have already started the internationalization process. In other words, technological innovation and the discovery of new market opportunities are mutually linked, and well-designed Technological Credit can act as a catalyst.

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Tables and Figures

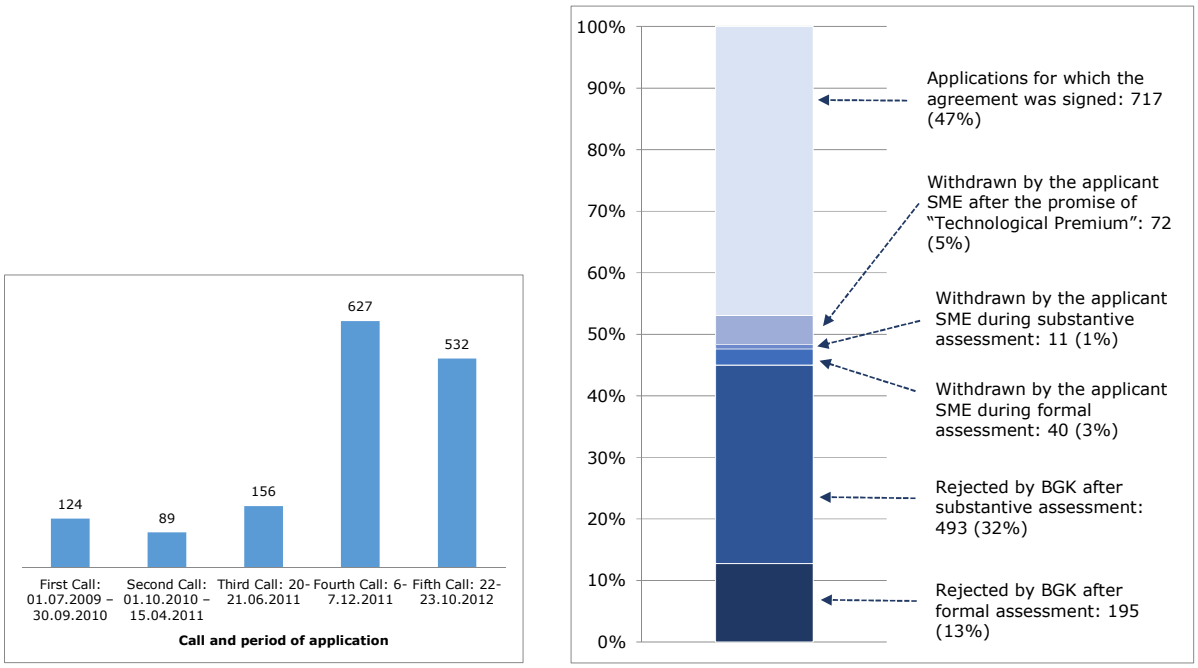

Figure 1. Number of applications and beneficiaries of Technological Credit in Poland
Note: left panel - number of applications for each call; right panel – status of applications received (n= 1,528)
Source: Authors' elaboration of data provided by BGK.

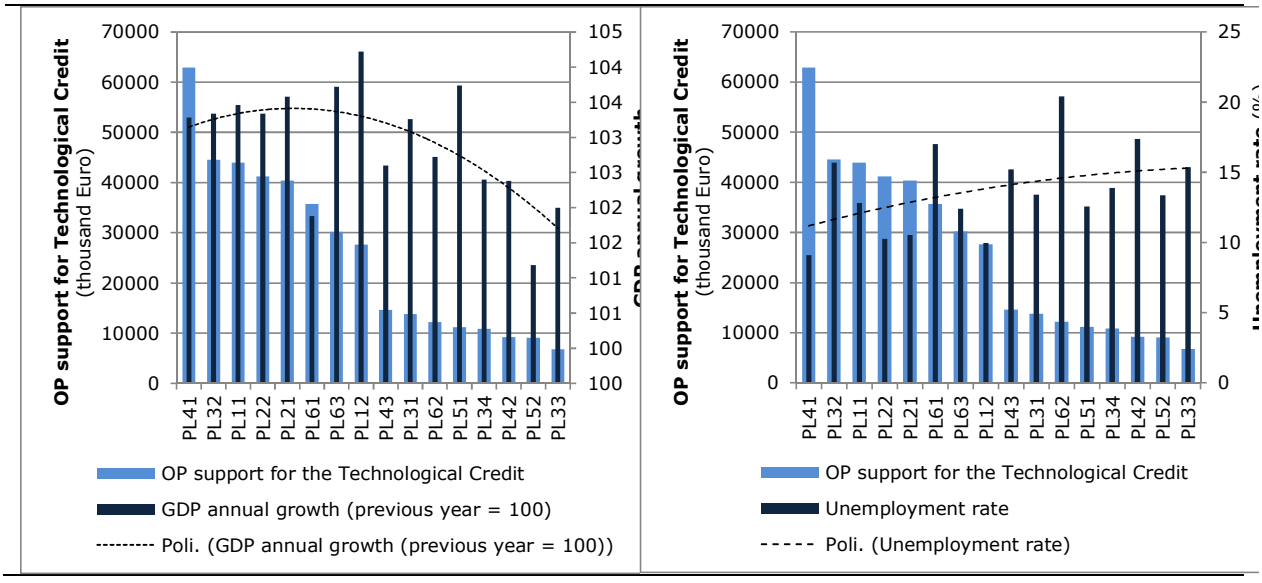

Figure 2. Geographical distribution of OP support for Technological Credit in Poland and regional economic outcomes
Note: left panel - regional GDP growth (average 2008-2012), right panel – unemployment rate (average 2009-2014). Regions: Łódzkie (PL11); Mazowieckie (PL12); Małopolskie (PL21); Śląskie (PL22); Lubelskie (PL31); Podkarpackie (PL32); Świętokrzyskie (PL33); Podlaskie (PL34); Wielkopolskie (PL41); Zachodniopomorskie (PL42); Lubuskie(PL43); Dolnośląskie (PL51); Opolskie (PL52); Kujawsko-pomorskie (PL61); Warmińsko-mazurskie (PL62); Pomorskie (PL63).
Source: Authors'elaboration of MA and National Statistical Office data.

Table 1. Financial support to enterprises benefiting from the Technological Credit in Poland, by size class of firm

	Micro enterprises (n=87)			Small enterprises (n=216)			Medium enterprises (n=283)		
	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
Value of the investment project (thousand EUR)	1,061	32	2,571	1,192	38	4,302	1,748	25	5,165
Value of public support from the OP (thousand EUR)	609	19	970	641	23	970	814	12	1,001
Value of EU financing (thousand EUR)	518	16	825	545	19	825	692	11	851
Aid intensity (public support / value of the investment)	59%	30%	70%	58%	18%	70%	49%	21%	61%

Note: Figures are at enterprise level.
Source: Authors'elaboration of MA data.

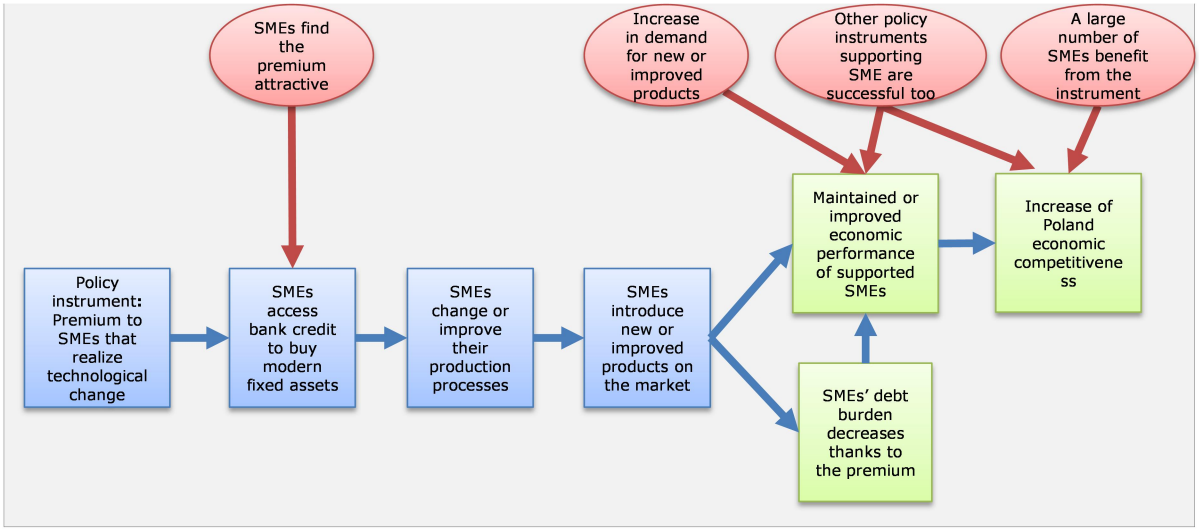

Figure 3. CMO configuration 1 – expected economic effect of the Technological credit instrument directed at Polish SMEs

Note: *outcomes* pursued by the policy maker in green boxes; external conditions (*context*) upon which desired changes occur in red circles; the *mechanisms* at work along the causal chain leading to the outcomes in blue boxes.

Source: Authors' elaboration

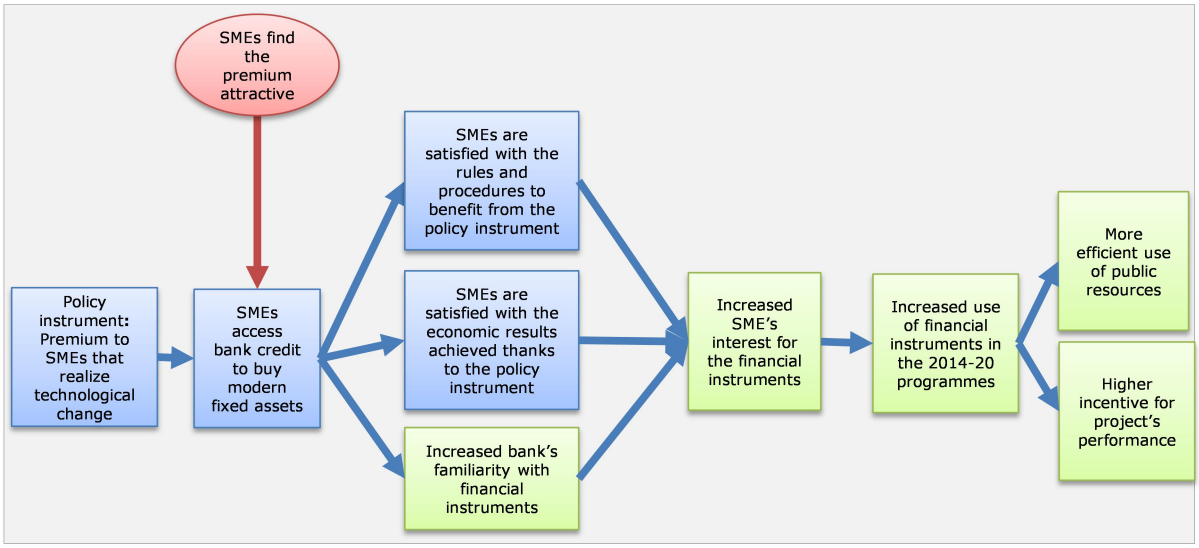

Figure 4. CMO configuration 2 – expected perception of the financial instruments as a result of Technological credit directed at Polish SMEs

Note: *outcomes* pursued by the policy maker in green boxes; external conditions (*context*) upon which desired changes occur in red circles; the *mechanisms* at work along the causal chain leading to the outcomes in blue boxes.

Source: Authors' elaboration

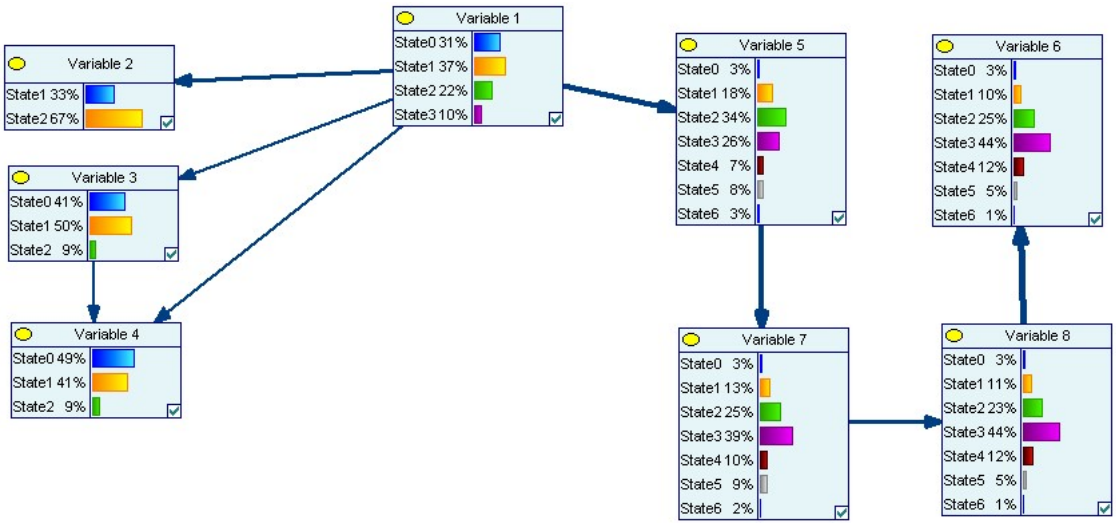

Figure 5. Schematic representation of BN graph.
Source: Authors' elaboration.

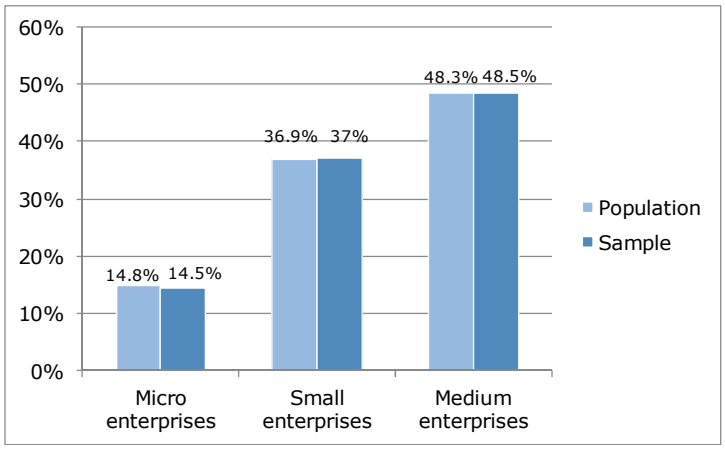

Figure 6. Sample composition and representativeness (1) – share of respondents by size
Source: Authors' elaboration based on the survey carried out by CSIL in collaboration with CASE and BGK

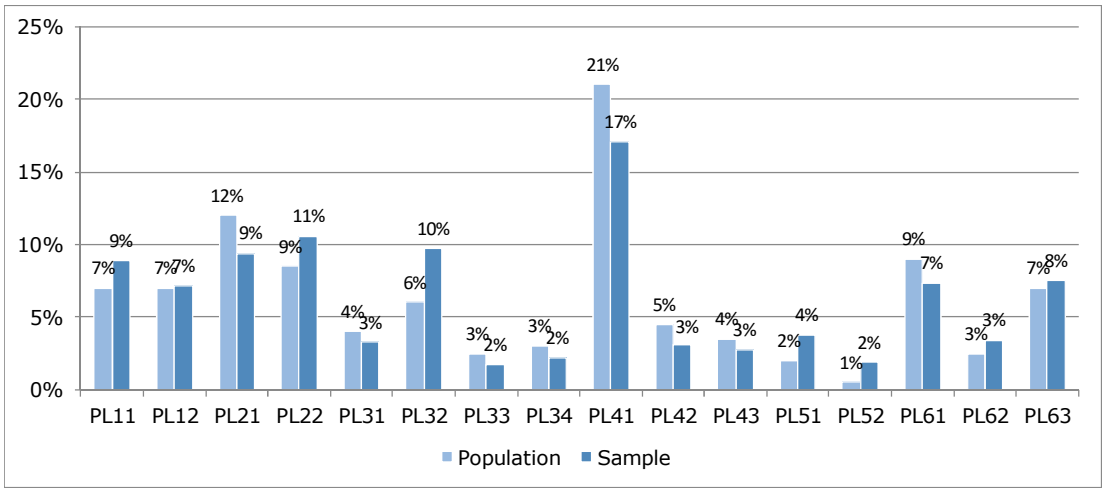

Figure 7. Sample composition and representativeness (2) – share of respondents by region (NUTS2)

Note: Łódzkie (PL11); Mazowieckie (PL12); Małopolskie (PL21); Śląskie (PL22); Lubelskie (PL31); Podkarpackie (PL32); Świętokrzyskie (PL33); Podlaskie (PL34); Wielkopolskie (PL41); Zachodniopomorskie (PL42); Lubuskie(PL43); Dolnośląskie (PL51); Opolskie (PL52); Kujawsko-pomorskie (PL61); Warmińsko-mazurskie (PL62); Pomorskie (PL63).

Source: Authors' elaboration based on the survey carried out by CSIL in collaboration with CASE and BGK

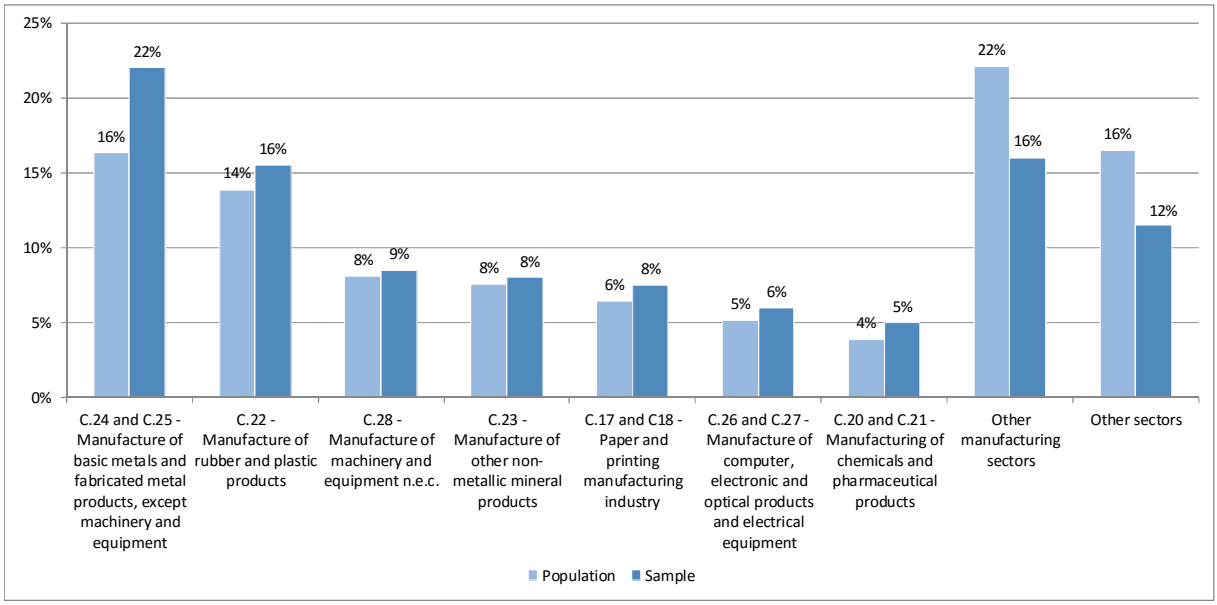

Figure 8. Sample composition and representativeness (3) – share of respondents by activity sector (NACE)

Source: Authors' elaboration based on the survey carried out by CSIL in collaboration with CASE and BGK

Table 2. Sample composition and representativeness (4) – value of public support and of investment project

	Value of the public support (thousands EUR on average per SME)		Value of the investment project (thousands EUR on average per SME)	
	sample	population	sample	population
median	692	641	1252	1172
average	626	601	1216	1181
min	19	19	32	32
max	1001	971	3777	4555
st.dev.	308	307	726	727

Source: CSIL elaboration based on the survey carried out by CSIL in collaboration with CASE and BGK

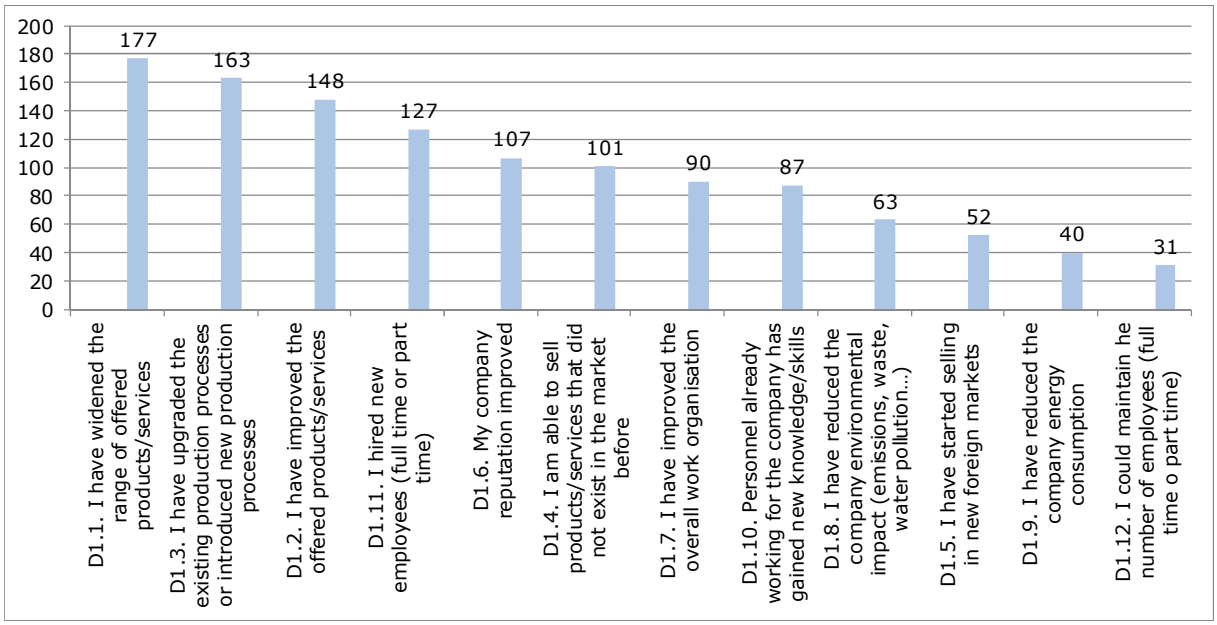

Figure 9. Investment results of the analyzed policy instrument

Note. Answer to the question: Did the implementation of the technological investment projects supported by BGK bring about any of the following changes to your enterprise? n=200 respondents. Enterprises could select more than one answer.

Source: CSIL elaboration based on the survey carried out by CSIL in collaboration with CASE and BGK.

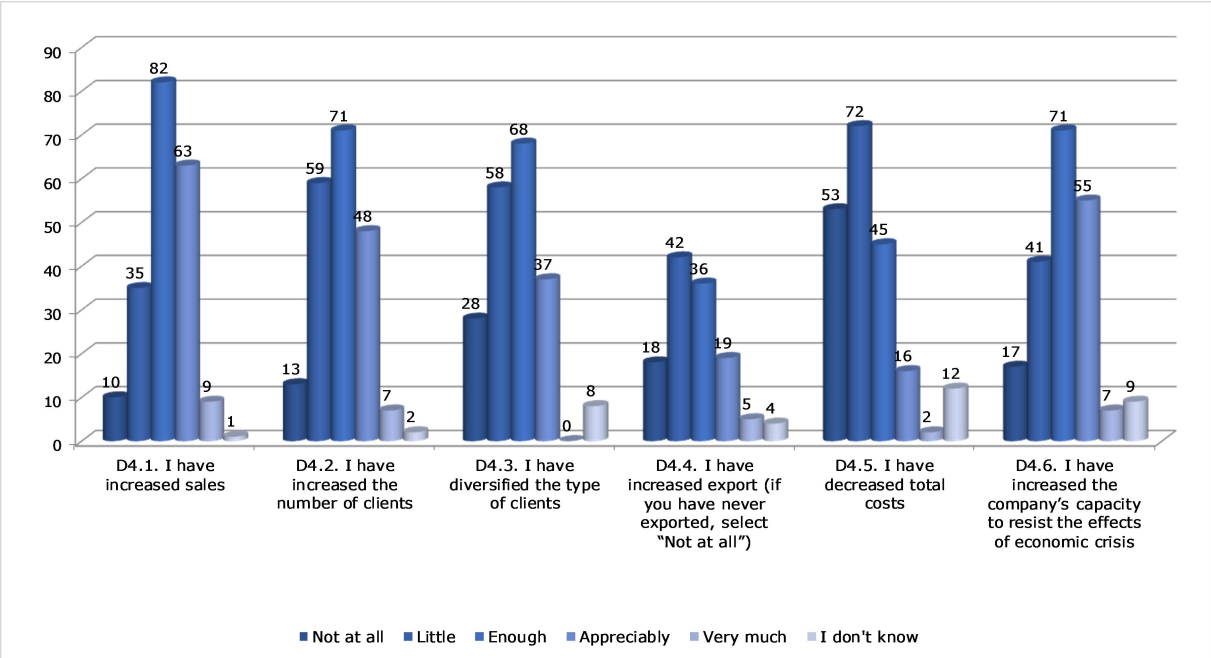

Figure 10. Economic results of the analyzed policy instrument

Note. Answer to the question: Which economic results has your enterprise already achieved thanks to the technological investments supported by BGK? n=200 respondents (except question D4.4 where n=124,- exporting enterprises only)

Source: CSIL elaboration based on the survey carried out by CSIL in collaboration with CASE and BGK

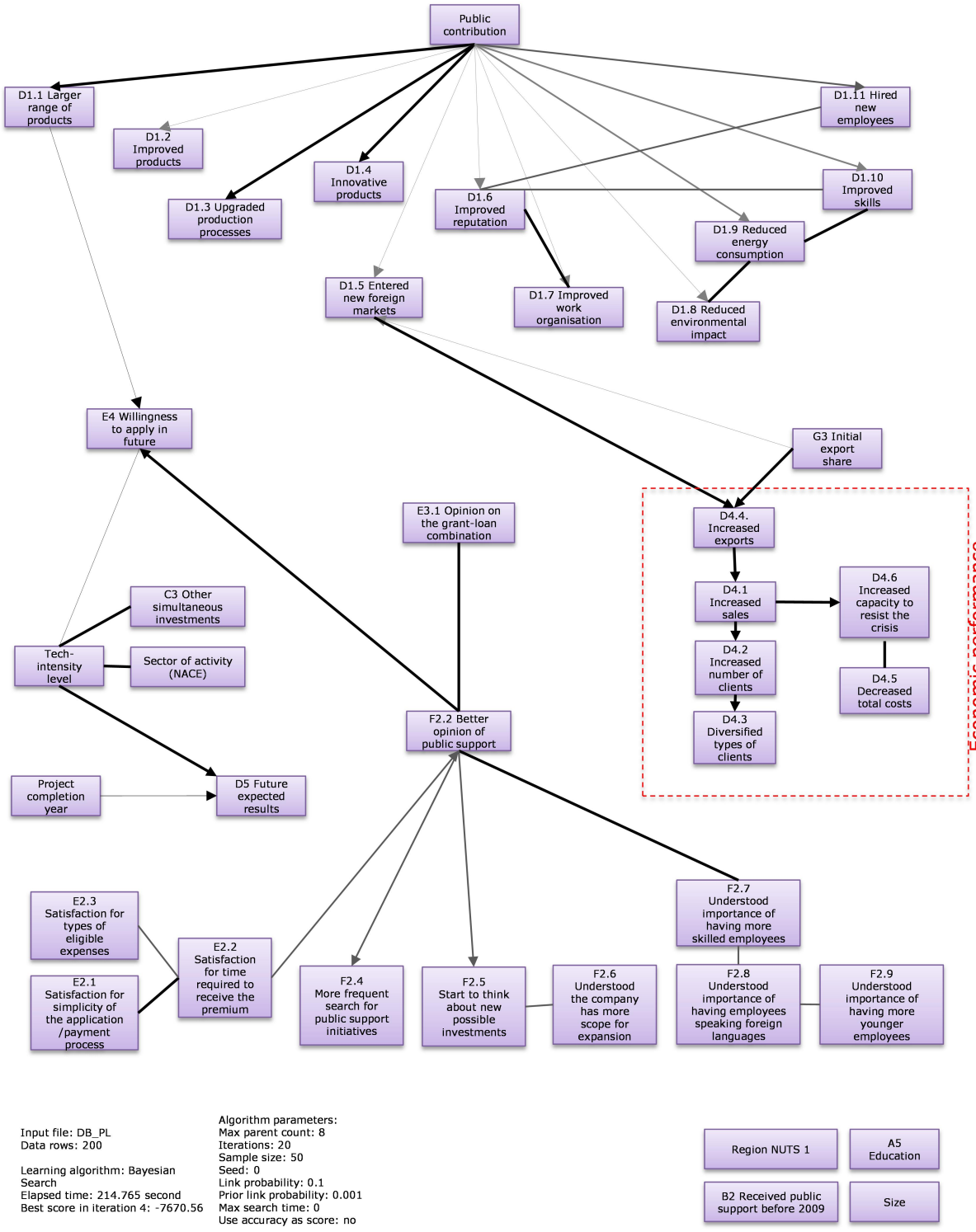

Figure 11. The change generated in Polish SMEs by the EU policy instrument (Technological Credit) according to the Bayesian Network Analysis

Note: Directed arrows show a causal relation; simple links between variables indicate correlation, without any certain causal direction. The thickness of the arrow reflects the magnitude of the correlation between the variables (estimated by GeNIe). Bottom right variables have been used as control variables but they do not result to be strongly linked to any other particular variable.

Source: CSIL elaboration

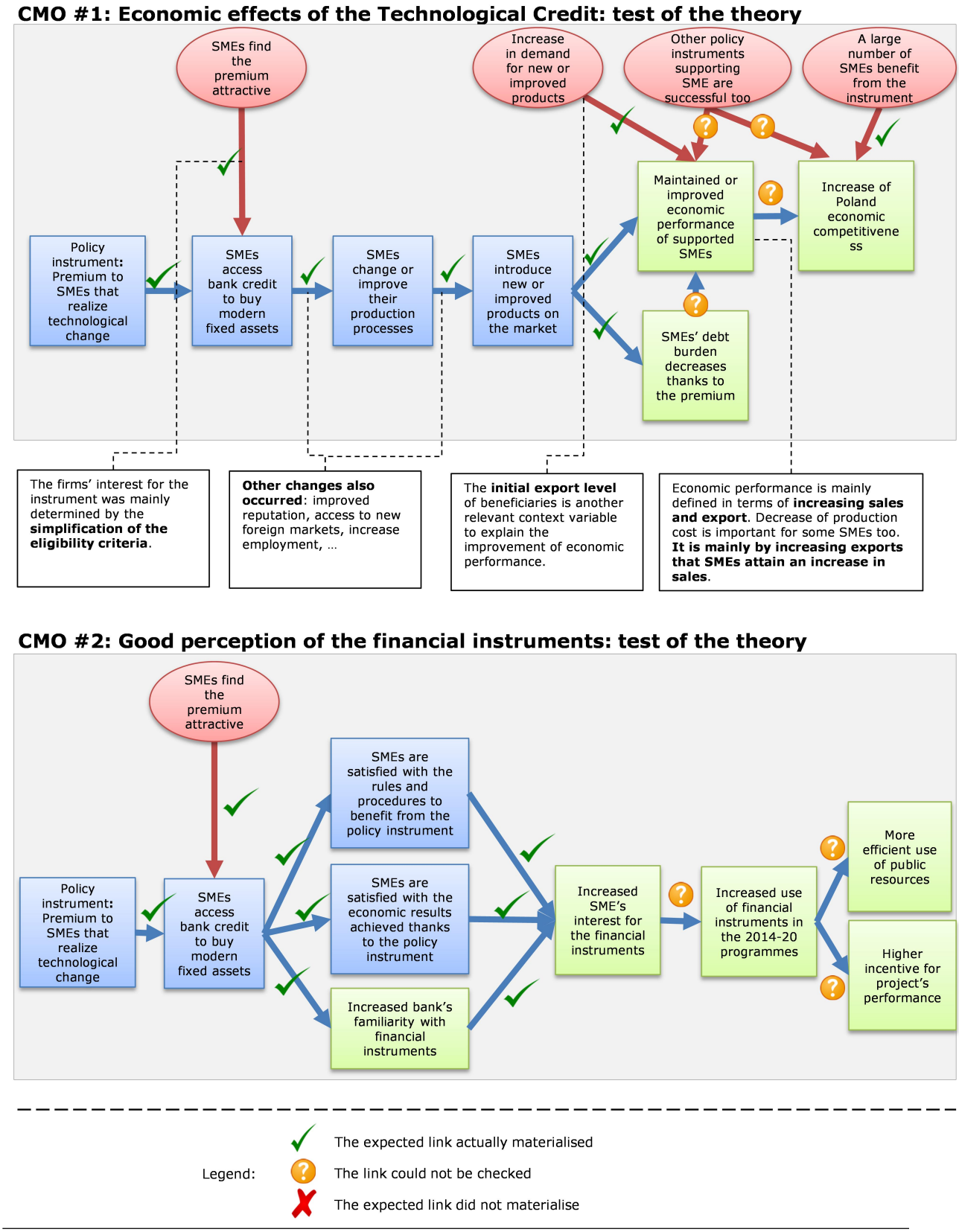

Figure 12. Test of the theory of intervention of the Technological Credit

Note: Green-coloured boxes indicate the outcomes pursued by the policy maker; red-coloured circles indicate external conditions (i.e. specifications of context) upon which desired changes occur; blue-coloured boxes indicate the mechanisms at work along the causal chain leading to the outcomes.

Source: CSIL.