REVIEW 315/2014

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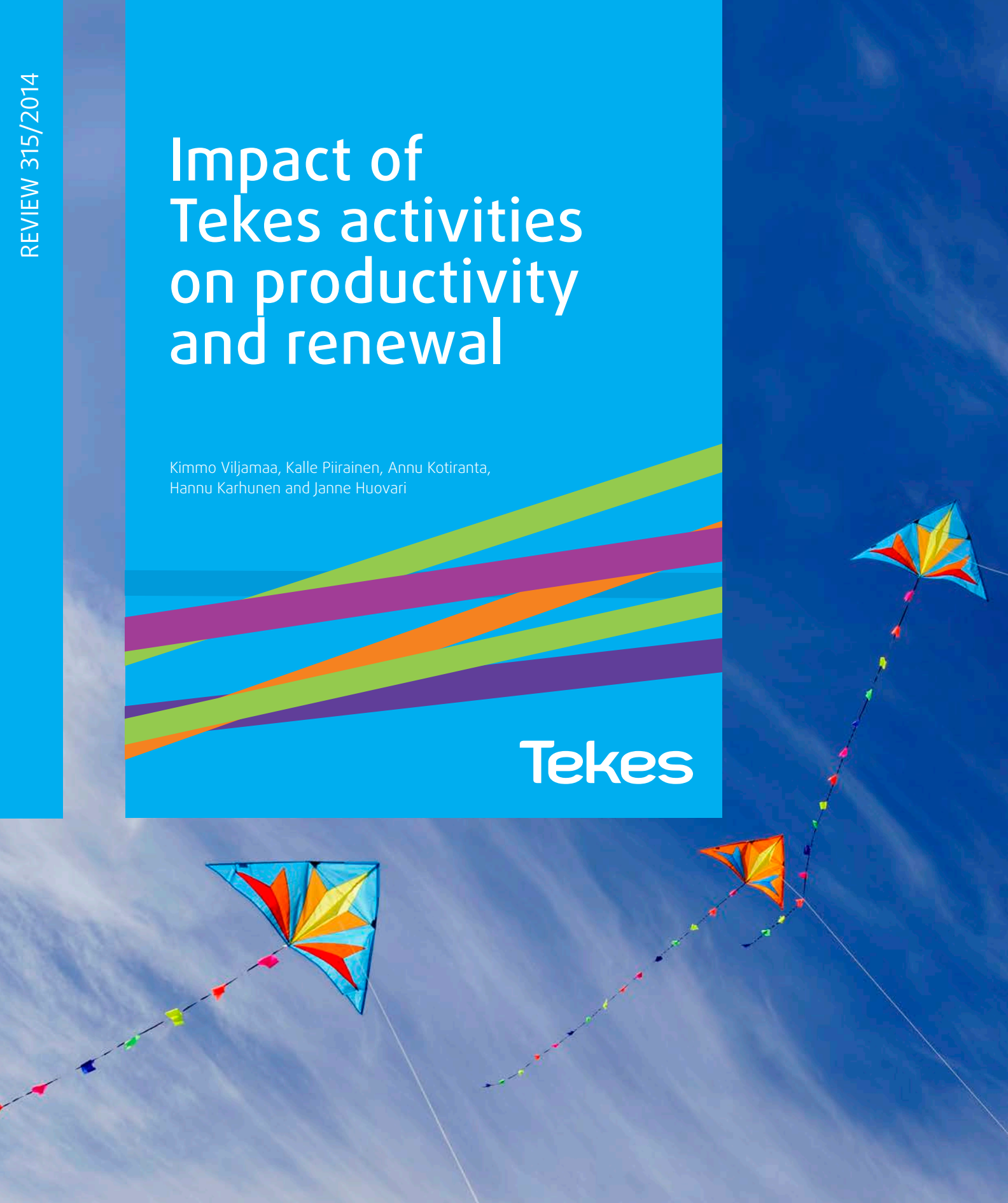

Tekes

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Tekes Review 315/2014
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Tekes – the Finnish Funding Agency for Innovation
Tekes is the main public funding organisation for research, development and innovation in Finland. Tekes funds wide-ranging innovation activities in research communities, industry and service sectors and especially promotes cooperative and risk-intensive projects. Tekes' current strategy puts strong emphasis on growth seeking SMEs.

Tekes programmes – Tekes´ choices for the greatest impact of R&D funding
Tekes uses programmes to allocate its financing, networking and expert services to areas that are important for business and society. Tekes programmes have been contributing to changes in the Finnish innovation environment over twenty years.

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Foreword

In Finland, productivity growth is increasingly based on investments in intangible assets such as expertise, knowledge, and innovations. A good level of productivity growth in the private sector has created wealth and improved our ability to fund our welfare services.

The workforce in Finland is growing slowly. Therefore, our future economic growth must be increasingly built on the growth of productivity. Hence, we need even stronger incentives for innovation activities and intangible investments. To further this, Tekes encourages developing innovations that aim at launching high added-value products and services in the market. Tekes also encourages the development of new product and service processes.

Successful RDI policies foster the development of new alternatives, platforms, and processes for the market. Every nation implements economic policies and measures tailored to its own innovation environment, but these measures generally include objectives intended to support economic renewal and bring about an increase in added value, exports, employment, expertise, and wellbeing. Productivity growth serves as the most important indicator of innovation policy success.

Continuous, long-term renewal is required to improve our productivity growth. Growth in productivity will also create the preconditions for profitable investments. Together, these factors will generate turnover, export revenue, and jobs.

Economic renewal is particularly important from the perspective of Finland's competitiveness. The continuous development of knowledge, expertise and competencies makes an impact on the state of the national economy and the country's innovation environment.

An ultimate focus of this study was to answer these challenges. The purpose of this procurement was to produce an overall analysis of how Tekes has succeeded in reaching its objectives related to productivity and renewal of industries with its innovation activities. This target involves taking productivity in sectors and clusters essential to Finnish economy and society to a top level internationally and making Finnish enterprises globally competitive. There will be a special focus on young innovative companies and growth companies.

The report indicates that the most significant impacts have been made by Tekes-funded projects of strategic importance to SMEs. In addition, the positive results and productivity development reported by recipients of the young innovative company funding (YIC), in particular, suggest that continuing to carefully select companies and provide more comprehensive support is worthwhile.

This impact study was carried out by Ramboll Management Consulting Oy and Pellervon taloudellinen tutkimuslaitos. Tekes wishes to thank the evaluators and researchers for their thorough and systematic ap¬proach. Tekes expresses its gratitude to steering group and all others that have contributed to the evaluation.

Tekes – the Finnish Funding Agency for Innovation

Contents

Yhteenveto

Tarkastelu kohdistui uusiutumisen osalta kaikkiin t&k-projekteissa 2000–2008 mukana olleisiin yrityksiin, jotka olivat täyttäneet kolme vuotta hankkeen jälkeen jälkiraportointiraportin. Tuottavuustarkastelu rajoitettiin rahoitusta saaneisiin pk-yrityksiin. Vaikutusarviointi perustui pääosin Tekesin keräämään hankkeiden jälkiraportointiaineistoon sekä tilastokeskuksen tuottamaan yritystason mikroaineistoon.

Tekesin toiminnan vaikutuksia tuottavuus- ja uusiutumiskehitykseen tarkasteltiin erityisesti yritystasolla perustuen pääosin Tekesin keräämään hankkeiden jälkiraportointiaineistoon sekä tilastokeskuksen tuottamaan yritystason mikroaineistoon.

Hankkeissa havaitut laadulliset vaikutukset keskittyvät erityisesti hankkeiden suoriin tuotoksiin, joskin selkeitä positiivisia vaikutuksia on havaittavissa myös toimijoiden verkottumisessa sekä prosessien laadun kehittämisessä. Aineiston perusteella näyttää tosin siltä, että myös yritykset itse kiinnittävät enemmän huomiota innovaatiotoiminnan suoriin tuotoksiin ja liiketoiminnan kehityksen suhteessa välillisiin vaikutuksiin, kuten kyvykkyyksien kehitykseen.

Kansainvälistymisvaikutukset eivät kokonaisuudessaan ole erityisen merkittäviä, joskin joidenkin erityisryhmien, kuten Nuorten Innovatiivisten yritysten (NIY) ja Tutkimuksesta liiketoimintaan -ohjelmien (TULI) myötävaikutuksella syntyneiden yritysten kohdalla ne ovat muita yrityksiä merkittävämpiä.

Hankkeiden tuottama lisäarvo näyttäytyy myös erityyppisenä riippuen siitä onko kyseessä nuori vai vakiintunut yritys. Nuorten yritysten kohdalla Tekes-rahoitus ei juurikaan näyttäisi suuntaavan innovaatiotoimintaa vaan sen sijaan auttaa tehostamaan sitä. Vakiintuneilla yrityksillä t&k-rahoitus sen sijaan näyttäisi mahdollistavan uusien avauksien tekemistä nykyisten vahvuusalueiden ulkopuolelta ja sitä kautta edistävän yritysten uudistumista.

Kokonaisuudessaan aineisto antaa alustavasti sellaisen kuvan, että hankevalinnan yhteydessä olisi itse hankesuunnitelmien lisäksi syytä kiinnittää huomiota niiden merkityksellisyyteen ja painoarvoon suhteessa yrityksen kokonaistavoitteisiin ja niiden strategiseen painoarvoon yrityksissä. Strategisesti merkittävät hankkeet pienissä ja keskisuurissa yrityksissä vaikuttaisivat olevan vaikutuksiltaan kaikkein merkittävimpiä.

Lisäksi erityisesti NIY-yritysten raportoimat positiiviset tulokset ja positiivinen tuottavuuskehitys antavat ymmärtää, että yritysten tarkka valinta sekä niiden kokonaisvaltainen tukeminen pelkkien t&k-hankkeiden ohessa tuottaa hedelmällisiä tuloksia.

Suurempien yritysten osalta t&k-toiminnan tukemista on perusteltu pitkälti niiden tuottamina ulkoisvaikutuksina niihin sidoksissa olevissa verkostoissa. Vaikuttaisi kuitenkin siltä, että myös suurempien yritysten osalta nykyistä tarkempaa huomiota tulisi kiinnittää niiden strategiseen merkitykseen yrityksen kehitystavoitteiden näkökulmasta, jotta hankkeet eivät jäisi tuloksiltaan liian irrallisiksi.

Tuottavuuskehityksen tarkastelu kohdistui 10–249 työntekijää työllistäneisiin yrityksiin, joiden kehitystä pyrittiin vertaamaan mahdollisimman samankaltaiseen verrokkiryhmään. Tarkasteltaessa kaikkia rahoitusta saaneita yrityksiä tuottavuuskehitys ei poikkea merkittävästi vertailuryhmästä. Yksityiskohtaisempi tarkastelu sen sijaan löysi eroja eri ryhmien välillä.

Erityisryhmistä erityisesti NIY-yritykset poikkeavat positiivisesti tuottavuuden suhteen. Toinen erittäin mielenkiintoinen havainto oli kehityksessä havaitut alueelliset erot. Analyysi paljasti, että maakuntakeskuksissa sijaitsevien yritysten tuottavuuden kasvu oli viisi vuotta t&k-hankkeen jälkeen 5% vertailuryhmää suurempi. Vastaavasti keskusten ulkopuolella toimivien Tekesin asiakkaiden tuottavuuskehitys on ollut keskimäärin vertailuryhmää heikompaa.

Julkisen t&k-tuen vaikutuksissa havaittiin jonkinasteisia eroja myös yrityksen koon mukaan. Pienillä yrityksillä havaittiin hieman parempi tuottavuuskehitys suhteessa keskisuuriin yrityksiin. Lisäksi pienten yritysten tuottavuuskehitys oli jonkin verran vertailuryhmää nopeampaa viiden vuoden jälkeen tuen saannista, joskin tämä ero ei ollut tilastollisesti merkittävä.

Vaikka tuottavuuskehitys näyttäytyy Tekesin asiakkaiden osalta positiivisena erityisesti nuorten innovatiivisten yritysten osalta sekä alueellisesti keskuksissa sijaitsevien yritysten kohdalla, kaiken kaikkiaan arviointi herättää kysymyksen, onko tuottavuus paras mahdollinen mittari yritystasolla sekä erityisesti pk- ja kasvuyritysten kohdalla paras mahdollinen indikaattori mittaamaan julkisen t&k-tuen tuottamaa lisäarvoa. Kansainvälinen tutkimus sekä tämä arvioinnin tulokset antavat ymmärtää että tämän tyyppisissä yhtäältä innovaatiotoimintaan ja toisaalta kasvuun tähtäävät investoinnit ovat keskeisessä asemassa ja saattavat tätä kautta jopa vähentää tuottavuutta lyhyellä aikavälillä sekä alkuvaiheen kasvussa. Pienten yritysten sekä kasvuyritysten kehitystä arvioitaessa voisikin olla parempi arvioida yhtäältä yritysten innovaatiotoiminnan panostuksia sekä toisaalta yrityksen kasvua lyhyen aikavälin tuottavuuskehityksen sijaan.

Tekesin vaikutusmalli ja nykyinen strategia näyttäytyy tulosten valossa oikeansuuntaisena, missä pienten ja keskisuurten innovatiivisten yritysten tukeminen on painopisteenä. Uusiutuminen näyttäytyy tässä tapauksessa toteutuvan lähinnä yritysten sisällä innovaatiotoiminnan tuloksien ja kyvykkyyksien kehittymisen kautta. Panostus kasvuyrityksiin ja innovatiivisiin yrityksiin on myös tulosten valossa oikeansuuntainen valinta. Hankevalinnassa on kuitenkin syytä myös jatkossa kiinnittää tarkkaa huomiota hanke- ja liiketoimintasuunnitelmien laatuun myös näissä yrityksissä, jottei rahoituksen suuntaaminen tee rahoitusta näille yrityksille liian helpoksi ja sitä kautta alenna itse julkisesti rahoitetun t&k-toiminnan laatua

Tekesin rahoittamien t&k-hankkeiden välillä oli myös havaittavissa huomattavia eroja. Jatkossa saattaisikin olla hyödyllistä jäljittää niin sanottujen menestyshankkeiden ja -yritysten kehitystä sekä analysoida aiempaa syvällisemmin Tekesin roolia näiden yritysten ja/tai innovaatioiden kehityksessä. Nykyistä enemmän tulisi myös kiinnittää huomiota erityisesti pienten yritysten osalta yritysten kasvuun, innovaatiotoiminnan kehitykseen yritysten sisällä sekä yritysten pitkä aikavälin kyvykkyyksien kehittymiseen. Yhteistyöverkostojen ja kerrannaisvaikutusten merkityksestä voisi myös olla tarpeellista kerätä nykyistä tarkempaa tietoa.

1 Introduction

1.1 Background and aim of the analysis

Tekes – the Finnish Funding Agency for Technology and Innovation – is the most important publicly funded expert organisation for financing research, development and innovation in Finland. Tekes operates on the idea that the success and continuous renewal of the Finnish industries is a precondition for sustainable growth and the wellbeing of people and the environment. The aim of Tekes operations is to create new growth enterprises, and particular focus is placed on small- and medium-sized enterprises (SMEs) that seek international growth. Tekes funds research and development (R&D) and innovation, which play a pivotal role in the renewal of the companies and thus the national economy.[1] According to Tekes[2]:

> *"several Finnish and foreign studies show that public R&D funding for companies serves to boost the companies' own R&D investments. The research findings show that R&D investments substantially increase corporate expertise and networking. They generate patents and new products, processes and services. Expertise and new procedures manifest themselves as a growth of turnover, productivity and employment."*

Consequently, the purpose of Tekes funding is to encourage businesses to engage in more R&D. Ultimately, the innovations funded by Tekes "contribute to the welfare of citizens and of the environment"[3]. The current study addresses the impact of Tekes activities – in light of the Tekes mission statement – on the productivity and renewal of companies. The focus/target group examined in this study are small- and medium-sized enterprises (SMEs). Particular attention is paid to Young Innovative Enterprises, TULI enterprises, and High-growth companies (gazelles).

The Ministry of Employment and the Economy (TEM) and the Finnish Funding Agency for Technology and Innovations (Tekes) have agreed that Tekes' impact and the achievement of objectives will primarily be monitored through impact analyses and studies of individual target areas. Tekes has three main target areas, as follows: 1) productivity and renewal of industries, 2) capabilities and 3) welfare (Figure 1).

The purpose of this study has been to analyse how Tekes has succeeded in reaching its objectives related to one of these key objectives, *productivity and renewal of industries,* through its innovation activities. This target included taking productivity to a top level internationally and making Finnish enterprises globally competitive in sectors that are essential to Finnish economy and society. Within the general impact analysis, a special focus was placed on *young innovative companies and growth companies*.

More specifically, the aim of the study was to assess the contribution of Tekes activities to the *renewal of the Finnish private sector and productivity growth* in Tekes-funded companies. The main research question for the assessment was *how have Tekes' activities succeeded in improving productivity and renewing industries in Finland.*

The study is based on Tekes' impact model (Figure 2). The basic concept in this model is additionality. Four dimensions in the concept of additionality describe input's impact on outputs: input, behavioural and output additionality and the

1 http://www.tekes.fi/en/community/Innovation_funding/346/Innovation_funding/1238
2 http://www.tekes.fi/en/community/Results_and_impact/468/Results_and_impact/1283
3 www.tekes.fi

Figure 1. Tekes objectives. (Source: Tekes)

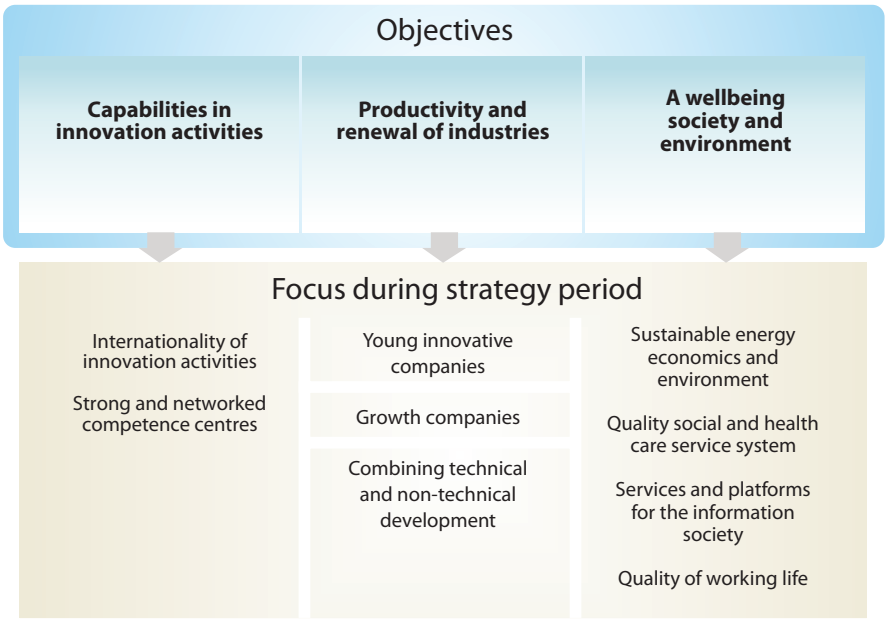
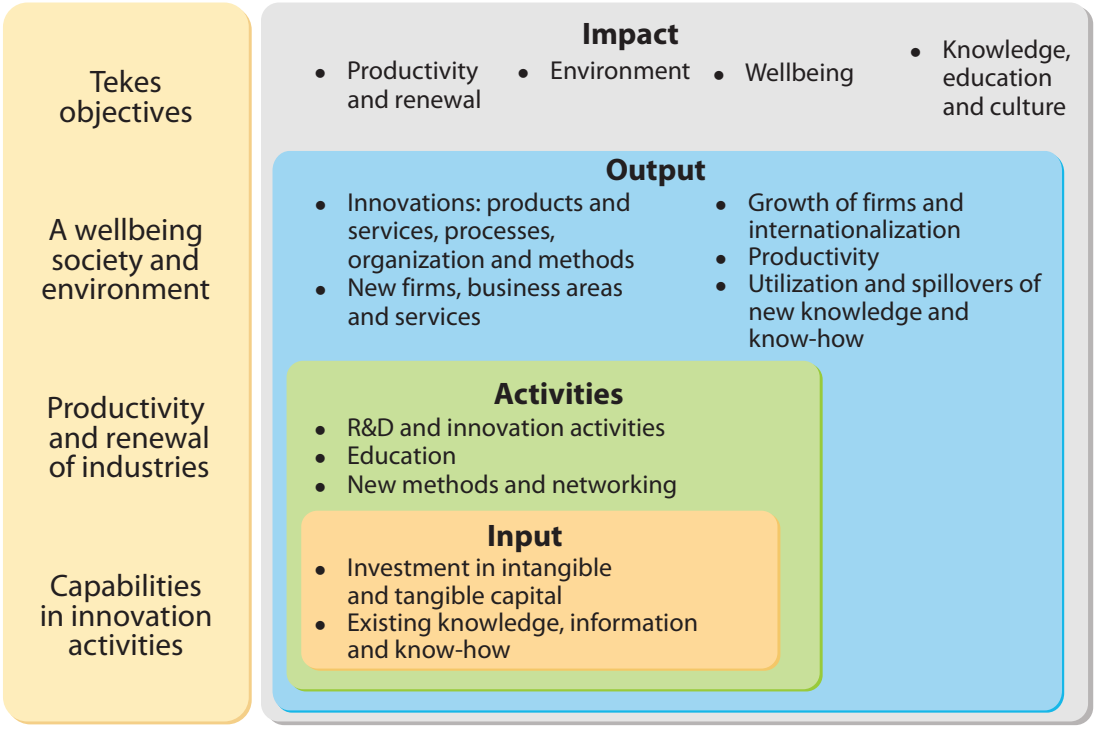


Figure 2. The Tekes impact model. (Source: Tekes)



impacts on the whole economy and society[4]. These dimensions correspond quite well with the following four levels of the Tekes impact model: input, activities, output and impact. The different forms of additionalities are discussed in greater detail in Section 1.2.1.

The main tool for supporting productivity and renewal of industries is Public Research and Development funding, which is a public subsidy for private enterprises to undertake research and development. Funding is commonly dispensed through instruments that aim to reach predetermined policy objectives. In the present study, the terms funding and subsidies are used interchangeably. It is important to note that although most of the quantitative data used in this study is based on Tekes-funded R&D projects, Tekes also has other support instruments and services that facilitate innovation.

The current report consists of six chapters. The first chapter sheds light on the subject of the analysis, the productivity and renewal of enterprises. The chapter introduces the key concept used in this study to assess firm-level renewal, behavioural additionality, and provides a brief account of the recent developments in productivity and renewal. Importantly, the first chapter discusses the materials, procedures and working methods used to approach the question of this assignment.

The second chapter summarises the findings of key studies in the field. This chapter provides insight into recent studies on the impact of R&D expenditures and public R&D funding and studies on firm-level renewal. Moreover, the second chapter addresses the question of firm-level renewal, linking it with the concept of behavioural additionality. Furthermore, the chapter explains recent findings from other Tekes evaluations.

The third chapter examines the Tekes impact model. The impact model describes the various possible effects that result from the Tekes operations and identifies the relationship of policy and policy results. The Tekes objectives and strategy regarding renewal are analysed. The chapter also examines the Tekes instruments currently in use and the different client groups for which the instruments are aimed. Section 3.2 approaches the question of impact with the concept of additionality. Additionality, as used in this report, represents the identified effects of the policy, which occurred because the policy instrument was implemented. Section 3.4 assesses the effect of the impact model on the Tekes strategy – and vice versa.

The fourth chapter uses ex-post project evaluations and quantitative data to analyse the impact of Tekes funding on firm-level renewal. Renewal in this context represents the diversification of the firm, the creation of new markets and enterprises, changes in firm behaviour and capabilities and various (knowledge) spillovers across firms and whole industries. The focus is on the main Tekes target groups, which are then compared with other companies that are not funded by Tekes. Section 4.3 of the chapter presents case studies of funded enterprises, examining the behavioural and output additionality of the funding.

The fifth chapter undertakes an econometric impact analysis that focuses on the effects of Tekes funding on the productivity of the recipient enterprises. The chapter explores the relationship between the R&D subsidies and the productivity developments in the enterprises. The analysis is facilitated by comparisons of Tekes-funded enterprises to enterprises that are not Tekes-funded. As indicated in the chapter, it is generally quite challenging to measure the causal effects of policies on outcomes such as firm productivity. The fifth chapter's solution to this challenge is to approach the question of causality by comparing the target group, the Tekes-funded enterprises, with a closely matched group of companies.

Using the above-mentioned method, the fifth chapter examines the productivity development in firms that reported growth in their productivity, and specifically linked the productivity growth to the funding received from Tekes. In addition, the chapter approaches productivity growth in Young Innovative Enterprises, TULI enterprises, and High-growth companies (gazelles) using the same method of comparison. Section 5.4 also addresses the linkage between productivity and the location of the firm. The key finding of the chapter is that productivity growth in Tekes-funded enterprises is not significantly different from productivity growth in other similar enterprises that do not receive Tekes funding.

Chapter six summarises the key findings of the report and issues recommendations for future actions.

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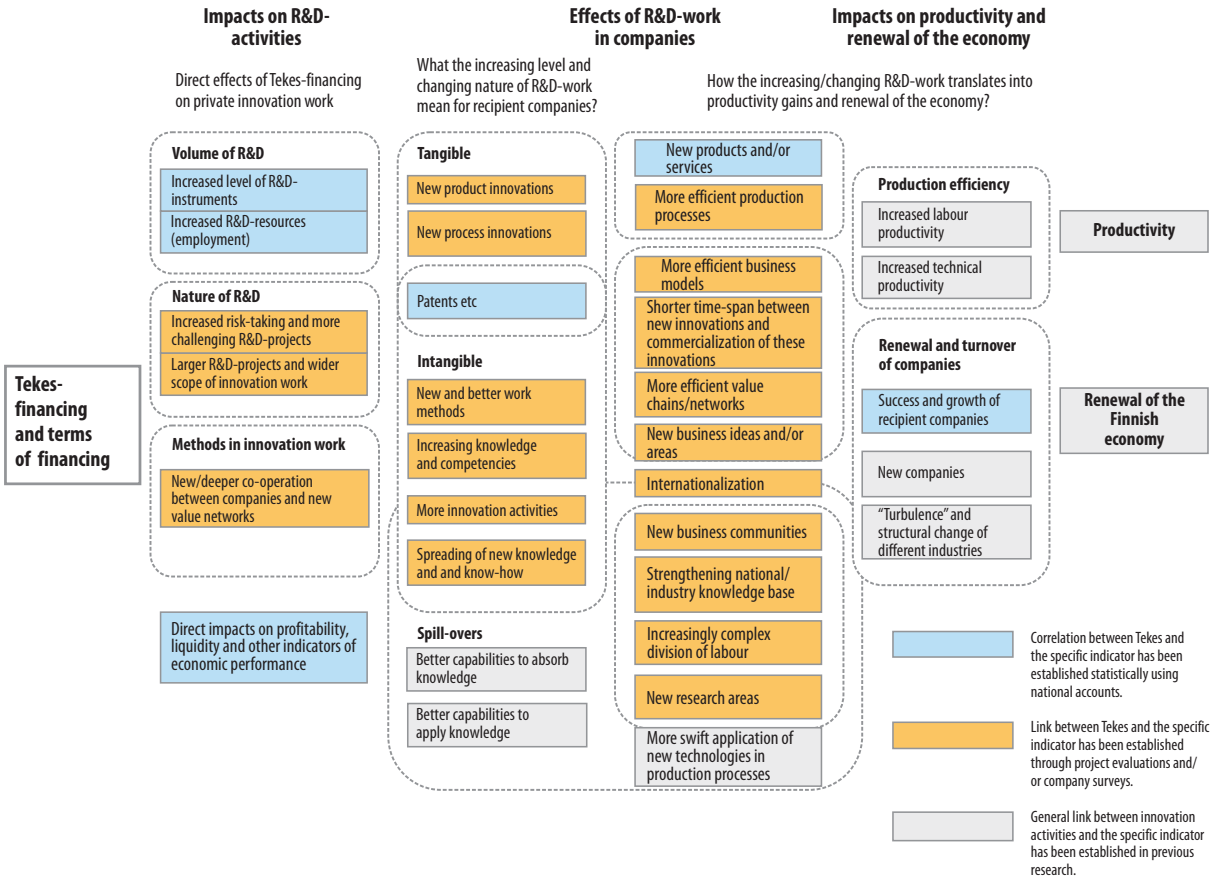
4 E.g. Georghiou & Clarysse & Steurs & Bilsen & Larossa (2004).

1.2 The object of the assessment: the contribution of Tekes' activities on productivity and renewal

1.2.1 Concepts of productivity and renewal

In an earlier report[5], productivity and renewal were analysed as the macro-level impacts of innovation activities. This is evident in the impact model, in which several mechanisms from inputs to impacts were identified (see Figure 3 below). Although this model is quite successful in identifying various mechanisms on the way to economic impacts, the present study takes a slightly different approach. We concentrate on productivity development and renewal as micro-level (project and firm-level) phenomena that take place in the firms that receive Tekes' support for their innovation activities. We approach the impact model from an additionality perspective, which has also been used by Tekes during the recent years.

Figure 3. Links from Tekes' activities to productivity and renewal of the economy at the macro level. (Source: Riipinen et al. 2012)



5 Riipinen, T., Valtakari, M., Rajahonka, M., Ilmakunnas, P. and Väänänen, L. (2012)Tuottavuus ja uusiutuminen – Katsaus Tekesin vaikuttavuudesta. Tekesin katsaus 293/2012.

Productivity is one of the key elements in the success of a country – or a company – and is considered a key source of economic growth and competitiveness. Productivity is commonly defined as the ratio of a volume measure of output to a volume measure of inputs and measures how efficiently production inputs are being used in the economy to produce outputs[6]. A company's competitiveness improves as more outputs can be produced with smaller resources. Productivity can be measured by calculating total factor productivity (TFP) via production function or by calculating labour productivity from the raw data. The present study uses labour productivity as a measure of annual firm productivity. In this study, productivity is studied at the firm level.

Compared with productivity, the *renewal* of industries is a more complex concept. Renewal can be achieved through many different routes, including diversification, the creation of new markets and enterprises, changes in firm behaviour and capabilities and various (knowledge) spillovers across firms and whole industries.

At the industry level, a popular concept that is related to renewal is 'creative destruction', which means in practical terms that innovations of new firms unleash selection pressures on existing firms, leading to the exit of uncompetitive firms and renewing whole industries in this sense. The other end of the spectrum is 'creative construction'[7], which holds knowledge spillovers from new firms as a key mechanism that underlies new venture formation and development at the micro level and economic growth at the macro level.[8] In this sense, creative destruction and creative construction represent different ends of the continuum.

At the firm level, the concept of renewal can be summarised in the concept of behavioural additionality.[9] Behavioural additionality refers to different levels of interactions that impact the behaviour of firms.[10] These can be changes at the project level (organisation, management, interactions) or firm level (changes in management, organisation, capabilities, networking etc.).

For the purposes of the following discussion, we have divided the concepts of productivity and renewal in three parts (Table 1). This division serves as the framework of this impact study.

The renewal processes through firm entries and exits is rather strongly discussed. However, the evidence on the renewal of existing businesses is less clear. The positive relationship between the (strategic) renewal and innovation by incumbent, existing firms and the performance of these firms, both in the short and long run, is a much less studied area.[11]

Table 1. Basic approach to productivity and renewal.

Impact	Firm-level instruments	Strategic instruments
Productivity (macro level)	Increased value added and operational efficiency	
Industrial renewal	Spillovers, creative construction	New enterprises, creative destruction (selection)
Renewal of enterprises	Persistent changes in firm behaviour and capabilities (behavioural additionality)	Diversification

6 OECD (2006). OECD Compendium of Productivity Indicators 2006.

7 Agarwal, R.; Audretsch, D.B.; Sarkar, MB (2008) : The process of creative construction: knowledge spillovers, entrepreneurship and economic growth, Jena economic research papers, No. 2008,008.

8 "As entrants build on knowledge and networks built in incumbent organizations to create new novel combinations that in a Schumpeterian sense causes the destruction of lesser entities, reverse flows from entrants to incumbents can lead to a dynamic process of growth, and thereby a win-win scenario where the positive externalities of knowledge spillovers are highlighted in the process of both value creation and appropriation." (Agarwal et al. 2008).

9 Although in some cases input additionality, i.e., increase in firm-level R&D expenditure, may indicate renewal in the firms strategy

10 Larosse, (2004) Conceptual and empirical challenges of evaluating the effectiveness of innovation policies with "Behavioural Additionality"(the case of IWT R&D subsidies); Gök (2010).

11 Lehtoranta,O. (2010) Innovation, Collaboration in Innovation and the Growth Performance of Finnish Firms. VTT PUBLICATIONS 729

Partly because of the relatively small number of previous studies and the limited data available for this study (mainly Tekes project evaluation data), the current impact study emphasises the firm level and, more specifically, the firms that have received Tekes funding for R&D projects. We therefore limit the analysis of productivity and renewal to firm-level analysis, although we also consider some of the project-level spillovers.

1.2.2 Concepts of renewal

Industrial renewal may take a variety of forms. It may be seen as the renewal of firms and their internal regimes, the renewal of their product/service portfolios and markets or, in the Schumpeterian sense, as the renewal of industries in terms of the entry of new firms and exit of incumbents (also called creative destruction, or selection). The difference between the first two and the last is the level of analysis, as industrial renewal is a macro or meso-level phenomenon, which can be analysed on the level of economies or sectors, whereas the renewal of firms can be analysed on the enterprise level.

Of note, the renewal of industries can be reduced to the behaviour of individual firms within the industry. According to Schumpeter, the question was not "how capitalism administers existing structures, whereas the relevant problem is how it creates and destroys them".[12] Evolutionary economics aims to explain industry renewal through the concepts of evolution theory. Evolutionary economics proposes that firms are like any living organism that is born, lives and dies according to its ability to adapt to the constantly changing industry conditions within the framework of the markets.[13] Firm exit, or death, can be viewed from an economic perspective as a response to overcapacity. From this perspective, a firm that is forced to exit and its offering are surplus to requirements, which can be attributed to the failure of "internal control systems", i.e., management of change.[14] Thus, the problem can be reduced to the question of the firms' agility in adapting their structures and capabilities through, for example, R&D as a response to customer demand and their competitors' actions.

Considering Tekes' objectives, it seems that the most important aspects of renewal are the impacts of Tekes funding on the volume and output of firms' R&D. Innovation taxonomies have been discussed extensively, and one of the most common distinctions is the radicality or newness of innovation. However, newness can be separated into two dimensions, newness to the innovator and newness to markets. In this taxonomy, 'really new' innovations are new to the innovator and new to the markets and actual radical innovations are new to the innovator's value network and create a new market. Here, radical innovations naturally create the most added value and increase firm productivity in terms of factor productivity or value added per labour input. (See fig. 4)

The other point of departure is the focus of innovation on the product, service or process. In practice, though, industrial innovation tends to be complex and intertwined; a new product often requires new production technologies. On the other hand, new production technologies can be disruptive if they lower marginal costs and /or increase labour productivity significantly.

However, radical innovations are often 'competence destroying'[15] within the industry. In this context, firms that cater to a roughly homogenous customer segment are called an industry. According to the resource-based view of the firm (RBV), a firm's competitive advantage is based on aspects of its resources that are Valuable, Rare Inimitable and Operational (VRIO)[16] and its capability to configure and use them to create new value added[17]. Even for capabilities that satisfy the VRIO requirements, there are at least two ways for them to become

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12 Schumpeter, J. A. (1976). Capitalism, Socialism and Democracy. New York, Harper & Row.

13 e.g., Nelson, R.R. & Winter, S.G. (1982). An Evolutionary Theory of Economic Change, Harvard University Press, Cambridge, MA.

14 Jensen, M.C. (2000). The Modern Industrial Revolution, Exit, and The Failure of Internal Control Systems, in: Theory of the Firm, Harvard University Press, Cambridge MA.

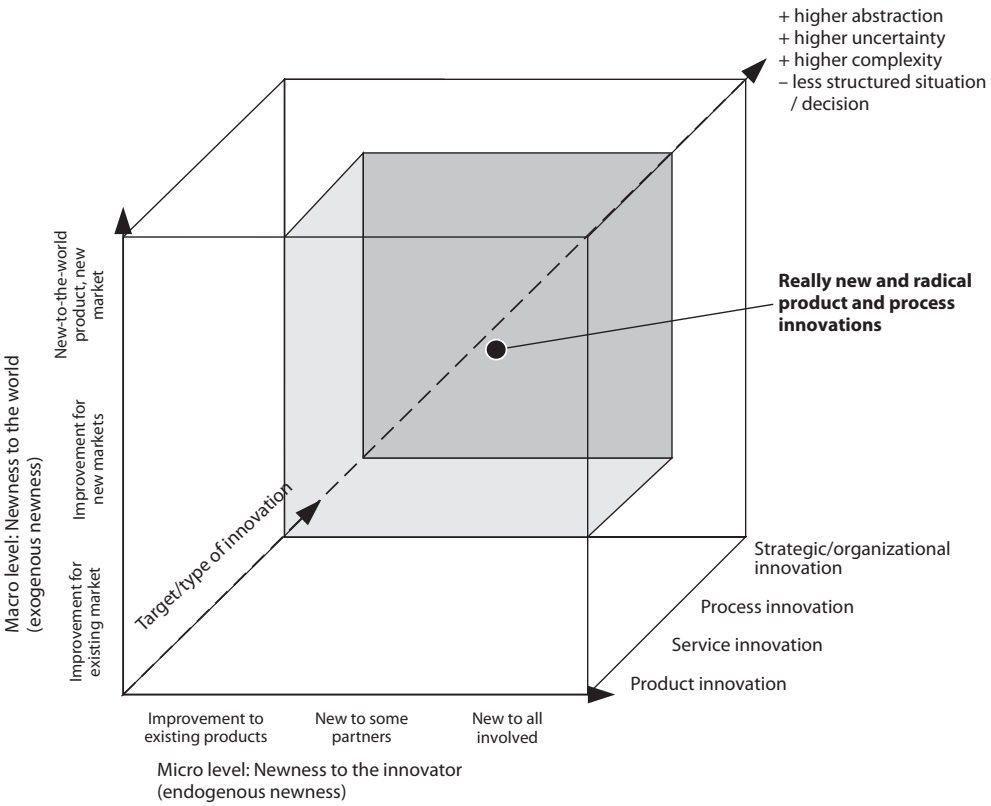
15 *"Competence-destroying innovations are negatively associated with incumbent performance, while competence- enhancing innovations are positively associated with incumbent performance—even as both are associated with system-wide organizational change."* (Tushman & Anderson, 1986).

16 e.g., Barney, J.B. (1991). Firm resources and sustained competitive advantage, Journal of Management, Vol. 17, 101.

17 Teece, D.J. & Pisano, G. & Shuen, A. (1997). Dynamic Capabilities and Strategic Management, Strategic Management Journal, Vol. 18 (7), 509–533; Eisenhardt, K.M.; Martin, J.A., 2000. Dynamic capabilities:What are they?, Strategic Management Journal, Vol. 21 (10/11), 1105–1122.

obsolete, as follows: erosion when adapting to competitive changes and replacement by different capability.[18] A given firm has a set of capabilities and a portfolio of technology. The technology development is generally cumulative, that is, based on previous projects and ideas, a condition called path dependence.[19] Capabilities are also considered path dependent, as they are based on a body of knowledge and evolve through learning and the reflection of new information against the existing body of knowledge. In plain terms: the firm evolves based on previous experience and generally does not make sudden turns on the path of development. In this view, an innovation can be considered capability-enhancing if it fits the path of previous development and enhances the existing competence through positive feedback from the market. Correspondingly, a competence-destroying innovation is a product or technology that is a clear side step away from the natural path and requires significantly different capabilities than presently available.

Figure 4. Renewal from the perspective of innovativeness.[20]



[18] Collis, D. J. (1994). Research Note: How Valuable are Organizational Capabilities?, Strategic Management Journal, Vol. 15, Special Issue: Competitive Organizational Behavior (Winter, 1994), 143–152.

[19] Cohen, W.M. & Levinthal, D.A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation, Administrative Science Quarterly, Vol. 53 (1), pp. 128–152.

[20] Garcia, R. & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: a literature review, The Journal of Product Innovation Management, 19, pp. 110–132.

When a firm in the industry creates a completely new, competence-destroying technology and/or service offering, it may render the other firms' resources virtually worthless or set them substantially back until they recover by mimicking the new offering's value. This may create a situation in which productivity increase in one firm is cancelled out by the setback of others in the same industry and market. Historically, there are well-documented cases in which the incumbents who did everything 'right' perished because of a new radical innovation.[21] This so-called competence trap can be explained through path dependency. The relevance to Tekes' impact is that when examining the aggregate effect of funding, some of the effects may cancel each other out in the short term. However, in the longer term, the developed knowledge may benefit the whole economy through spillovers.

To sum, it seems that there are two important aspects of R&D funding. First, it should have an impact on the outcome of innovation in terms of profitability and productivity. Second, it should also enable the firms to develop their capabilities to configure their resources to new capabilities, to enable flexibility in the face of change and future disruptive innovations.

1.2.3 Behavioural additionality as a perspective to tackle firm-level renewal

In the evaluation of public support for innovation, the additionality approach has commonly been utilised during recent years. As stated above, this approach has been the basis for Tekes' impact model. The additionality approach focuses on the impact that public R&D funding has on the project or the recipient organisation. Input additionality refers to public funding that adds to the firm's own investments. Output additionality, on the other hand, considers the project outputs and economic outcomes and how public R&D funding has contributed to these. The third type of additionality, behavioural additionality, describes the impact of public R&D funding on the firm's behaviour and cognitive capacity.

The traditional input additionality and output additionality discussion is greatly influenced by neoclassical economics. These additionalities are mainly based on the assumption of *market failures*, i.e., that profit-seeking firms tend to underinvest in R&D because of the public good character of knowledge.[22] The background of the behavioural additionality is includes evolutionary and structuralist theories and the role of policy in overcoming *system failures.* According to this approach, a policy action is successful only if it changes the persistent behaviour of the agents.[23]

The behavioural additionality approach can be considered as a new and improved evaluation framework in which policy analysis focuses on the firm itself as opposed to mainstream understanding, which views the firm as a black-box.[24] Moreover, behavioural additionality (as well as output additionality) is not typically confined inside one firm but, rather, through various mechanisms spread across organisational boundaries. These "spillovers" may be considered as key results.

Behavioural additionality can be understood in at least four ways:[25]

i) an extension of input additionality,
ii) the change in the non-persistent behaviour related to R&D and innovation activities,
iii) the change in the persistent behaviour related to R&D and innovation activities, and
iv) the change in the general conduct of the firm with substantial reference to the building blocks of behaviour

In the present study, we mainly refer to the fourth and the broadest definition of behavioural additionally, i.e., *all changes in the firm as a result or affected by Tekes' co-funded R&D activities*. This broad approach is based on the view that behavioural additionality is not necessarily confined to R&D and innovation-related activities, but includes all change in the general conduct of the firm. Secondly, behavioural additionality includes not only the effects during the project but also persis-

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21 Christensen, C.M. (1997). The Innovators Dilemma: When New Technologies Cause Great Firms to Fail, Harvard Business School Press, Cambridge MA.

22 Does Europe change R&D-behaviour? Assessing the behavioural additionality of the Sixth Framework Programme (2009).

23 Gök (2010) The Evolutionary Approach to Innovation Policy Evaluation: Behavioural Additionality and Organisational Routines. PhD, The University of Manchester.

24 Gök (2010).

25 Gök (2010).

tent and long-term effects such as network relationships, new knowledge and new cognitive capacities.

Behavioural additionality thus broadens the traditional additionality approach by considering whether actors have become more involved in R&D activities, the R&D activity has had a broader impact on firm activities and capabilities and any of these changes have been permanent or institutionalised. Especially these permanent changes can be considered as firm-level renewal, which on an aggregate level contributes to the renewal of industries and the economy as a whole. As Georghiou[26] notes, "while input and output additionality operate at a point in time, behavioural additionality effects may be expected to endure beyond the period of the R&D and to be integrated into the general capabilities of the firm".

Behavioural additionality includes several types of mechanisms and impacts. At least the following different (partially overlapping) mechanisms have been identified:[27]

Project-level additionalities:

- Project additionalities – research project is cancelled (full project additionality) or changed, unless it receives public co-funding
- Scale additionalities – public funding allows the project to be conducted on a larger scale
- Acceleration additionality – the project is carried out more rapidly
- Scope additionalities – without public co-funding, objectives are narrowed down or moved to shorter-term focus
- Challenge additionality – public funding allows more challenging and risky projects, which may produce better results

Higher-level additionalities after project implementation:

- Network and/or collaboration additionality – impact of public support on the collaborative behaviour of the organisations
- Follow-up additionality – when government support helps to establish follow-up projects
- Cognitive capacity additionality – impact on competencies and expertise
- Management additionality – the impact of the projects on skills related to the management of innovation processes, such as the ability to network or innovation management capabilities
- Strategic additionality – impacts that are of a more strategic nature, in particular on the R&D strategy of the organisations involved

Behavioural additionality also generates positive impacts at different levels. The first-level additionality is in the project, allowing the project to be carried out in a more beneficial way. At the second level, behavioural additionality generates variety within the firm. Various spillovers therefore disseminate this variety to other firms and create variety at the industry level. Thirdly, government intervention might help some widely exercised routines (i.e., social technologies or institutions) to the

Table 2. Additionalities at different levels.

Project-level	Firm-level	Industry-level	Societal
• Scale • Risk • Scope • Time • Quality	• Management • Partnerships • Strategy chance • New business areas • Cognitive capacity	• Networks and collaboration (organisation) • Knowledge spillovers	• Spillovers with positive effect on societal objectives and needs

26 Georghoiu L. (2002) Impact and Additionality of Innovation Policy. In Boekholt P. (Ed.) Innovation Policy and Sustainable Development: Can Innovation Incentives Make a Difference? IWT-Observatory.

27 Bach L., Matt M. (2002). Rationale for science and technology policy. In: Georghiou L., Rigby J. (Eds). Assessing the socio-economic impacts of the Framework Programme. Report to European Commission DG Research. ;Falk, R. (2007). Measuring the effects of public support schemes on firms' innovation activities: Survey evidence from Austria. Research Policy, 36, 665–679; OECD (2006). Evaluation of Publicly Funded Research: Recent Trends and Perspectives. In: OECD (ed.) OECD Science, Technology and Industry Outlook; Does Europe change R&D-behaviour? Assessing the behavioural additionality of the Sixth Framework Programme (2009).

macro order and hence create yet another level of variety or a broader societal impact.

Tekes has been using the additionality theory (including behavioural additionality) as a base of evaluation activities since 2005.[28] This approach has been influenced by the framework set up by Georghiou[29] on impact and additionality of innovation policy. The figure below describes the basic dimensions of behavioural additionality as defined by Tekes.

As shown from the list above and the Tekes framework, most of the key mechanisms in the general framework have been identified by Tekes. Moreover, nearly all of these aspects have also been addressed in the Tekes project evaluation system.

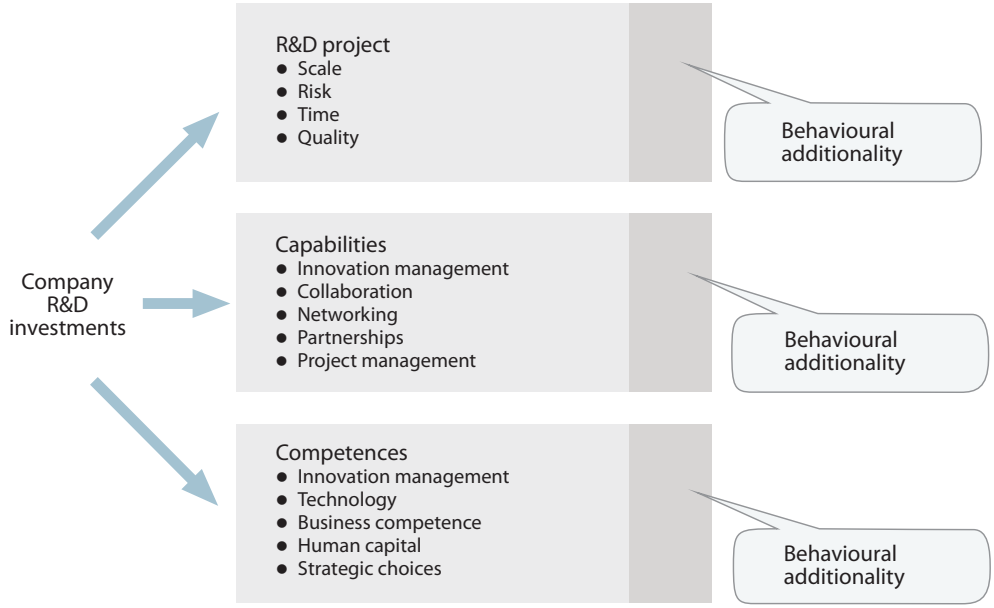
In the current impact study, we do not focus on project-level additionalities; rather, we concentrate on firm-level changes (firm-level renewal) and the broader spillover effects on other firms and the society in general.

1.3 Recent developments of productivity and renewal

Productivity is one of the key elements in the success of a country – or a company. As more out- puts can be produced with smaller resources, the competitiveness of the company improves. Generally, the productivity in Finland has improved significantly over the past 35 years. The economic recession of the early 1990s and 2008 have slowed development, especially in the manufacturing sector.

The improved productivity in Finland has been driven by the rapid development of agriculture and, especially, manufacturing. Simultaneously, the labour-intensive service sector has not enhanced its productivity accordingly. However, the manufacturing sector has been the most vulnerable to changes in the national and global economy. As the service sector accounts for more than 60% of the national GDP, the pace of

Figure 5. Tekes' approach to behavioural additionality.[30]



28 Hyvärinen, J. (2009) Tekes impact goals, logic model and evaluation of socio-economic effects. Research Evaluation, 20(4), October 2011, pages 313–323.

29 Georghiou, L.(2002) Impact and additionality of innovation policy. In Innovation Policy and Sustainable Development: Can Public Innovation Incentives Make a Difference? ed. P Boekholt. Contributions to a six countries programme conference, 28 February – 1 March 2002. IWT-Observatory, Brussels.

30 Source: Tekes (2006)

Figure 6. Productivity index.[31]

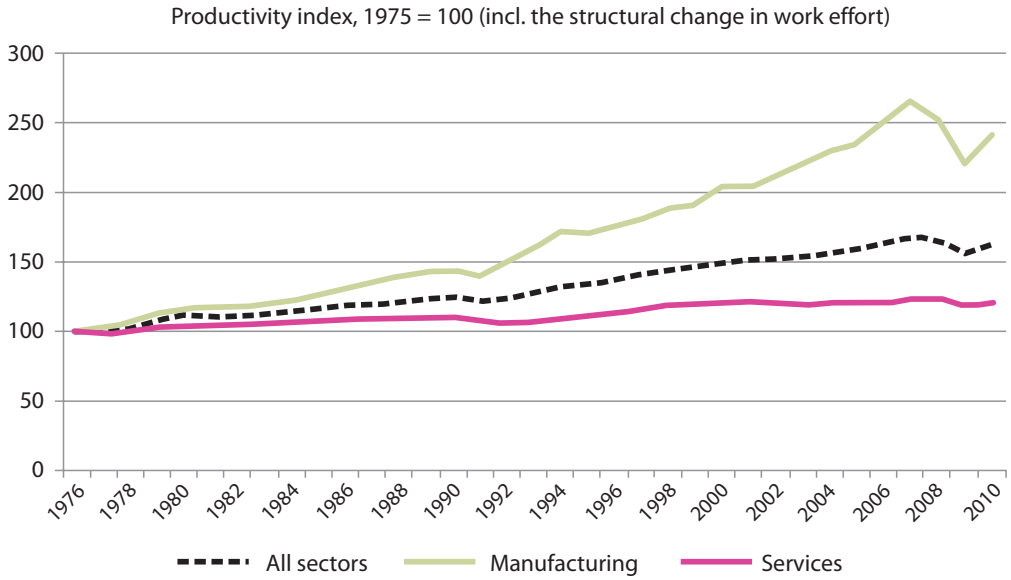
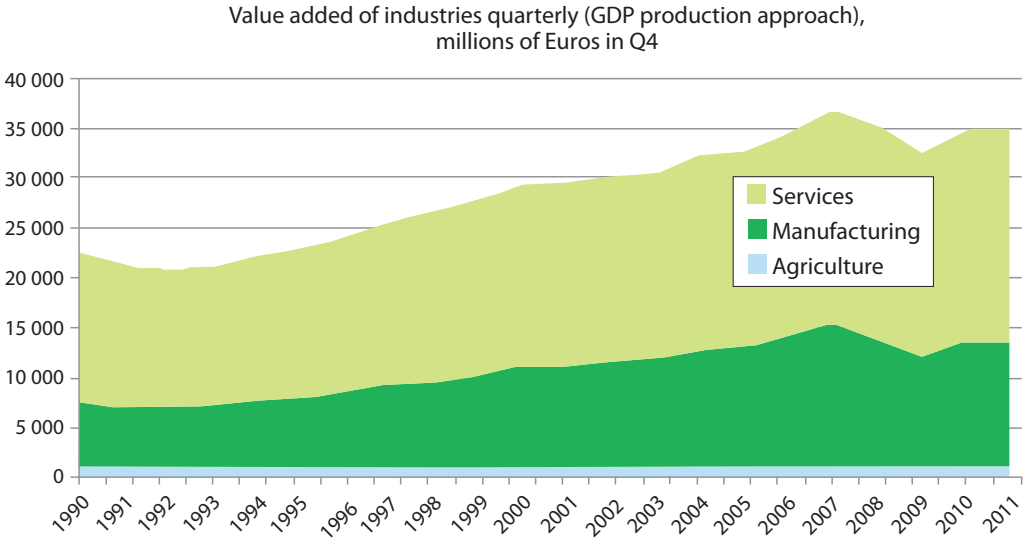


Figure 7. Value added of industries.[32]



31 Source: Statistics Finland.

32 Source: Statistics Finland.

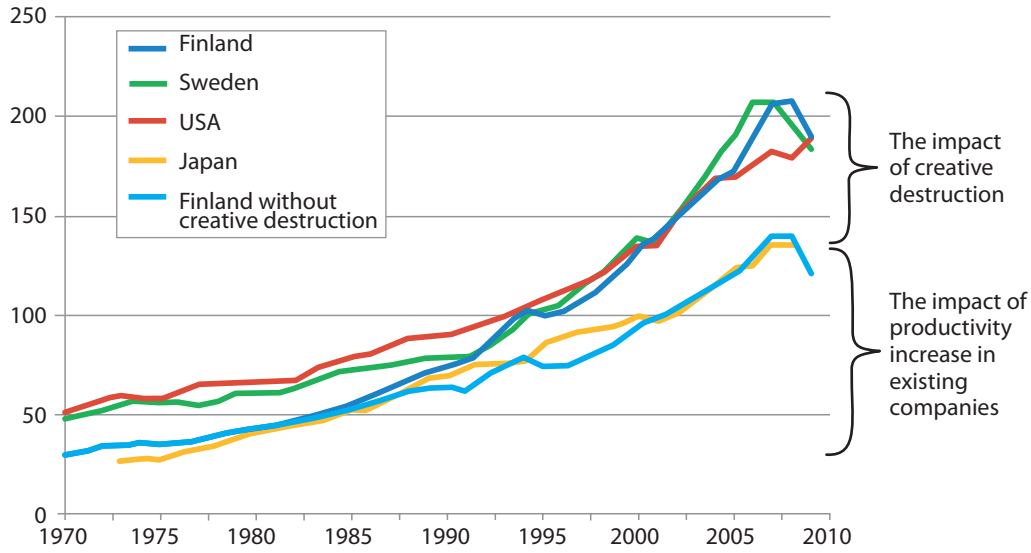
the productivity development is an important determinant in the national productivity development.

In the literature, the role of the public sector R&D funding in productivity growth is somewhat controversial. Some studies suggest that the public funding support system in Finland could slow down the renewal process by funding companies that would not be able to survive without additional help. If the help is continuous, as it often seems to be[33], public funding enables the survival of individual companies, often based on regional reasons, and decreases the pressure on improved productivity. Thus, it slows the process of creative destruction, industry renewal and productivity development.[34]

As mentioned above, one of the most important mechanisms of productivity development of the industry is the so-called "creative destruction"[35], in which companies that are not able to respond to the increasing needs of improved productivity vanish and those that are able to develop new, less work- or capital-intensive means of producing outputs remain. The following figure provides an estimate of the role of the creative destruction process in the productivity development in Finland. The figure shows that creative destruction explains one-third of the overall productivity growth of the manufacturing sector in Finland.

The facilitation of creative destruction is, however, not the direct aim of the public support system or Tekes' funding.[37] The rise in productivity is based on intangible investments and innovations created by these investments. However, the emphasis on young companies and growth companies may indirectly contribute to the process of creative destruction.

Figure 8. The impact of creative destruction on labour productivity (Finland 1995 = 100).[36]



33 Koski & Ylä-Anttila, 2011.

34 Ottaviano & Kangasharju & Maliranta, 2009

35 See, for example, the following classic and the more practical up-to-date article: Schumpeter (1976); Maliranta, Rouvinen, Ylä-Anttila (2010).

36 Source: Groningen University, EU KLEMS, OECD STAN.

37 See, for example, the following: Yritystukiselvitys (2012), TEM-raportteja 7/2012.

1.4 Description of the materials, procedures and working methods used

As mentioned above, the aim of the present study is to assess the contribution of Tekes' activities to the renewal of the Finnish private sector and productivity growth in Tekes-funded companies based on the available data. In the latest Tekes strategy, even more emphasis is placed on a continual renewal of industries. This is also visible in the focus of forerunners that aim at significant renewal. Priority is also given to growth-oriented innovative enterprises.

The detailed impact model and main Tekes objectives form the basis of the conceptual framework of the analysis. This study contributes to the model with more detailed insight into the impact models while exploring different possibilities for assessing productivity, analysing selected target groups by explorative analysis and taking into account the various conceptualisations of Tekes' strategic objectives. Thus, the statistical methodology is to some extent defined in the first phases of the study, and explorative analysis of qualitative data is planned.

One integral part of this evaluation is to provide more information on the immediate results of Tekes funding toward the final goals, such as productivity gains, the renewal of the economy and economic welfare. Although the econometric analysis provides interesting figures and the possibility to utilise the detailed and broad available data, the detailed model linking Tekes' activities to objectives and productivity renewal also poses questions that cannot be answered with purely statistical analysis. Therefore, this study utilises a magnitude of methods that can be used in complementing the theory of change, or intervention logic, that aims to explain and model the mechanisms that affect productivity at the company, industry and national level. Information on the actual impacts has been subtracted, for example, in the case studies, econometrical analysis and complementary interviews.

Table 3. Research design summarised.

Research questions	Data Sources	Methodological approach
Literature Review (surveys, Tekes Programme Reports, discussion papers, journal articles, etc.), interviews and indicators		
1. Based on the newest literature and interviews, how has Tekes funding succeeded in improving productivity and renewal in Finland? How has Finland succeeded compared with other countries? 2. What are the findings of international literature, how public R&D&I funding and innovation activities in general improve productivity and renewal? 3. What types of methods for continuous monitoring, measurement and indicators can be identified to support Tekes management in this target area related to productivity and renewal for innovation activities?	International research literature (updated from last study)	Systemic review of research literature Coding of findings to the code-tree for literature review
Firm-Specific Statistical Analysis (with specific emphasis on firms that have answered that productivity growth has been remarkable or somewhat remarkable)		
4. How have these firms answered question 4 compared with other Tekes-funded firms? (Question 4 How has your firm's competitive advantage improved because of the project when concerning the markets and other competitors?) 5. How have these firms answered question 5 compared with other Tekes-funded firms? What broader impacts have you noticed when considering the whole sector, business chains or innovation networks of the firm? (spillovers in business sector) 6. How have these firms answered question 6 compared with other Tekes-funded firms? What type of indirect impacts of the project can be found on the society level? (Spillovers in economy and society) 7. How have these firms increased their productivity compared with other Tekes-funded firms and control group not funded by Tekes?	Tekes project follow-up questionnaire. Research Laboratory of Statistics Finland using the Business Register, financial statement, enterprises' innovation activity and Business subsidies data.	Estimation of the effects of Tekes funding on productivity is done by estimating a dynamic representation of production function. Tekes funding is included among regressors. Possible time lags are taken account.
Tekes main target groups		
8. How have Tekes-funded specific target groups increased their productivity compared with other Tekes-funded firms and control group not funded by Tekes? 9. How has the Tekes funding succeeded in improving productivity and renewal through the selected main target groups? 10. How have Tekes and the other actors in the Finnish innovation environment succeeded in improving firm growth, internationalisation, networking to global value nets, new start-ups and spin-offs in these main target groups?	Tekes project reports and data from the monitoring system. Programme evaluations, other Tekes publications, Additional expert interviews.	Comparison analysis of Tekes Clients towards Control Group and results from the statistical analysis. Qualitative analysis.
Tekes' Strategy, Objectives and Impact Analysis		
11. According to earlier Impact Study of Productivity and Renewal of Industries, how have Tekes and the Finnish Innovation Environment reacted to these recommendations? 12. Concerning productivity and renewal, how has Tekes succeeded in achieving its objectives? 13. Associated with productivity and renewal, how has Tekes implemented the objectives and strategic choices for innovation activities, an increase of innovations, competence, internationalisation and networking into Tekes financing criteria, financing instruments and operating methods? 14. How should Tekes impact model be used to analyse the impacts of R&D&I funding? 15. What are the Tekes services on productivity and renewal as presented in the impact model?	Expert opinions. Objective analysis and comparison to the analysis from different data sources. Expert opinions. Overall analysis based on different data sources.	Interviews. Literature and data analysis. Explorative statistical analysis, literature review.

2

Review on the impact of public R&D funding on productivity and renewal

Using productivity as an indicator of success for publicly subsidised innovation effort is a much-debated issue in the literature. Productivity has been considered as a rather good innovation indicator and there have been numerous studies on the relation between innovation and productivity. For example, Hall (2011)[38] discusses the challenge of using productivity growth as an innovation indicator. She reviews 25 studies that have attempted to estimate a quantitative relationship between firm-level productivity and innovation measures, many of them using the so-called CDM model, introduced by Crepon et al. (1998)[39]. She concludes that multi-factor or total factor productivity growth could serve as a reasonable measure of successful innovation of (nearly) all types in the economy and at multiple levels of aggregation (firms, sectors, regions, member states).

Various studies also generally show that innovation activity has a positive effect on productivity.[40] In general, most of the studies show that private returns to R&D are strongly positive and somewhat higher than those for ordinary capital, whereas the social returns are typically measured to be even higher, although these are variable and the analysis of social returns is often imprecise.

Most of the existing studies estimate elasticity of the output with respect to the R&D effort or a rate of return to firms' R&D expenditures.[41] In the latter case, the empirical estimates of the rate of return have varied between 20% and 50%. Sveikauskas (2007), in his literature review[42], found the overall rate of return to R&D to be approximately 25 per cent as a private return and as much as 65 per cent for social returns. However, these returns apply only to privately financed R&D in industry. Returns to many forms of publicly financed R&D appear to be much lower, even near zero. However, it is important to bear in mind that the effect of an increase in R&D is likely to take time before it is fully reflected in a firm's productivity growth.

In his study on various effects of public R&D support to firm R&D, Chang-Yang Lee identifies the following four potential channels:[43]

- the technological-competence-enhancing effect,
- the demand-creating effect,
- the R&D-cost-reducing effect and
- the (project) overlap (or duplication) effect

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38 Hall, B.H. (2011). Using productivity growth as an innovation indicator. Report for the High Level Panel on Measuring Innovation, DG Research, European Commission. October 2011.

39 Crépon, B. & Duguet, E. & Mairesse, J. (1998). Research and Development, Innovation and Productivity: An Econometric Analysis at the Firm Level. Economics of Innovation and New Technology. 7(2), 115–58.

40 Mairesse & Mohen, 2010; Hall, 2010.

41 Baghana, 2010.

42 Sveikauskas, L. (2007). R&D and Productivity Growth: A Review of the Literature. Bureau of Labour Statistics Working Paper 408.

43 Chang-Yang Lee (2011). The differential effects of public R&D support on firm R&D: Theory and evidence from multi-country data . Technovation Volume 31, Issues 5–6, May–June 2011, Pages 256–269.

Because these various different channels can be identified, it is clear that evaluating is difficult to the aggregate effect of public R&D support and that there are differential effects of public R&D support on firm R&D, depending on various firm- or industry-specific characteristics. The empirical analysis in the study also reveals the following observations:

- Public support has a **complementarity effect** on private R&D for firms
  a. with low technological competence
  b. in industries with high technological opportunities and for firms facing intense market competition
- Firms with high technological competence and firms that have enjoyed fast demand growth in recent years show a **crowding-out effect**.

However, despite several studies, the link between public R&D subsidies and productivity remains somewhat ambiguous. This is partly due to bias in the samples of firms and differences in various instruments. Many studies on the connection between R&D and productivity examined the manufacturing sector and established firms. When considering SMEs and/or young companies as well as the service sector, the picture becomes more complicated. This has much to do with the fact that in small firms and especially technology-intensive firms, the investment in R&D may be rather large when there might not be existing markets for the services or products. As a result, the short- or even medium-term effect of R&D on productivity may be negative (although it is expected to be positive in the long term).

It is also important to note that publicly funded R&D projects are not a one-time affair for many firms. According to Koski and Tuuli (2010)[44], there are strong continuities in participation both within and between different public support programmes and the firms that enter the subsidy system actively seek further support from the same organisation and other public agencies. Therefore, in some cases, it is difficult to distinguish the exact effect of each public intervention.

2.1 Recent studies on the impact of R&D expenditures and public R&D funding

In one of the earlier impact reports, a quite extensive meta-analysis was re-viewed. One task of the analysis was to complement the previous impact assessment study by reviewing the latest findings of international and Finnish literature on how public R&D&I funding and innovation activities in general improve productivity and renewal. The key observations from the related literature that was published between 2009 and 2012 follow.

Doraszelski & Jaumandreuz (2009) studied a group of more than 1800 Spanish manufacturing firms in nine industries during the 1990s. According to their analysis, R&D expenditures play a key role in determining the differences in productivity across firms and are a primary source of productivity growth over time. They also show that the link between R&D and productivity is subject to a high degree of uncertainty, nonlinearity and heterogeneity.[45]

Klette & Moen (2010), while studying R&D grants in Norway, found positive dynamic effects, i.e., temporary R&D subsidies seem to stimulate firms to increase their R&D investments even after the grants have expired. The results also suggest that grants do not crowd out privately financed R&D, but that subsidised firms also do not increase their privately financed R&D.[46]

In another recent study with empirical data from Quebec, Canada, Baghana (2010) empirically analyses the impacts of public R&D grants on private R&D investments and the productivity growth of the manufacturing firms in situations in which fiscal incentives are also present. The main findings of the study are as follows:[47]

- For the each additional dollar of public R&D grant, output increases by 0.134 dollars – the additional return of direct subsidies is positive but lower than the return on the R&D financed by the firm's own funds or R&D tax credits.
- Firms that use public grants for R&D in *conjunction* with tax credits for R&D perform better in terms of R&D input additionality than firms that use only tax credits for R&D.

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44 Koski, H. & Tuuli, J. (2010). Business subsidies in Finland: the dynamics of application and acceptance stages, ETLA Discussion Papers No. 1225.

45 Doraszelski, U. & Jaumandreuz, J. (2009). R&D and productivity: Estimating endogenous productivity May 4, 2009, mimeo, Harvard University.

46 Klette, T.J. & Møen, J. (2010). R&D investment responses to R&D subsidies: A theoretical analysis and a microeconometric study.

47 Baghana, R. (2010). Public R&D Subsidies and Productivity: Evidence from Firm-Level Data in Quebec (UNU-MERIT Working Paper Series No. 055). United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology.

Merito et al. (2010) studied the impact of R&D subsidies on firm performance in Italy by analysing the grant effects on the innovation and market results of firms using a counterfactual approach. Their results show that the innovative performance improves only temporarily and no significant differences between grant recipients and non-recipients emerge in terms of labour productivity and sales growth. However, growth in qualified employment is observed among manufacturing SMEs in the long run. They also conclude that more knowledge is needed on the size and timing of the funding.[48]

Haskel & Wallis (2010) analyse data on market sector productivity, R&D and non-R&D intangible assets, and public sector R&D spending in the UK. Their analysis has the following key findings:

- no evidence of spillover effects from intangible investment at the market sector level, including from R&D,
- strong evidence of market sector spillovers from public R&D spending on research councils, and
- no evidence of market sector spillovers from public spending on civil or defense R&D. [49]

The findings tentatively suggest that government innovation policy should focus on direct spending on innovation rather than tax incentives, such as the R&D tax credit, to firms.

Lagos Cardenas (2010) has also recently analysed the impact of subsidies on R&D, innovation and productivity. The main results of the study are as follows:

- In the case of manufacturing firms, public support shows a positive effect on R&D participation. The R&D intensity has a positive effect on product innovation, but no significant effect on process innovation. Process and product innovation has a positive impact on output production function.
- In the case of service firms, receiving public support increases the probability that a service firm engages in R&D and engages in R&D more intensively. The R&D intensity has a positive effect on both process and product innovation. Process innovation has a positive impact on output production function.[50]

Garcia & Mohnen (2010) studied innovation in Austrian firms based on the micro data from the third wave of the Community Innovation Survey, CIS 3, covering the years 1998–2000. They found that (central) government R&D support yields a 2.5 percentage point increase in the share of new-to-firm innovative sales. The total effect on the share of new-to-market innovative sales is 3.4 percentage points.[51]

Sissoko (2011) has studied the productivity of French firms involved in a European Eureka programme. The study shows that firms experience, on average, productivity gains towards the end of the four-year subsidy period. However, the average increase in productivity hides substantial firm heterogeneity, i.e., firms with low productivity gain more from the Eureka R&D subsidies than highly productive firms. Furthermore, firms with low productivity, which are also characterised by a high marginal cost, adopt the new technology faster than highly productive firms.[52]

Colombo et al. (2011) studied a group of new technology-based firms in Italy and found that subsidies awarded on a competitive basis lead to a positive (performance) effect in high-tech start-ups, whereas those awarded without competition between applicants do not have a significant effect.[53]

Bernini and Pellegrini (2011) study the impact of state aid on capital accumulation in subsidised firms in the southern Italian regions over the period 1996–2004. The analysis shows

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48 Merito, M. & Giannangeli, S. & Bonaccorsi, A. (2010). Do Incentives to Industrial R&D Enhance Research Productivity and Firm Growth? Evidence from the Italian Case. Do incentives to industrial R&D enhance research productivity and firm growth? Evidence from the Italian case. International Journal of Technology Management. Volume 49, Number 1–3/2010, pp. 25–48.

49 Haskel, J. & Wallis, G. (2010). Public Support for Innovation, Intangible Investment and Productivity Growth in the UK Market Sector. Forschungsinstitut zur Zukunft der Arbeit Institute for the Study of Labour Discussion Paper No. 4772. February 2010.

50 Lagos Cardenas, J. (2010). The Impact of Subsidies on R&D, Innovation and Productivity: An Analysis for the Spanish Manufacturing and Services firms. Unpublished.

51 Garcia, A. & Mohnen, P. (2010). Impact of government support on R&D and innovation, UNU-MERIT Working Paper 2010-034.

52 Sissoko, A. (2011). R&D Subsidies And Firm-Level Productivity: Evidence From France (Discussion Papers (IRES - Institut de Recherches Economiques et Sociales) No. 2011002). Université catholique de Louvain, Institut de Recherches Economiques et Sociales (IRES).

53 Colombo, M. & Grilli, L. & Murtinu, S. (2011). R&D subsidies and the performance of high-tech start-ups. Economics Letters Volume 112, Issue 1, July 2011, Pages 97–99.

higher growth in output, employment and fixed assets in subsidised firms but a lesser increase in Total Factor Productivity than in unsubsidised firms. They conclude that the negative impact on long-term productivity and growth reduces the positive temporary effects of regional subsidies.[54]

Cincera (2012) studied the connections between R&D spillovers and firm productivity. According to the study, the estimated effects on the firm productivity of both geography- and technology-based R&D spillovers are positive and quite large. Interestingly, they are higher than the effects of the firm's own R&D. As a result, firms have an incentive to underinvest in R&D in the hope of free riding from the investments of other companies. Public intervention through subsidies, tax credits or public procurement for R&D projects is needed to bring R&D closer to optimal levels.[55]

Criscuolo et al. (2012) study a more broad-based business support policy instrument "Regional Selective Assistance" in the UK. In their micro-econometric study, they find evidence for a positive treatment effect in terms of employment and investment. The study also finds the program effects to be stronger for smaller firms but essentially zero for larger firms, which strengthens the arguments to remove subsidies from large companies.[56]

One of the latest Finnish studies on R&D subsidies is the series of essays by Ali-Yrkkö (2008). The main findings of the studies are as follows:

- According to empirical analyses, public R&D funding does not crowd out privately financed R&D but rather, increases privately funded R&D
- Public R&D financing increases both group-level and domestic R&D employment
- In the short run (in 1–2 years), no statistically significant productivity impact of R&D is found. However, R&D has an economically and statistically significant impact when R&D efforts made 3–5 years earlier are taken into account.[57]

In a more recent study on the benefits of targeted R&D subsidies, Takalo et al. (2012) studied project-level data from Finland. They find that the social rate of return on targeted subsidies is 30-50% but that spillover effects of subsidies are smaller than effects on firm profits. The analysis also had the following findings:

- Large firms generate a larger spillover rate (spillover per dollar of R&D), as do the technically more challenging projects
- Firms with higher current value added have higher marginal returns to R&D and higher application costs.
- Profitability and application cost shocks are positively related, implying that firms do not apply for subsidies for the privately most profitable projects.[58]

Furthermore, Laakso (2011) studied the impact of public R&D and business support in Finland. She has come to a more critical conclusion that Tekes fails to support the private R&D expenditure growth. Thereby, the results indicate that there may be some crowding out related to the public support allocated by Tekes.[59] However, at the same time, a positive impact on turnover can be observed.

Lehtoranta (2010) analyses the dynamic effects of innovation and collaboration in innovation in the growth performance of Finnish firms. The main interest in the study is the long run (5 years) average annual growth rate of innovative firms. The study reveals only partial evidence that process and product innovations have a significant and positive effect on

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54 Bernini, C. & Pellegrini, G. (2011). How are growth and productivity in private firms affected by public subsidy? Evidence from a regional policy. Regional Science and Urban Economics 41, 253–265.

55 Cincera, M. (2012). R&D spillovers and firm productivity. In: Science, Innovation, Firms and markets in a Globalised World Université Libre de Bruxelles SCIFI-GLOW Final Policy Report. May 2012.

56 Criscuolo, C. & Martin, R. & Overman, H. & Reenen, J.V. (2012). The Causal Effects of an Industrial Policy (Working Paper No. 17842). National Bureau of Economic Research.

57 Ali-Yrkkö, J. (2004). Impact of public R&D financing on private R&D: Does financial constraint matter? (No. 943). Helsinki: The Research Institute of the Finnish Economy (ETLA).

58 Takalo T., Tanayama, T. & Toivanen, O. (2012) Estimating the Benefits of Targeted R&D Subsidies. The Review of Economics and Statistics. Accepted for publication.

59 Laakso (2011). Public R&D and Business Support in Finland Objectives and Impact. Department of Economics Aalto University. School of Economics.

the post-innovation total sales growth among innovation active firms. Further, the findings on the effect of collaboration with foreign competitors and history as spin-offs from large firms to total sales growth are partial. However, the positive relationship between the occurrence of innovations and the future productivity growth of the innovative firms is a robust result.[60]

In conclusion, the latest studies have not provided radically new results compared with the previous studies. In general, it seems as though public R&D incentives have a positive effect on the volume of private R&D. The link between R&D and productivity also seems to exist although there is much uncertainty and heterogeneity between firms.

A few studies that also examine the changes in productivity show mixed results regarding the role of public R&D subsidies. The results also vary in terms of how much of the productivity gains are direct results and how much is gained through spillovers.

The results regarding the type of instruments and the type of recipients also seem to be somewhat mixed. Overall, in many cases, the growth of SMEs is more typically observed than increase in productivity. In large companies, spillover effects seem to be more important than the direct impact on productivity. There also seems to be some indication that direct R&D incentives may be more effective than indirect instruments, such as tax incentives.

2.2 Recent studies on firm-level renewal and behavioural additionality

The analysis of the role of public R&D funding in firm-level renewal has mainly focused on two processes, intra-firm renewal through behavioural additionality and spillovers from collaborative R&D. In the following, we present a few recent findings related to behavioural additionality of public R&D support.

In Australia, the Department of Industry, Innovation, Science, Research and Tertiary Education has recently commissioned two studies that examine the behavioural additionality of R&D assistance. These studies also consider some of the issues related to renewal.

The first study "Behavioural Additionality of Business R&D Grant Programmes in Australia[61]" found that government R&D grant funding contributed to behavioural changes in all of the firms studied. The most marked changes in firm behaviour were an increased commitment to R&D, an increased understanding of the benefits of R&D, improved project management skills and routines and the formation of new collaboration with companies. Additionally, funding encouraged firms to apply for other forms of public funding.

A more recent study on behavioural additionality effects of the R&D Tax Concession Program[62] found that the R&D Tax Concession affected 86% of the firms during their R&D project. Interestingly, following the project, 98% of the firms reported long-term behavioural change. The study showed that R&D support had an impact on behaviour, including enhanced commitment to R&D, changes to R&D management, changes to business strategy and encouraging new collaboration with companies and, to a somewhat lesser extent, product commercialisation, new collaboration with companies and the encouragement of new collaboration with universities.

Another recent study on the renewal elements in the form of behavioural additionality (in addition to other impacts) examined the IWT R&D grants in Belgium.[63] The study found evidence for different types of behavioural additionality. The funded IWT clients indicated that the support had a positive impact on the goals, the scale, the number of partners and the speed of the project, although this impact was small. Interestingly, the support was more likely to have an impact on the behaviour of companies in more traditional sectors that are much less innovative.

Perhaps one of the most important potential firm-level renewal effects is the potential for firms to permanently be-

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60 Lehtoranta, O. (2010). Innovation, Collaboration in Innovation and the Growth Performance of Finnish Firms. Espoo 2010. VTT Publications 729.

61 Behavioural Additionality of Business R&D Grant Programmes in Australia. (http://www.innovation.gov.au/Innovation/ReportsandStudies/Documents/BehaviouralAdditionality.pdf).

62 Department of Industry Tourism and Resources (2007) How R&D Assistance Influences Company Behaviour: A survey investigating behavioural additionality effects of the R&D Tax Concession Program.

63 Steurs, G., Verbeek, A., Vermeulen, H. and Clarysse, B. (2012) A look into the Black Box What difference do IWT R&D grants make for their clients? IWT-Studies 56.

come more R&D intensive. Arque-Castells and Mohnen[64] observed Spanish manufacturing firms over a minimum of 9 consecutive years during the period 1990-2002 and found that for approximately 9% of the companies, the public R&D funding served as a trigger to permanently increase R&D activities. In this way, public R&D funding can encourage new entrants into R&D.

2.3 Recent findings from Tekes evaluations

In addition to international and Finnish research literature, we also analysed the recent studies and evaluations on Tekes' activities. External researchers have conducted various studies and evaluations on the Tekes projects and programmes. Several separate assessments of various functions and Tekes from different perspectives have recently been conducted or commissioned by Tekes.

An analysis based on VTT SFINNO database[65] concludes that Tekes has funded the development of approximately 60 per cent of SFINNO innovations. In 80 per cent of these cases, Tekes funding is significant. Moreover, the analysis indicates that Tekes plays a pivotal role in funding the development of innovations with a high degree of complexity. According to the report, this highlights the role of Tekes in the renewal of firms and industries.

In a review of Tekes funding in the software industry, Raivio et al. (2012)[66] found that Tekes funding was essential for the recipients' R&D activities and that the development work would have been slower or impossible to carry out without this support. However, although company survival was dependent on Tekes' support in a number of cases, in other cases, the same products would have been developed in the absence of funding. Generally, Tekes funding contributed positively to companies' behaviour and ways to do business. According to the report, effects on productivity have mostly been indirect, as applications developed in the programmes most likely have improved the productivity of the companies. In addition, especially the Verso programme profoundly contributed to the growth and internationalisation of companies. The issue of respondent variability is encountered in several evaluations and can often be linked to the characteristics of the recipient firms.

According to an evaluation of Finnish space activities (2012)[67], the participation of Finnish companies in European Space Agency (ESA) activities has both direct and indirect effects on the companies (membership in ESA and its programmes are funded by Tekes). The direct effects are related to new markets and business opportunities in the space sector. However, the report highlights that assignments from ESA programmes cannot be the main business of the companies and effects are subject to the ability to integrate space technology into other markets and products outside of ESA activities (indirect effects). SMEs' participation in ESA activities may provide valuable references and networking opportunities.

A report on Tekes funding of wood industry programmes[68] concludes that results of the programmes in 1990s are evident in technology innovations and redirection of company strategies towards a more customer-oriented end-user approach. The role of Tekes in accelerating development and coordinating resources of the wood industry is significant. Some issues would have been addressed without Tekes funding, but would have been slower and with smaller inputs.

An evaluation of Tekes-funded SISU 2010 – Innovative Manufacture technology programme and intermediate evaluation of the Concepts of Operations (2007–2011)

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64 Arqué-Castells, P. and Mohnen, P. (2011) How can subsidies be effectively used to induce entry into R&D? Micro-dynamic evidence from Spain. International workshop on R&D Policy Impact Evaluation: Methods and Results.

65 Hyytinen, K., Kivisaari, S., Lehtoranta, O., Toivainen, M., Loikkanen, T., Lyytinen, T., Oksanen, J., Rilla, N., van der Have, Robert (2012). Funder, activator, networker, investor... Exploring Roles of Tekes in Fuelling Finnish Innovation. Tekes Review 289/2012.

66 Raivio, T., Lunabba, J., Ryynänen, E., Timonen, J., Antikainen, M. and Lanér, S. (2012) Software, mobile solutions and games industry – Evaluation of Tekes software related programmes. Evaluation Report 2/2012.

67 Eronen, A., Haila, K., Halme, K., Salminen V. (2012) Vaikuttavuutta sovelluksista – suomalaisen avaruustoiminnan arviointi. Tekesin katsaus 294/2012.

68 Tommila P., Hjelt M., Luoma P., Mikkanen P., Seppänen J. (2011). Kakkosnelosta ja liiketoimintaluovuutta – Puualan ohjelmien jälkiarviointi. Tekesin ohjelmaraportteja 2/2011.

programme[69] analysed the effects of Tekes funding on the growth of participating companies. However, a connection between Tekes funding and companies' growth could not be statistically indicated.

According to an evaluation of Tekes' ICT programmes[70], the impacts on the participated organisations' procedures varied by the companies' size. Whereas the larger organisations remained virtually unaffected, the programmes had many impacts on the SMEs' strategies and procedures. In fact, many of the participated SMEs designed their key products in the projects and, therefore, the strategies and procedures of the companies were formed at the same time. According to case interviews, SMEs estimated the programmes' impact on company's economic functions as being very important. Concerning the companies' R&D functions, generally, the companies estimated that the programmes had a positive effect. The estimations varied strongly between participants, with more positive effects for SMEs than larger companies. In many cases, the R&D activities of SMEs are entirely run on Tekes funding.

Although it is difficult to establish a general conclusion of these studies and evaluations, some observations can be raised. Firstly, there seems to be substantial heterogeneity between projects and firms in terms of results. This is partly natural because R&D projects always involve risks. However, at the same time, this suggests that emphasis must be placed on the project evaluation and selection processes. Secondly, positive findings regarding the role of Tekes in supporting innovation processes, innovative behaviour and networking seem to emphasise the importance of behavioural additionality as one of the key contributions of public R&D subsidies.

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69 Valtakari, M., Rajahonka, M., Riipinen, T., Kivikko, L. (2010). Kohti uutta tuotantoajattelua – SISU 2010- ja Tuotantokonseptit -ohjelmien arviointi. Tekesin ohjelmaraportti 7/2010.

70 Kotiranta, A., Oosi, O., Toivanen, M., Valkonen J., Wennberg, M. (2011). Co-operation to Create Converging and Future Networks – Evaluation of Five Telecommunications Programmes. Tekes Programme Report 6/2011.

3

Analysis of Tekes' strategy impact model

3.1 Overview of Tekes' objectives and strategy regarding renewal

3.1.1 Tekes' objectives and strategy

Tekes' strategy is updated every third year. The projects studied in the current impact assessment span from years 2000 to 2008; therefore, several updates to the strategy were carried out during this period.

The 2002 strategy stated that the starting point in formulating the technology strategy has been the competitiveness and structure of the Finnish industrial and business. The strategy included several thematic areas but also several targets related to activities, outputs and impact, namely networking, cross-technological cooperation, long-term commitment, innovativeness and productivity. Productivity was specifically included because it was considered as the precondition for competitiveness and welfare and because a sound application of technologies (the target of Tekes' activities) increases productivity.

The 2005 strategy, on the other hand, emphasised the role of renewal, although productivity was also one of the key strategic objectives. The strategy began from the assessment that Finland's future is in knowledge and competence, particularly in knowledge-based business and its renewal and growth. The background assumption was that knowledge and competence play a major role in the renewal of both the private and the public sector and in increasing productivity. The role of business development and creation of new business models as sources of renewal together with innovation was emphasised. The strategy strongly associated renewal with new products and new business concepts.

The 2008 strategy observed that many problems are complex by nature and that renewing them requires multi-disciplinary and increasingly open innovation processes. The Tekes' key objectives could also be viewed as a continuum in which increased capabilities in innovation activities contribute to renewal and productivity development. On the other hand, one of the key components is welfare, which may be considered the final objective of Tekes in this sense.

In the 2008 strategy, a special focus on young innovative companies and growth companies was introduced as part of the objective of productivity and renewal. This is an important notion because the impact assessment carried out in the present study mainly focuses on projects that were initiated and carried out before the strategy selection.

According to the current Tekes strategy, Tekes' mission is to support sustainable welfare of the economy, people and the environment. Tekes aims to support sustainable growth through improvement in productivity and renewal of enterprises.

The main target group of Tekes consists of SMEs that seek growth in internationalisation.[71] Tekes aims to focus its actions and instruments on the front-runners of research, development and innovation, who aim to renew businesses and industries. The most important foci of Tekes actions are as follows:

- Young innovative enterprises
- Innovative, growing businesses
- Growth in productivity and value added
- Combining technical and non-technical R&D
- Successful partnership in international value networks.

It is evident that Tekes' strategy is heavily geared towards sustainability on the one hand and renewal of the economy or industries on the other. The specific aim of combining technological and non-technical innovation, i.e., service and business model innovation, is a departure from Tekes' heritage of primarily funding research and technology development.

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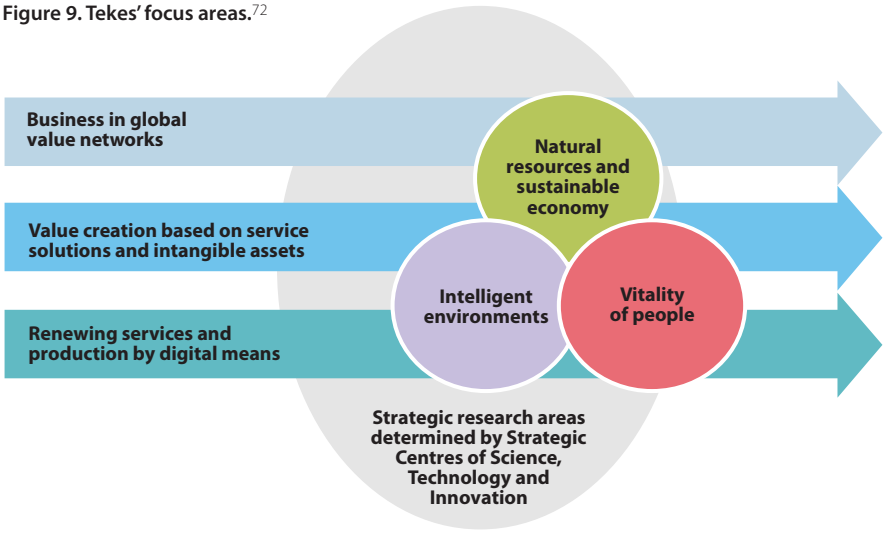
71 http://www.tekes.fi/en/community/Focus_areas_and_programmes/1305/Focus_areas_and_programmes/2806

Figure 9. Tekes' focus areas.[72]



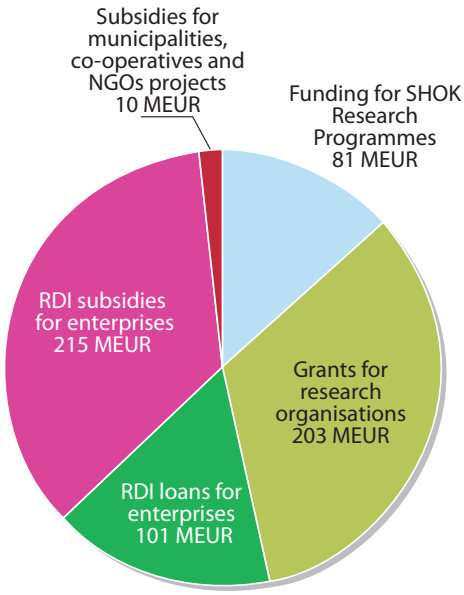
3.1.2 Tekes' instruments

In the year 2011, Tekes total funding was 610 MEUR for 1928 individual projects. According to Tekes, roughly one-third of the funding (excluding the SHOK instrument) is channelled to research grants for research organisations and two-thirds are used to fund R&D projects in enterprises through different instruments. Of the enterprise funds, one-third goes to young innovative enterprises, one-third to established but growth-seeking enterprises that employ less than 500 FTEs and one-third to large enterprises for networked projects.

Tekes implements its strategy and distributes its funding through a set of instruments including R&D projects and research grants as well as targeted instruments. The bulk of Tekes funding is distributed through open calls for R&D project funding and Tekes programmes, which are generally 4-year-long programmes with a general theme, under which the applicants can propose their own R&D projects.

In the current study, we will focus particularly on the measures directed for private enterprises, excluding research grants for SHOKs and research organisations and development grants for non-profit and public organisations. The following table summarises the present Tekes instruments and adjacent consolidated instruments. Additionally, Tekes has implemented a (pre)seed programme TULI (Tutkimuksesta liiketoimintaa, eng. Business from Research), which funded feasibility and market studies and business plan preparation for employees of higher education institutions.

Figure 10. Distribution of Tekes funding in 2011. Total funding 610 MEUR for 1928 individual projects.



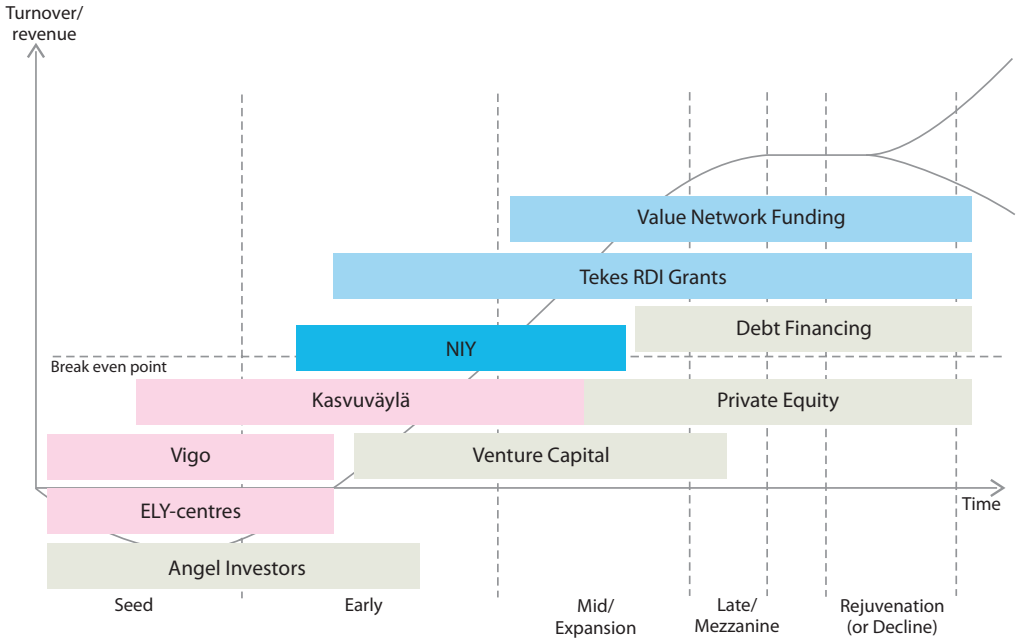
[72] Source: Tekes.

Table 4. Overview of Tekes' instruments per client group.[73]

Customer group	Instrument	Description
SMEs	R&D funding/subsidies	R&D project funding through grants and loans (especially for new product development and commercialisation).
	Funding for organisational/ workplace development	Grants for organisational development, e.g., development of management systems and practices, business processes.
	Young Innovative Enterprise Funding	Three-phase instrument for business development (only 25% of the granted funds can be used for R&D activities) in less than six years old R&D intensive (at least 15% of all expenses are used for R&D) SMEs that are 'on the verge of strong international growth'. Typical parameters (funded between 2008–2009): age 2–3 years, over 5 employees, some venture capital investments, median turnover .2 MEUR, 5 year target turnover, some domestic clients. Pre-phase (6 months, max. €50 000): Business plan development and market analyses. Expert fees and information services must be at least 50% of declared expenses. First phase (typically €250 000): for business development Second phase (Max funding in 1st and 2nd phase 1 MEUR per enterprise): For business and market development over several years, up to enterprise age 8 years. Note: because of the nature of the subsidy, a receiver of NIY-grant cannot receive other state aid in three years after the subsidy has been granted; however, NIY enterprises are eligible for simultaneous or successive Tekes R&D grants.
	Value network funding	Project grants for R&D project in new value network (up to 2–4 years). Especially for: Partnering, networking, processes and organisations, concept development market and customer analyses.
Large enterprises	R&D funding/subsidies	R&D project grants for production method, process and new product/service development, as well as organisational development.
	Value network funding	Project grants for R&D project in new value network (up to 2–4 years). Especially for: Partnering, networking, processes and organisations, concept development market and customer analyses.
Research organisations	Funding for public research	Research grants for applied research with a scientific contribution and foreseeable commercial exploitation opportunities.
Targeted and consolidated instruments	Kasvuväylä (Growth Channel)	Growth Channel is run by MEE under Yrityssuomi (Enterprise Finland) service portal. Growth channel is open for enterprises that employ more than 10 persons and have turnover of more than €500 000, and who aim for international growth. Growth Channel is mutually exclusive with Vigo-programme and Tekes NIY programmes. Growth channel works in conjunction with public authorities, venture capital funds and funding organisations (including Tekes) by appointing an account manager (Kasvuluotsi, Growth Pilot) for the target enterprise, who helps the enterprise to choose suitable services and funding sources and coordinates applications.
	Vigo-programme	Capital investments and business development expertise for seed-phase enterprises. The programme is implemented through nine business incubator organisations. The incubators consult the enterprises in developing the business and help gather venture capital and other funding from public and private sources (including Tekes) to enable growth of the firms. Vigo enterprises can apply for Tekes NIY funding, and Vigo services are allowable expenses with certain limits. The incubators choose the target enterprises by application and invest their expertise and possibly capital. The length of the intervention is 18 to 24 months. Vigo-programme is run by a private enterprise (PROFict Partners Ltd.) by appointment from Tekes, with partners including research organisations, venture capital funds and business incubators.

[73] Sources: Tekes; MEE; Vigo.fi; Yrityssuomi.fi

Figure 11. Position of Tekes and associated instruments over the business value chain (Tekes instruments coded with blue, other public in pink and private in grey).[74]



Considering the position of the instruments over the general life cycle of an enterprise, the bulk of the Tekes instruments in terms of volume cover the span from early to mature life cycle. In the traditional sense, the R&D project, organisational development and value network development grants are pure 'traditional' project funding instruments.

NIY funding is targeted specifically for enterprises that are in the early phases and planning to enter the expansion, and the bulk of the funding cannot be used to subsidise R&D. Tekes guidelines recommend that NIY enterprises be ready to expand their shareholder base during the intervention. In practice, this represents snowballing venture capital and other equity investments and implies that there is an expectation that Tekes funding approval will serve as a 'seal of quality' and attract VC investors.

Vigo is similar to business angel activity. In fact, several of the partners in Vigo incubators are serial entrepreneurs themselves. Vigo and NIY participation can overlap with each other as well as with private (and public) venture capital investments. Growth Channel differs from the previous instruments, as it is not a funding instrument. Rather, it is an intervention that helps the target enterprise to secure funding and organise interaction with public authorities.

3.2 Additionality and impact of public R&D funding

The literature on the impact of public R&D subsidies has discussed the so-called additionality of subsidies broadly. Generally speaking, the literature separates four types of additionality, as summarised in the following table. To clarify the relationship, the types of additionality can be classified according to program theory on the input-activity-output schema. However, according to the literature, the division between activity and output is not clear or completely consistent, namely measures of output additionality commonly include process or intermediate results such as intellectual property rights (IPR).

74 Cf. Hiekkanen-Mäkelä, nd., Tekesin yritysrahoituksen uudet periaatteet (eng. New principles for Tekes funding for enterprises), unpublished.

Table 5. Proposed (types of) additionality of public R&D subsidies at the project and firm level.[75]

<table>
<tr><th></th><th>Input</th><th>Activities</th><th>Output</th><th>Outcome/ Impact</th></tr>
<tr><td>1st order additionality</td><td colspan="2">Input additionality:
Leverage effect of public subsidy to private investments to R&D activities (as measured by private investment per public investment)</td><td>Output Additionality:
The proportion of outputs of innovation (products, services, processes, IPRs; new products and services) that would not have been realised without R&D subsidy</td><td rowspan="2">Productivity (value added per labour), renewal (in terms of new products, services and enterprises), increased profitability and growth</td></tr>
<tr><td>2nd order additionality</td><td></td><td>Behavioural additionality:
R&D subsidies will change the behaviour of the funded organisation and expose the funded to new practices and knowledge;
Risk, volume and speed, level of ambition in projects run with subsidy compared to privately funded R&D programmes</td><td></td></tr>
</table>

The relationship between R&D subsidies and 1st order additionality has been broadly discussed, as exhibited in the previous sections. However, the results are somewhat ambiguous, some results propose a statistical link between productivity and R&D funding and some find little significant impact. The research findings generally support the proposition that public subsidies effectively snowball private investment[76], although the evidence seems to be strongest in the case of SMEs[77] and that public R&D funding is as effective as private funding[78].

The relationship was also investigated in previous Tekes impact assessments, and there seems to be a positive association between R&D subsidies and growth of productivity. The main conclusions of the previous impact assessment were the following:

- There is evidence of a link between Tekes funding and the growth of the recipient enterprises.
- The correlation between Tekes funding and the productivity of recipient enterprises has not been established statistically. There are signs about this link but based on current knowledge, a generalisation that Tekes funding has led to productivity gains is not warranted.
- Existing Finnish research does not portray a clear picture of the link between Tekes funding and the renewal of the Finnish private sector.
- Existing research has found evidence that public R&D-funding
  a. has an impact on the business conduct of recipient enterprises,
  b. increases the volume of innovation activity of recipient enterprises, and
  c. leads to direct results of innovation work.

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75 Autio, E. & Gustafsson, R. & Kanninen, S. (2008). First- and second-order additionality and learning outcomes in collaborative R&D programs. Research Policy 37, 59–76; Clarysse, B. & Wright, M. & Mustar, P. (2009). Behavioural additionality of R&D subsidies: A learning perspective, Research Policy, 38, 1517–1533.

76 e.g., OECD (2000). R&D and Productivity Growth: A panel data analysis of 16 OECD countries, DSTI/EAS/STP/NESTI(2000)40, Paris.

77 Lööf, H. & Hesmati, A. (2004). The Impact of Public Funding on Private R&D investment. New Evidence from a Firm Level Innovation Study (Additionality or Crowding Out? On the effectiveness of R&D subsidies), CESIS Working Paper Series in Economics and Institutions of Innovation; 06, KTH Royal Institute of Technology.

78 Czarnitzki, D. & Ebersberger, B. & Fier, A. (2007). The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany. Journal of Applied Econometrics 22, 1347–1366.

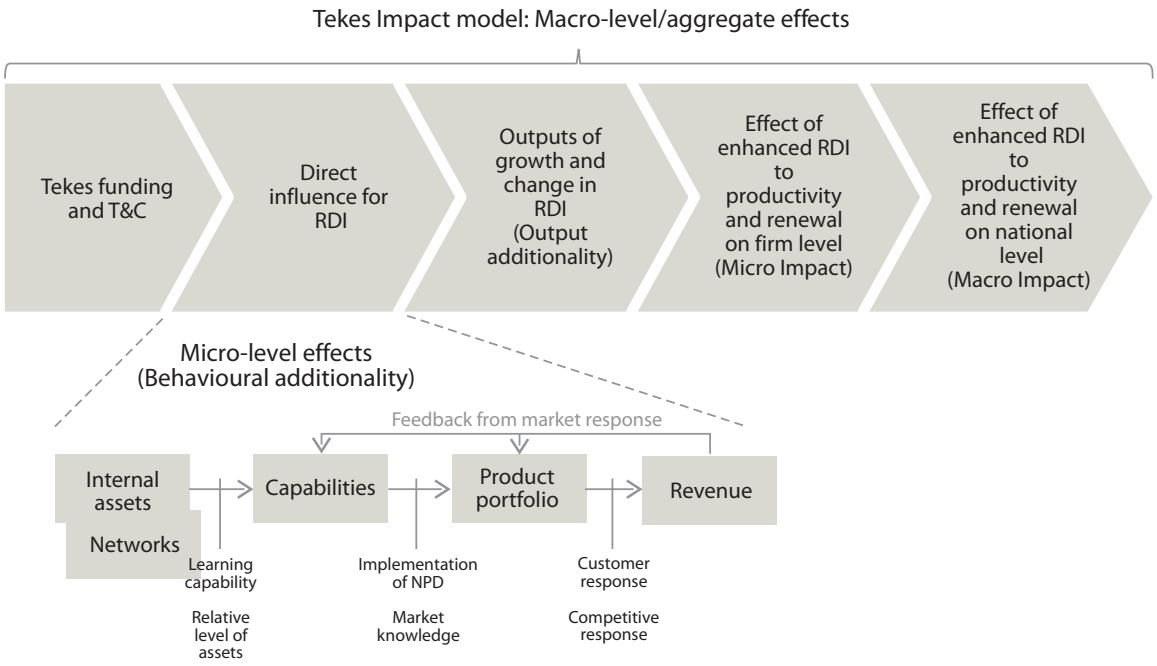
- An analysis of the effects of Tekes funding becomes more difficult as one moves further from the immediate results towards the final goals. The attempt to establish the link between Tekes funding and the desired outcomes (productivity gains, renewal of the economy, economic welfare) at the national level is the most demanding task. Our view is that more research resources should be allocated to this challenge in the future.

These findings raise the question of the degree to which the internal characteristics of individual enterprises moderate the impact of subsidies. Econometric studies tend to treat the internal processes and activities as a "black box", observing the covariation between inputs and outputs. The analysis of enterprise performance and impact of subsidies based on objective measurable indicators shows whether there are differences between enterprises, but it does not reveal how much the factors inside the black box, including the existing knowledge base, management processes, attitudes, as well as firm-independent outside influences, such as competitive response, impact the end result.

If we simplify the Tekes impact model (see fig. 2) to a process description, we can illustrate the concept of behavioural additionality at the micro level. The existing research on behavioural additionality suggests that subsidised R&D programs raise the absorptive capacity absorptive capacityof firms[79], whereas the impact of R&D subsidies is affected by sources of knowledge, absorptive capacity, and objectives of support[80].

If we take that behavioural additionality is linked to absorptive capacity, we can consider what the literature on the Resource Based View of the firm (RBV) predicts about the relationship of R&D and firm performance. Simply stated, following the RBV, as the firm's absorptive capacity and second-

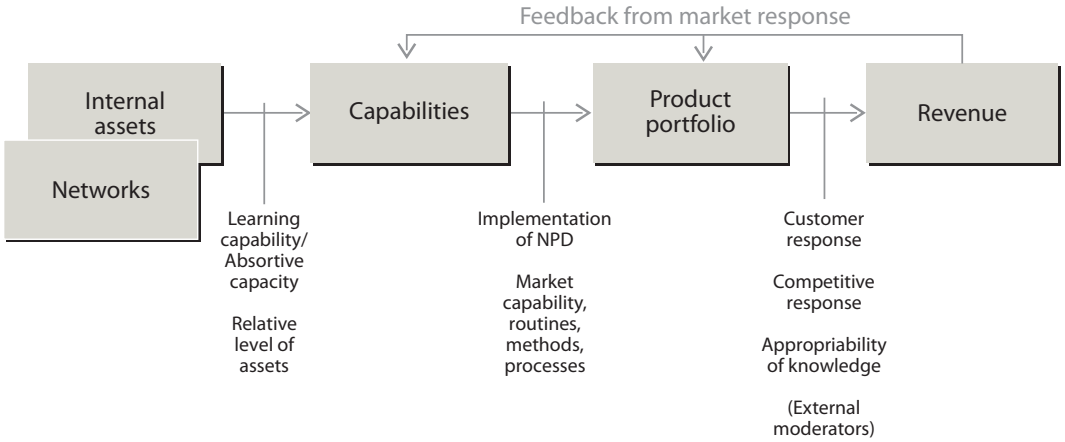
Figure 12. Illustration of levels of analysis regarding additionality and its relationship to organisational attributes.



79 Clarysse, B. & Wright, M. & Mustar, P. (2009). Behavioural additionality of R&D subsidies: A learning perspective, Research Policy, 38, 1517–1533.

80 Guellec, D. & Van Pottelsberghe de la Potterie, B. (2004). From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter? Oxford Bulletin of Economics and Statistics, 66(3) 353–378.

Figure 13. R&D process and moderators for performance are predicted by literature.



order capabilities improve, its capabilities in the future and profitability in the long term increase.[81] This cyclical behaviour can be explained by the systemic relationship of R&D and firm performance. Firms that perform R&D draw on their resource base to activate the necessary capabilities to perform R&D. In doing so, these firms learn and acquire a new resource, which provides a broader base to draw upon in the future.[82] At the same time, learning is affected by present knowledge, absorptive capacity and quality of learning systems, and the compatibility of source knowledge and intensity of learning activities (see fig. 14).

As proposed in the RBV literature, firm assets and the capability to use them is reflected in the quality of the service and product portfolio of an enterprise, which are important for the market response. Special attention has been paid to establishing the relationship between absorptive capacity and performance, as it offers a relatively tangible object of measurement for research. However, the relationship is complex, and the ability of a firm to structure its assets to active capabilities depends on its capacity to learn. In turn, management capabilities moderate how well the capabilities are translated into customer offerings. The final link from product and service development to profitability and productivity is especially vulnerable to "contamination" by external factors, such as competitive response and the appropriateness of knowledge embodied in the offering.[83]

Following the literature, with the assumption that firm absorptive capacity predicts its performance in the long run, we propose that absorptive capacity can be used as a surrogate construct for measuring behavioural additionality. The following table presents a version of the Tekes impact framework that was originally proposed by Tempo Economics. It delineates the confirmed and proposed Tekes impacts to the input-activity-output-schema and proposes indicators for the constructs.

We also analysed briefly the "3 years after" self-assessment data from projects that ended in 2009. The self-assessment was renewed for that year. As a result, the project data were not included in the general analysis. However, the new data[84] involved additional questions regarding the role of Tekes with regard to other actors and instruments in the national innovation system.

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81 Clarysse et al. (2009); Kortelainen, S. (2011). Analysis of the Sources of Sustained Competitive Advantage: System Dynamic Approach, Nide 421 / Acta Universitatis Lappeenrantaensis.

82 Kortelainen (2011).

83 Noblet, J.P. & Simon E. & Parent, R. (2011). Absorptive capacity: a proposed operationalization, 9, 367–377; Volberda, H.W. & Foss, N.J. & Lyles, M.A. (2010). Absorbing the Concept of Absorptive Capacity: How to Realize Its Potential in the Organizational Field, Organization Science; Zahra, S.A. & George, G. (2002). Absorptive Capacity: A Review, Reconceptualization, and Extension, Academy of Management Review, 27(2), 185–203.

84 The data involves 370 answers from SMEs and 202 answers from large enterprises.

Table 6. Revised Tekes impact model.[85]

	Aspect of impact	Corresponding constructs	Notes	Indicators
Impacts on R&D activities Direct effects of Tekes funding on private sector innovation work (Input additionality)	Volume of R&D	Increased level of R&D investments		R&D investment per public funding; growth of R&D investments; investments/per industry average
		Increased R&D resources (employment)		Fraction of R&D personnel of staff; fraction of highly skilled workers
Indirect/intangible results of R&D work in companies (Behavioural additionality)	Intangible/capability creation	New/deeper co-operation between companies and new value networks	Learning is facilitated by number of partners (up to a degree) and new network connection (eg. Clarlysse et al., 2009)	Number of new partners introduced through collaborative R&D projects; number of network connections and centrality in network; IP and other licensing agreements; number and share of collaborative/risk sharing R&D projects
		Changes in management (capability)		Increased risk-taking and more challenging R&D projects; degree to which innovation management capabilities were increased
		Increasing knowledge and competences	The most common surrogates for knowledge creation	Patents, trademarks etc.; number of IPRs compared to industry average; number of publications
		More innovation activities		Increase in attention to R&D and innovation; higher frequency of R&D projects (Clarysse et al., 2009)
		Spreading of new knowledge and know-how		Number of other organisations in projects (Clarysse et al., 2009)
	Nature of R&D	Larger R&D projects and wider scope of innovation work		Project volume/industry average, newness of funded R&D projects from firm perspective
	Spillovers, absorptive and combinatory capability second order capabilities	Better capabilities to absorb knowledge	Absorptive capacity is associated with routines for acquiring knowledge, assimilating, transforming and exploiting it (Zahra & George, 2002); Absorptive capacity is moderated by prior knowledge, employee qualifications and skills, relative level of knowledge compared to the source of learning (Noblet et al., 2011)	Intramural R&D expenditure/turnover; Fraction of R&D personnel of staff; social integration mechanisms (Zahra, 2002); personnel turnover/growth; number of research and /or practice communities (Noblet, et al., 2011)

[85] Clarysse et al., 2009; Volberda et al., 2010; Zahra & George 2002; Guellec & Van Pottelsberghe de la Potterie, 2004; Hall et al, 2012; Kortelainen, 2011; Noblet et al., 2011.

Table 6. continues

	Aspect of impact	Corresponding constructs	Notes	Indicators
		Better capabilities to apply knowledge	Patent, invention disclosure associated with ability to use knowledge (Bransetter & Sakakibara, 2002); organisation learns if, through its processing of information, the range of its potential behaviours is changed." (Huber, 1991); Firms with well-developed capabilities for transformation and exploitation are more likely to achieve competitive advantage (Zahra, 2002)	Patents, invention disclosures; Behavioural changes 'Degree to which new innovation management capabilities were increased', the 'Degree to which research path in the company was changed' (Clarysse et al. 2009); protection systems; number of new product ideas/concepts; routines for knowledge creation (Noblet, 2011); More swift application of technologies in production processes
	Product and process innovations	New products and/or services		Number of new-to-market and new-to-firm products and services
		New/More efficient production processes		Number of new production of logistics processes
	Business innovations	More efficient business models		Productivity
		Shorter time-span between new innovations and commercialisation of these innovations		Time to market; time to market per industry average
		More efficient value-chains/ networks		
		New business ideas and/ or areas		Number of new business areas
	Internationalisation	Internationalisation		Number of new products/services for international markets; Fraction of revenue from exports; number of international partners
	Broader impacts on industry structure and knowledge production	New business communities		Number of new business communities, industry associations and other organisations etc. joined/ founded by subsidised companies
		Increasingly complex division of labour		Number of new partnerships founded during the subsidised R&D projects

Table 6. continues

	Aspect of impact	Corresponding constructs	Notes	Indicators
Direct results of R&D work in companies; Effects/impacts of innovation activities in companies (Output additionality)	Product and process innovations	New products and/or services		Number of new-to-market and new-to-firm products and services
		New/More efficient production processes		Number of new production of logistics processes
Impacts on productivity and renewal of the economy	Production efficiency	Increased labour productivity		Added value per work, total factor productivity
		Increased technological productivity		
	Direct impacts on profitability			Revenue, EBITA per cent, Added value per work
	Renewal and turnover of companies	Success and growth of recipient companies		Turnover, success/survival rate of new enterprises
		New companies		Number of new enterprises (within industry)
		Turbulence and structural change of different industries		Ratio between new and exiting companies within industry, average age of enterprises

The initial results from the data show that among SMEs, Tekes together with private investors were viewed as the most important actors to support the launching of firms' own R&D activities. Tekes was considered the most important organisation in supporting the creation of new commercialised innovations. The role of Tekes can be considered surprisingly high in facilitating the establishment of new firms and the development of R&D activities.

The role of Tekes was also the most important support organisation in facilitating collaborative research activities. It was rated as more important than, for example, the EU framework programmes. However, private investors together with Finpro were considered as more important to internationalisation of companies, and the role of Tekes was more modest. The role of Tekes was also less important in developing the supply chain and customer base, although support for finding new suppliers was emphasised for some projects.

3.3 Impact model and Tekes special interest groups

As previously mentioned, the objectives of the Tekes impact model (presented in Section 1) are to support productivity and renewal of enterprises, with a predominance of endogenous renewal, environment, wellbeing and capabilities. The preceding discussion implies that a commitment to R&D raises the capabilities of an enterprise and provides opportunities for renewal. Based on the project evaluations, the impacts on environment and wellbeing seem to be small. It could be suggested that beyond targeted programs for wellbeing and environment, the impacts come through spillovers and income distribution. Regarding spillovers, generally, the enterprises report deeper relationships with partners, contributions to the national knowledge base and internationalisation in some groups. This suggests knowledge exchange that can result in

both absorbing valuable knowledge from the network and spillover of knowledge to other institutions.

At the level of activities, Tekes funding has mostly had an effect on the volume and timing of R&D, and it also has an enabling effect on young SMEs. To some extent, there is also behavioural additionality in terms of improving processes and management attention to R&D activities. In terms of the outputs, the special interest groups report that the R&D projects have had the greatest impact on the quality of products, collaboration and networking with other enterprises and value added, and in the case of NIY and TULI enterprises, internationalisation.

As discussed above, the findings beg the question of whether the observed higher performance of NIY and, to some extent, TULI enterprises is a product of their internal characteristics, the funding instruments, or both. There is evidence of both interpretations. NIY enterprises, in particular, are hand-picked for the programme, which suggests that they are typically good targets for funding. However, the NIYs also view that NIY funding has specifically supported business and market development better than other instruments, and they seem to gain more from the R&D project grants than other enterprises. TULI enterprises are a different story; however, the cases suggest that TULI funding, which is similar in structure to NIY, has had similar effects on market awareness and presence.

Regarding the impact model, productivity is one of the main success measures set for Tekes. Although it is an important measure from the perspective of national economy and competitiveness, it seems that it is not as relevant to Tekes special interest groups. Young, fast-growing enterprises tend to invest more of their cash flow into R&D than established enterprises, and they often create little added value before R&D completion, which may take up to ten years. In addition, although productivity arguably measures the renewal of enterprises, as sustained increase in productivity demands keeping up with competition, other measures might represent renewal better. These indicators include the growth percentage of the enterprises, survival rate in different age cohorts, and measures of innovativeness, such as the number of spin-offs, new business areas and number of new (new-to-firm/network and new-to-market) and radical (new-to-network and new-to-the-world) innovations.

3.4 Impact model and Tekes' strategy

From the policy perspective, it is interesting to analyse how Tekes and other organisations in the Finnish Innovation Environment have reacted to the recommendations of the previous study on how Tekes has succeeded in achieving its objectives in terms of productivity and renewal.

No major changes in policy can be linked to the previous Impact Study on the level of the whole national innovation system. However, the key policy documents have had a genuine influence on innovation policy. The proposal for the national innovation strategy seems to have been a "strategy for change" in that it emphasised concepts such as non-technological innovation, user-orientation and a more systemic approach.

Productivity improvement and pioneering in innovation are the two foremost policy goals according to the Proposal for Finland's National Innovation Strategy. The strategy defines productivity improvement as the main objective (Chapter 2). This implies a balanced consideration of the following groups:[86]

- Developments *within* existing units,
- Re-allocation *between* existing units,
- *Entry* of new units, and
- *The exit* of old units.

This "broad" approach to productivity emphasises productivity improvement not only in existing companies but also through new-firm generation. Furthermore, the other main target of the strategy – pioneering in innovation – is close to the target of renewal because it emphasised the leading position in the global markets for specific sectors.

In the latest policy debate, there seems to be a tendency (and opportunity) to increase the division of labour so that R&D tax incentives cater to the more general R&D support and focus Tekes' activities to more risky new ventures. SHOKs, on the other hand, would play a larger role among existing strong industries and their strategic renewal.

Based on the literature review and interviews, it appears as though the recommendations of the individual studies serve as only one source of policy feedback among several channels at all policy levels. First, the results of studies and evaluations are considered at different policy levels but are

[86] International evaluation panel (2009): Evaluation of the Finnish National Innovation System. Helsinki, Taloustieto Oy (on behalf of the Ministry of Education and the Ministry of Employment and the Economy).

not typically used directly. Rather, they contribute to discussion and decision making. Tekes specifically uses and analyses all recent strategies, studies and analyses on a continual basis as part of its strategy process. Although productivity is explicitly highlighted in key policy documents (i.e., national innovation strategy) and the previous impact analysis supports its importance, the focus seems to have been on facilitating competitiveness through capability building, supporting the renewal process and supporting access to global markets.

The general view seems to be that Tekes has been quite successful in clarifying its impact logic, implementing the strategy and policy recommendations at the higher level. There appears to be a systematic change of focus towards facilitating renewal and "creative destruction". In the latest Tekes strategy, the focus on growth companies, new promising ventures and international markets is clear. At the same time, the focus on activities that emphasise productivity is less obvious and is not explicitly visible in the strategy.

When examining the Tekes success in meeting objectives, the objective of renewal appears to be especially positive. The analysis indicates that Tekes-supported R&D activity has produced behavioural additionality in the majority of target companies. The positive results in specific target groups, particularly NIY-firms and TULI-firms[87], highlight this finding. It seems that three levels of renewal processes can be distinguished, as follows:

- The process of renewal through Tekes co-funded R&D projects themselves (risk sharing, enabler)
- Contribution renewal at the industry/economy level, with emphasis on forerunners and young companies (selection)
- Contribution through thematic choices, programmes and the related discussions with the industry partners (areas with high development needs/potential).

However, the success in making an impact in terms of productivity change in the target companies is not particularly remarkable and remains unclear at best. At the same time, it must be noted (and was emphasised in the previous impact study) that the study of productivity change among Tekes-funded companies suffers from many problems. The challenges include the selection problem, difficulties in assessing externalities, uneven distribution of results, the time lag from intervention to desired outcome and the fact that it is relatively difficult to find a good comparison group for counterfactual analysis in a small country such as Finland.

In light of the current Tekes strategy and with the focus on forerunners, young companies and SMEs in general, it is also questionable whether productivity is the best indicator at the firm level to measure the impact of Tekes activities, as young and/or small companies tend to grow faster, invest more heavily in R&D and firms are often dependent on the turnover of a small number of products or product categories that may be partly in their development phase. As a result, this may lead to lower productivity growth in the short term.[88] This may have a negative effect on the results of productivity in the Tekes-funded firms if the focus increasingly falls on small and early stage companies.

Overall, it appears as though the basic task for Tekes has been the renewal of firms and industries rather than productivity growth in existing firms (although long-term productivity growth is also important at the micro level). In the various discussions about the role of Tekes and the latest strategy, the ultimate targets for Tekes (and the whole innovation policy) seem to be broader than mere productivity, including: renewal, growth, capabilities, and exports. Although productivity may be the most important indicator of competitiveness, the other targets may be easier to grasp. Moreover, the introduction of new innovation policy measures such as tax incentives and the broadening of the focus and content of Tekes instruments both mean that, at the national level, it may be even more difficult to differentiate the contribution of R&D subsidies from other instruments, especially in cases in which firms use many types of instruments.

Finally, the current analysis, in addition to the previous exercises, highlights the difficulties in measuring the contribution of public R&D incentives to productivity growth at the firm level. The observed impact typically takes place with a considerable delay. Thus, firm-level productivity growth is a rather difficult indicator to use in policy. It is therefore advised that more direct and short-term indicators are emphasised in the future to better support policy making.

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87 However, one of the key challenges in making judgements is that input and behavioural additionality can be distinguished and outputs, to some extent, but analysing impacts of the strategy change too early to judge.

88 Steffens, P.R. & Davidsson, P. & Fitzsimmons, J.R. (2009). Performance configurations over time: Implications for growth and profit oriented strategies. Entrepreneurship Theory and Practice, 33(1). pp. 125–148; Folkeringa M. & Meijaard, J. & van Stel, A. (2004). Strategic Renewal and Its Effect on Small Firm Performance: Testing for Firm Size Effects Using Dutch Micro Data. In Cooney, T. and Malinen, P.:New Perspectives on Firm Growth, 1st Inter-RENT Online Publication, European Council for Small Business and Entrepreneurship (ECSB).

4

Analysis of Tekes' activities and renewal

The renewal of industries and economic life is one of the main objectives of Tekes funding activities (see Figure 1). Renewal and its operationalisation in the context of this assessment were discussed above. In short, renewal can be approached from multiple angles, but we focus specifically on enterprise-level renewal and, to some extent, spillovers and their contribution to renewal in industries.

The following analysis is based on Tekes ex-post project evaluation questionnaires completed by the project managers, complemented with quantitative data from Statistics Finland and Voitto+ databases. The self-evaluation is based on a standard questionnaire with a battery of questions designed to assess the impact of the project within the enterprise and its externalities to other enterprises and society in general. The questionnaire is administered three years after the project completion. Regarding renewal, the most important questions are those that are linked to behavioural additionality, i.e., 'internal renewal' of the enterprise.

4.1 Impact of Tekes funding on firm-level renewal

Firms that received funding from Tekes are obligated to answer an ex-post project self-evaluation questionnaire three years after the project (the "Three years after"–questionnaire). In this section, we examine and compare answers from firms that reported positive productivity and those that reported no positive impact on productivity.

A total of 1087 large firms and 2239 small- and medium-sized firms answered the "Three years after" -questionnaire in 2006–2011 (i.e., the projects ended between 2003 and 2008). The questionnaire includes a large number of questions, including a question on how the project (which was partly funded by Tekes) affected firm productivity.

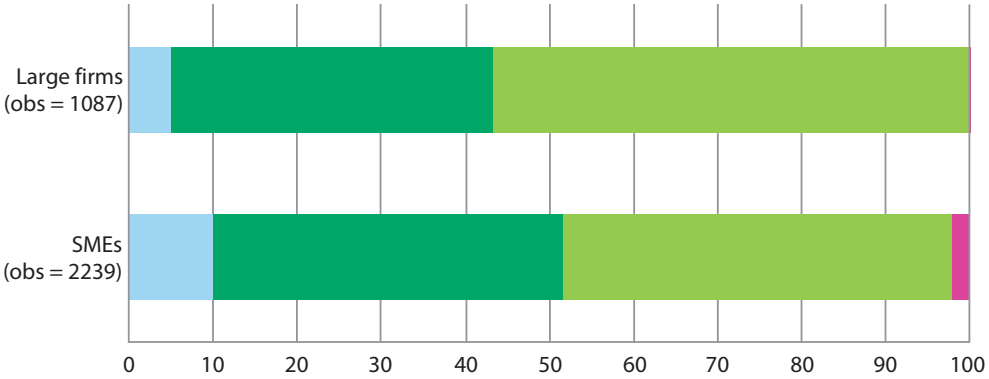
The sample limitations should be noted when interpreting the results from the questionnaire. Naturally, answers do not include firms that do not exist three years after the project. Furthermore, some firms did not answer the questionnaire. One possible reason for this is that the responsible employee(s) with the knowledge of the project were no longer employed by the firm three years after the project.

The questionnaire indicates that Tekes-funded projects demonstrated a positive impact on productivity in approximately half of the firms that completed the questionnaire (see Figure 14). The positive impact was somewhat more common among SMEs than among large firms. Over one-half of the SMEs reported that the project had a positive impact on their productivity, and 10 per cent reported that the positive impact was remarkable. Of the large enterprises, 43 per cent reported a positive impact on productivity, and only five per cent reported that the positive impact was remarkable. Nearly all of the remaining firms did not find an impact on productivity. Two per cent of the SMEs reported that the project had a negative impact on productivity.

Next, the firms that reported some impact or remarkable impact on productivity are compared with other firms. SMEs and large firms are examined separately. The questions relate to the impact on the firm's own business (Figure 42 in the Appendix), on the business environment (Figure 43 in the Appendix) and on society (Figure 44 in the Appendix).

Figure 41 shows how SMEs and large firms answer the questions concerning their own business. Firms are grouped depending on their answers to the productivity question. Overall, firms that reported a positive productivity effect also much more frequently reported a positive effect on other impacts on their business with two exceptions. For questions concerning the increase in collaboration with other firms and research institutes, companies with lower productivity impacts reported a greater impact.

Figure 14. How the project has affected firm productivity.



	SMEs (obs=2239)	Large firms (obs=1087)
1 = Remarkable impact	10%	5%
2 = Some impact	42%	38%
3 = No impact	46%	57%
4 = Decrease	2%	0%

However, the companies that evaluate the Tekes project had a positive impact on their productivity also evaluate that the project has made their product stand out from the competitors' products and more difficult to copy and improved their innovation and technology capabilities. The same notion applies to the wider impacts of Tekes funding on externalities in economic life. The companies that estimated that their productivity had improved due to the project were also more confident in the resulting positive societal and economic externalities (Figure 46. Projects' wider societal impacts; SME's that reported improved productivity compared with other SME's. Figure 46 and Figure 47). The generally positive response of the companies experiencing a positive impact on productivity suggests that these companies have been involved in successful projects, resulting in more positive evaluations in all sectors of the ex-post self-evaluation.

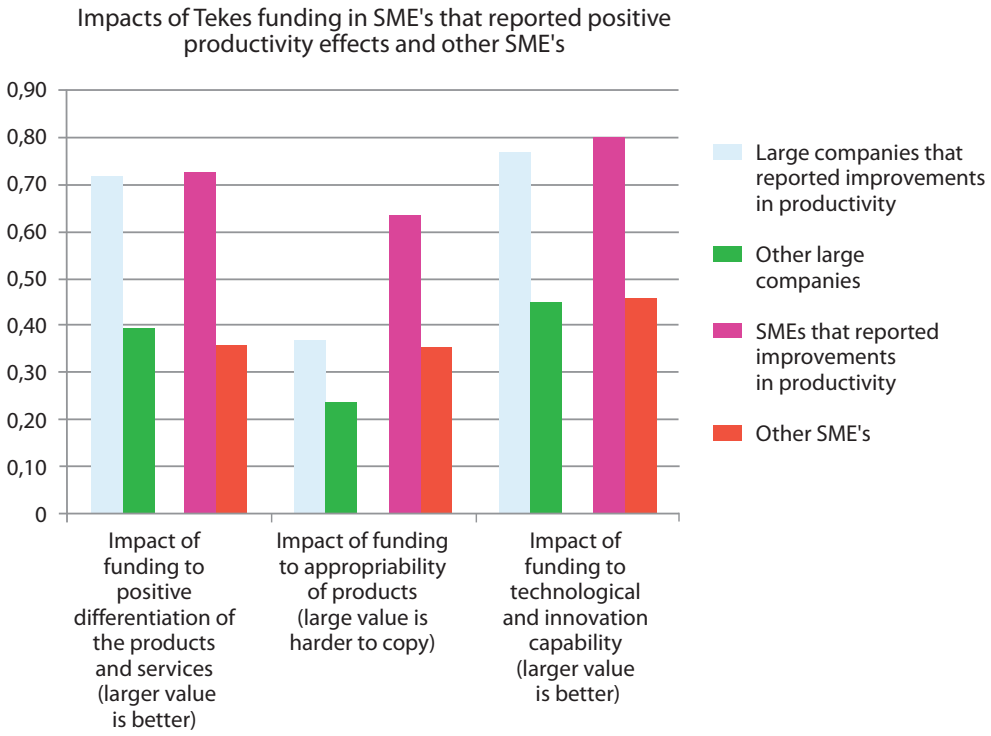
In general, the difference between SMEs and large firms is not substantial. SMEs that reported a positive impact on productivity also reported an impact on sales, market share and employment more often than corresponding large firms. On the other hand, large firms more often reported an impact on collaboration with public sector research institutions and organisations.

The following figures suggest that the main effect of the R&D funding is associated with output additionality for SMEs, i.e., new innovations, sales value added etc. The SMEs that reported a positive productivity effect also reported that the project had remarkable or somewhat remarkable effect on value added (92%), product quality (91%) and operational innovativeness and flexibility (89%). The lowest reported impact was on starting a new business (25%). SMEs that report no positive impact on productivity seem to have a more negative view on all questions.

By contrast, large firms reported that the effects of their projects are connected to operational innovativeness and flexibility (86%), continuing operational improvement and development (85%) and collaboration with other firms (84%). This suggests that the funding had more behavioural additionality, i.e., effect on renewal of the enterprise. Similar to the SMEs, the additionality of the R&D projects appears to be smallest in new business creation (26%). When compared with the answers of SMEs, the difference in all answers by large firms is not as large between the firms that report a positive productivity effect and those that do not report a positive effect.

Beyond the examination of the Tekes special interest groups versus other enterprises, an interesting question is:

Figure 15. Impacts on product differentiation, the appropriability of products, and technology and innovation capability; Companies that reported improved productivity compared with other companies.



how does the capability level of an enterprise prior to funding intervention moderate the impact of the intervention? When the self-evaluations are cross tabulated according to assessment of technology and innovation competence compared with competitors, we note that the extremes of the scale (enterprises that are behind the competition and those that are superior) have distinct profiles. Interestingly, the main differences arise in dimensions that correspond to behavioural additionality and spillover to industry and society as well as to output additionality. The profiles are robust, as the same pattern emerges when cross tabulating data according to how much the products of the enterprise stood out from the competition.

It appears as though enterprises that must catch-up feel that they receive more behavioural additionality than other groups, whereas those superior to competition think that they have more spillovers than others. This finding suggests that there are grounds for funding both laggards and leaders, although for different reasons. For enterprises lagging in capability, funding offers a possibility to improve innovation capabilities and systems for knowledge creation and use, which provide a basis for future productivity increase. As for the leaders, they will apparently benefit the industry and society through spillovers, even if the direct additionality of the funding is smaller.

Considering economic externalities (spillovers) for enterprises that had an impact on productivity, over 70% of the enterprises reported a deepening relationship with subcontractors and 80% with other enterprises. In addition, output measures, such as turnover and value added in other firms, was affected significantly in 60% of the projects that had an impact on productivity.

Figure 44 (in the Annex) shows how SMEs and large firms answered questions concerning the project and its ef-

Figure 16. Impact of funding in enterprises with different technological and innovation capabilities. (Source: Tekes project report data)

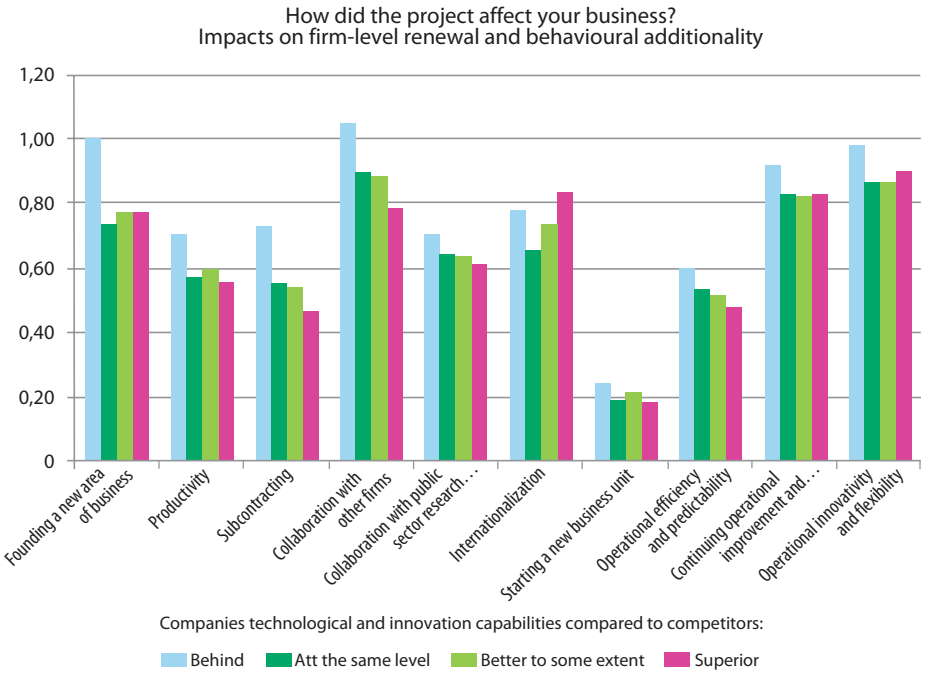
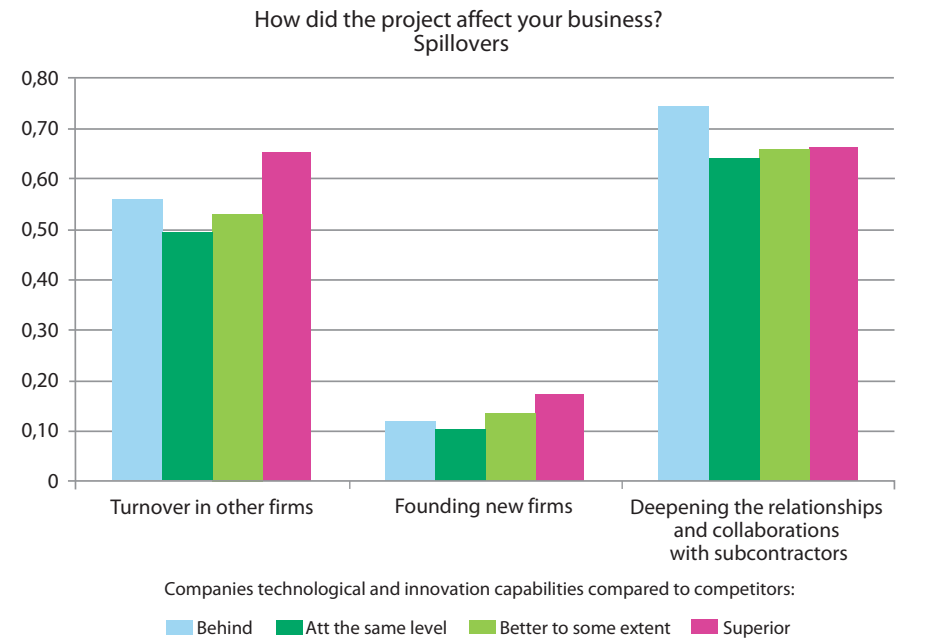


Figure 17. Impact of funding in enterprises with different technological and innovation capabilities, selected questions. (Source: Tekes project report data)



fect on society. Both SMEs and large firms (in both productivity groups) reported that the project had a remarkable or somewhat impact on national know-how (59–70%). This is important because it might indicate that externalities from the R&D projects can not only affect the firm success or business environment but also have wider impacts on the national knowledge base. These types of externalities are difficult to measure and identify in empirical studies.

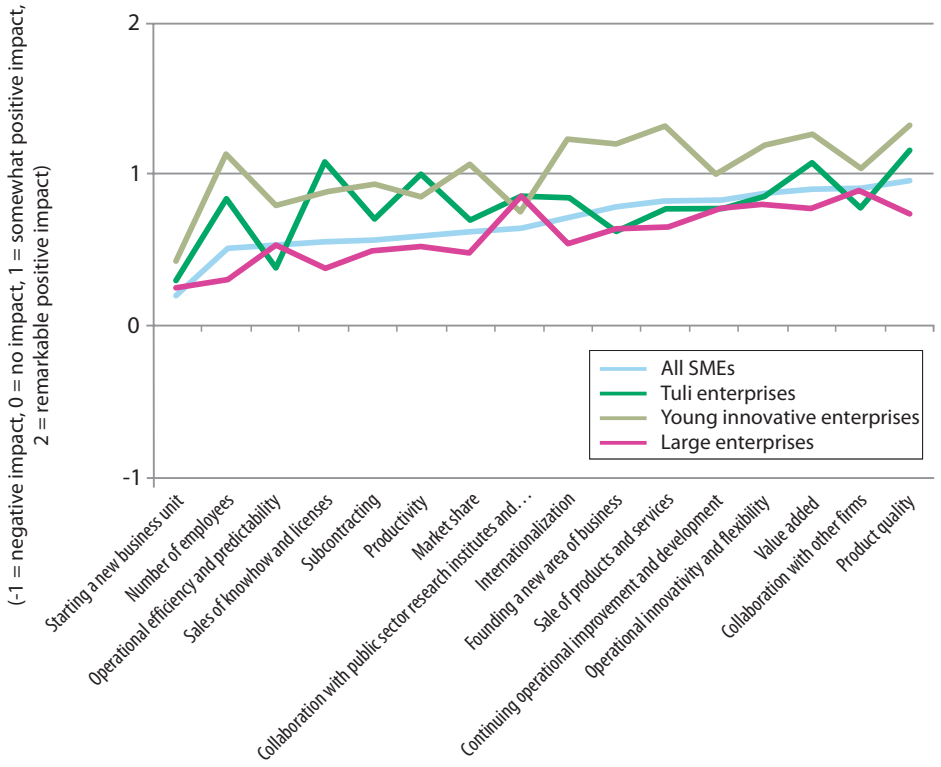
4.2 Renewal of the Tekes main target groups

This section presents an analysis of the impact and additionality of Tekes funding specifically to the renewal of the main target groups, including small and medium-sized enterprises (SMEs)[89] in general and subgroups that have received TULI or NIY funding. Additionally, high-growth enterprises, or more specifically gazelles, are analysed.

Examining how different enterprises view the impact of Tekes R&D grants, we can separate large enterprises from the Tekes special interest groups. The average profile begins (from the left) from quite small contributions to spin-off activity, employment and licensing. The impact rises steadily through productivity, collaboration with public entities and sales, to a marked impact to value added, product quality, innovativeness in processes and collaboration with other enterprises.

Interestingly, the enterprises are, on average, able to extract relatively little value from individual R&D projects. Examining the scale, score 1 is somewhat remarkable/tangible effect, and for average SMEs and large enterprises, the effects

Figure 18. Self-evaluation profiles for impact of R&D projects for different enterprise categories.
(Source: Tekes project report data)



89 SMEs are enterprises with less than 250 employees and less than 50 MEUR turnover and/or less than 43 MEUR balance sheet total (Source: European Commission, Recommendation 2003/361/EC). In this section, the enterprises are divided into groups based on number of employees.

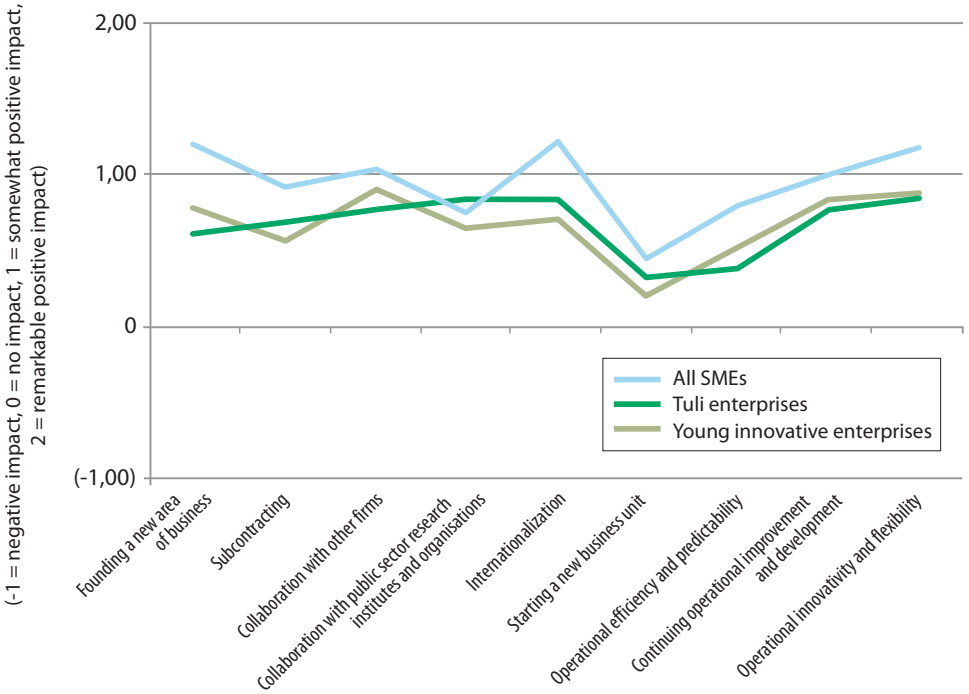
are consistently below this score on all dimensions. SMEs generally see more benefit than large enterprises, noting that large enterprises have two peaks in operational efficiency and collaboration with public entities. It can be speculated that the more recent dedicated funding on organisational and process development explains the peak in large enterprises' answers with regard to operational efficiency.

In sum, an average Tekes project has a somewhat marked impact on value added, product quality, networking and operational innovativeness. This is to say that output additionality dominates. This is expected, as the R&D projects are or have been generally quite focused on technology and products. However, the latter two dimensions, networking and operational innovativeness, exhibit behavioural additionality. The importance of networking hints that Tekes-funded projects may also have considerable spillovers outside of the firms through network effects.

The sub groups of TULI and Young Innovative Enterprises (NIY) are analysed in more detail below. However, it should be noted that especially NIY-funded enterprises are able to extract more value from their R&D projects, nearly reaching and, in some cases, exceeding marked impact on almost every dimension.

When specifically considering impact on behavioural additionality, or firm-level renewal, NIY enterprises experience more additionality than other special interest groups. For the SMEs at large, the greatest benefits are operational innovativeness, continuing improvement and collaboration with different partners. The least additionality has been experienced in starting a new business unit and operational efficiency.

Figure 19. Impact of Tekes funding on behavioural additionality, i.e., firm-level renewal.
(Source: Tekes project report data)



The main externalities to economic life are deeper relationships with public institutions and other enterprises, turnover in other firms, value added and product development in other firms. This suggests that networking is indeed facilitated by the projects. However, on average, the effects are not remarkable. Again, NIY-funded enterprises are ahead of others, followed by TULI enterprises. SMEs and large enterprises are on the same level in relation to externalities. The externality of turnover in other firms suggests that either the R&D projects are co-developed with partners' product for mutual advantage or that suppliers or contractors will have benefitted from the projects.

Regarding spillovers to other enterprises specifically in terms of behavioural and output additionality for the target groups, the most significant effects are deepening relationships, operational effectiveness and innovativeness as well as turnover and productivity in other enterprises. This suggests that the spillovers mirror the benefit that the beneficiaries receive from the funding intervention.

Examining the externalities to society reported for the projects, the main externality seems to be the increase in national know-how, which can also translate into knowledge spillovers through reportedly increased networking between enterprises, internationalisation of innovation activities, employment and entrepreneurship. However, the average externalities are quite small and should be interpreted with caution, as they are provided by project managers of the R&D project. Overall, NIY and TULI enterprises seem to extract or create the most value out of their projects in this respect.

Figure 20. Externalities in economic life. (Source: Tekes project report data)

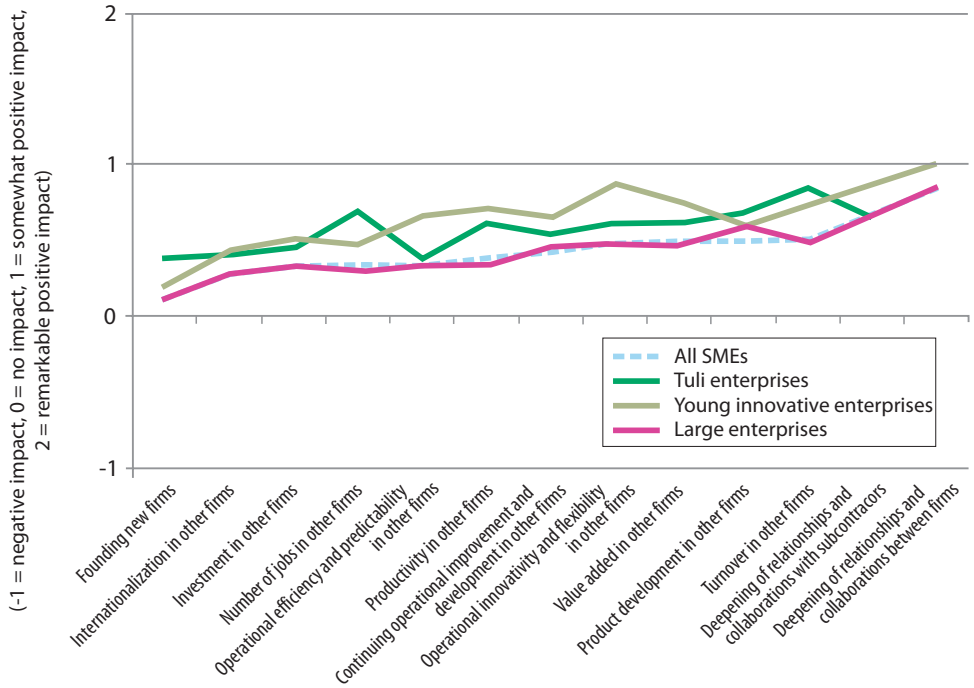


Figure 21. Impact of funding on spillovers to other enterprises. (Source: Tekes project report data)

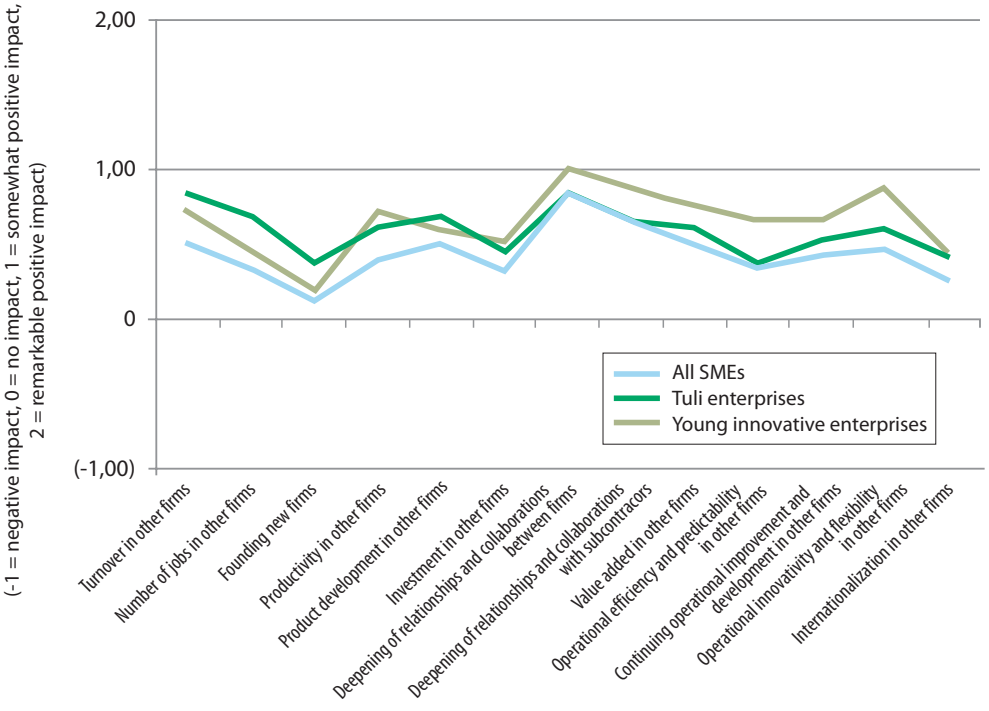
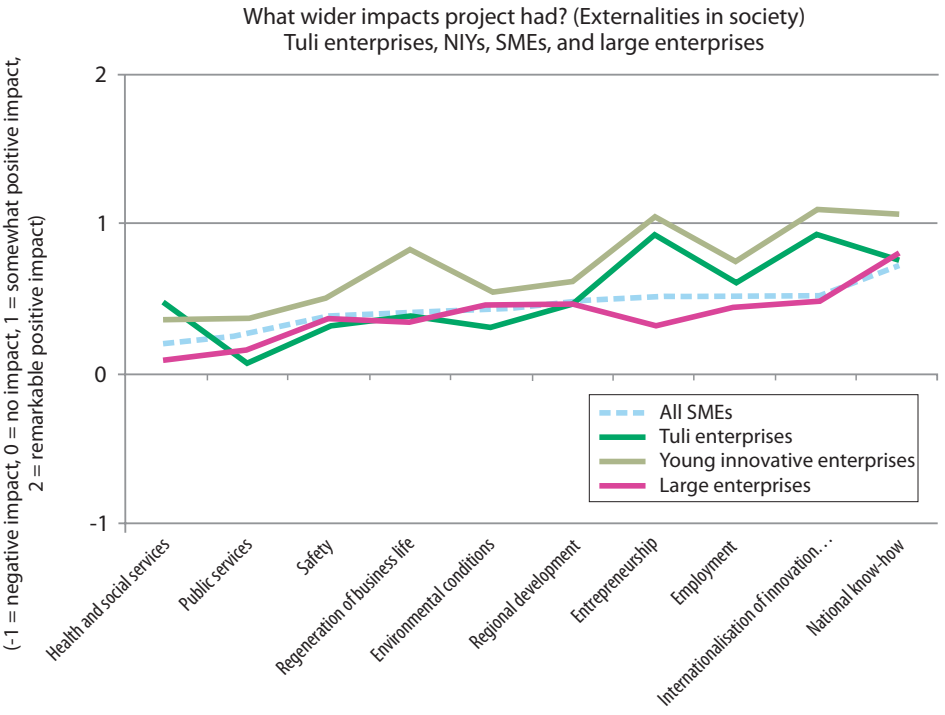


Figure 22. Externalities in society. (Source: Tekes project report data)



4.2.1 Small- and medium-sized enterprises (SMEs)

SMEs are the largest special interest group for Tekes. On average, the SMEs that participate in Tekes' programmes employ 30–35 people full-time. In comparison to the average SMEs, the companies that have received Tekes funding are substantially larger. An average company in the SME group employs only five persons full-time[90]. On average, the SMEs that receive Tekes funding are up to seven times larger than the average SME in terms of turnover (Appendix Figure 22).

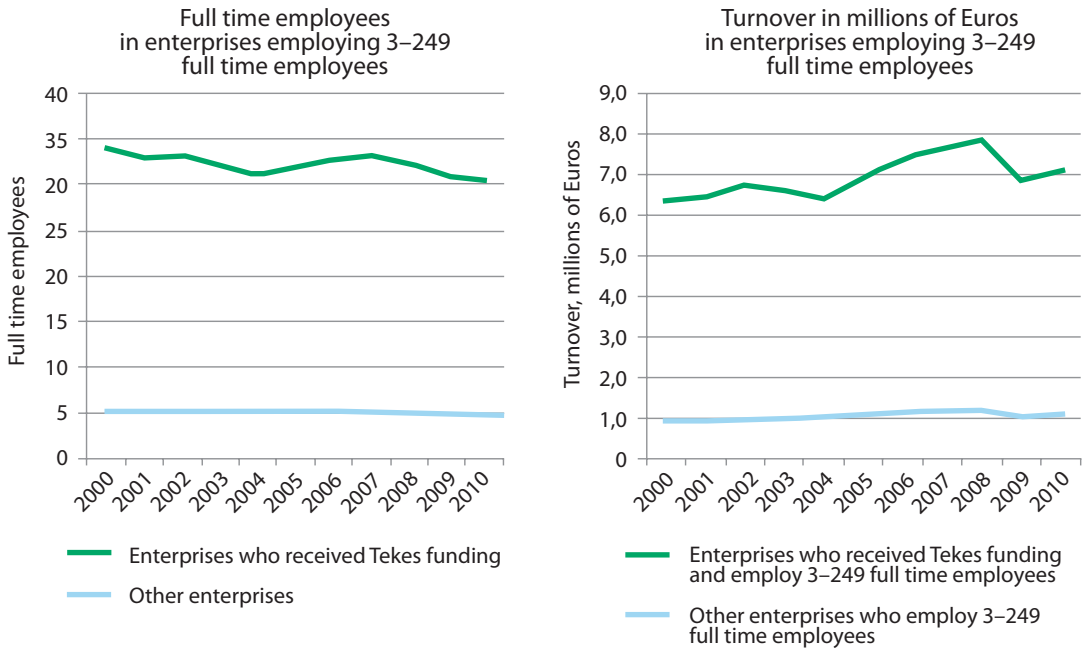
However, if the turnover is matched with the number of full-time employees, the companies that have received Tekes funding and other companies are rather similar. On average, companies in both groups succeeded in increasing the turnover per full-time employee until the financial crisis in 2008 (Figure 23). Interestingly, the trend in the turnover of the Tekes-funded companies increased, whereas the number of full-time employees decreased during the same period. This also indicates that productivity should be on the rise in Tekes-funded enterprises.

As discussed above, in general, SMEs report a larger impact of R&D funding than large enterprises. However, on the other hand, the average SME reportedly enjoys fewer benefits than the sub-groups of NIY- and TULI-funded enterprises. To recap, the main impacts are on product quality, collaboration/networking, value added and operational innovativeness and continuing improvement on processes. The findings support output and behavioural additionality, which can be interpreted as Tekes funding supports renewal of SMEs in general, although each project has a relatively small, incremental impact.

4.2.2 Young innovative enterprises (NIY)

Considering the self-evaluations of NIY-funded enterprises, the top impacts of the Tekes-funded R&D projects have been on the offering, sales, general innovativeness and internationalisation, closely trailed by founding a new area of business, value added and number of employees (Figures 17 and 22). In general, NIY enterprises have been able to extract more value out of their R&D projects than other SMEs, reporting, on aver-

Figure 23. Average number of employees and average turnover in Tekes-funded and other enterprises.



[90] In fact, the average SME in the population qualifies as a micro enterprise according to EC guideline, with a staff of less than 10 and turnover of less than 2 MEUR.

age, a somewhat remarkable impact on half of the dimensions. Examining the marked effect, the average NIY enterprise evaluates that it has been able to develop marketable products and technologies as well as operational innovativeness and internal processes.

The impact on operational innovativeness is especially significant in terms of renewal, as it indicates that the NIY enterprises are able to improve their operations as a result of R&D funding interventions. The fact that the enterprises are young and introduce innovative new products and services, some of which are radically new (as discussed below in the case studies), has significance for renewal at the industry level.

Many of the top dimensions are also typically associated with the NIY funding, which suggests that there are synergies between business development and R&D funding. It can be speculated that the NIY funding helps the enterprises to, for example, align their R&D with their strategy and to develop products and services that are better suited to their clients and/or that they confuse the effect of NIY and R&D projects.

Of note, the enterprises that perceived an impact on productivity also reported the greatest impact on the offering, operations and sales among others. This is to be expected, as productivity is by definition a factor of value added and amount of labour spent, and productivity impact can be decomposed to or covaries with value added, product quality, sales, and market shares. Productivity impact in R&D projects is associated with greater value added, quality, sales and market share as well as employment in approximately one-third of the firms. However, nearly three projects out of five that had a positive impact on productivity had an insignificant or negative behavioural additionality. In projects that did not have a significant impact on productivity, on average, one out of ten projects had other additionality.

Figure 24. Views of NIY enterprises on the effects of projects.

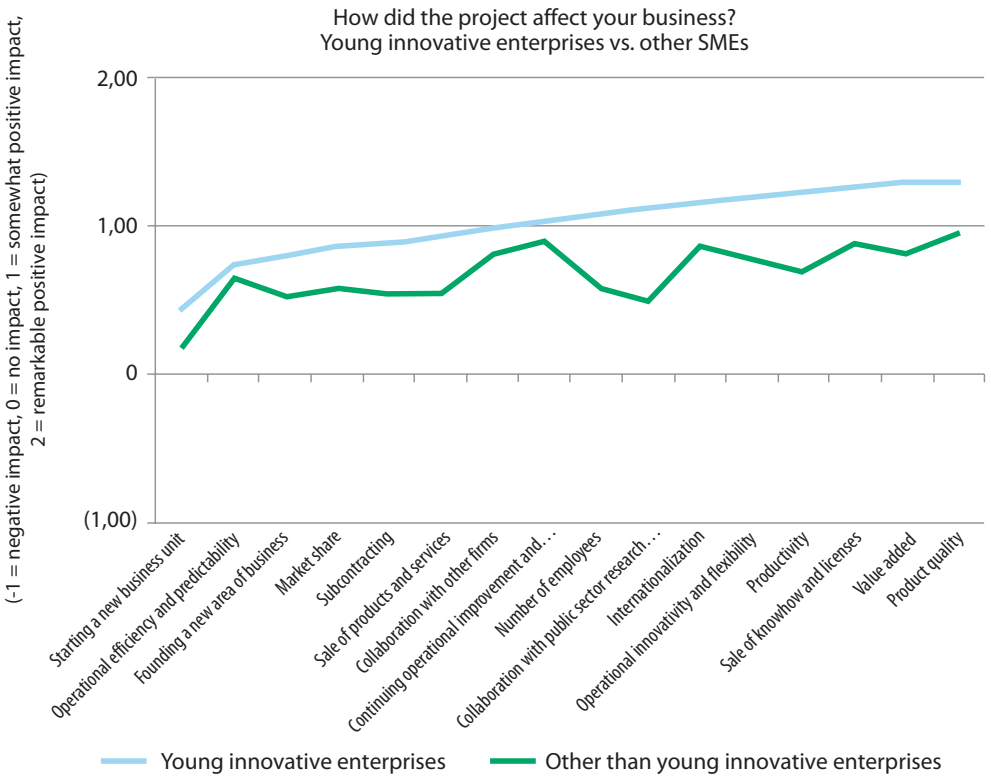
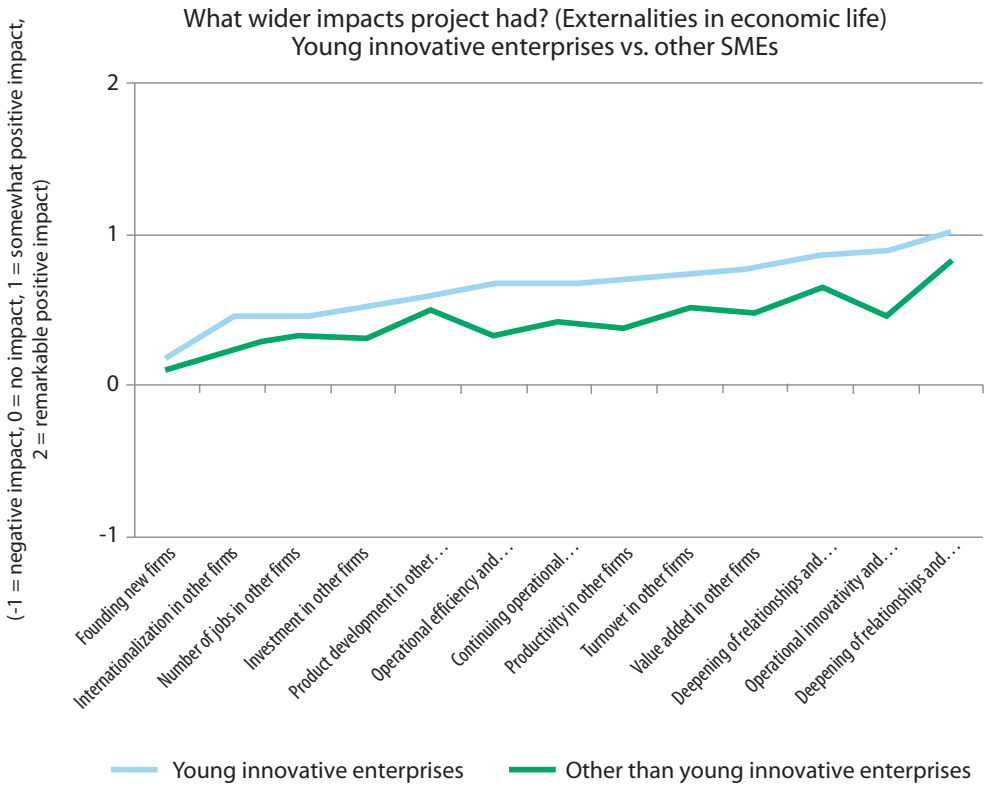


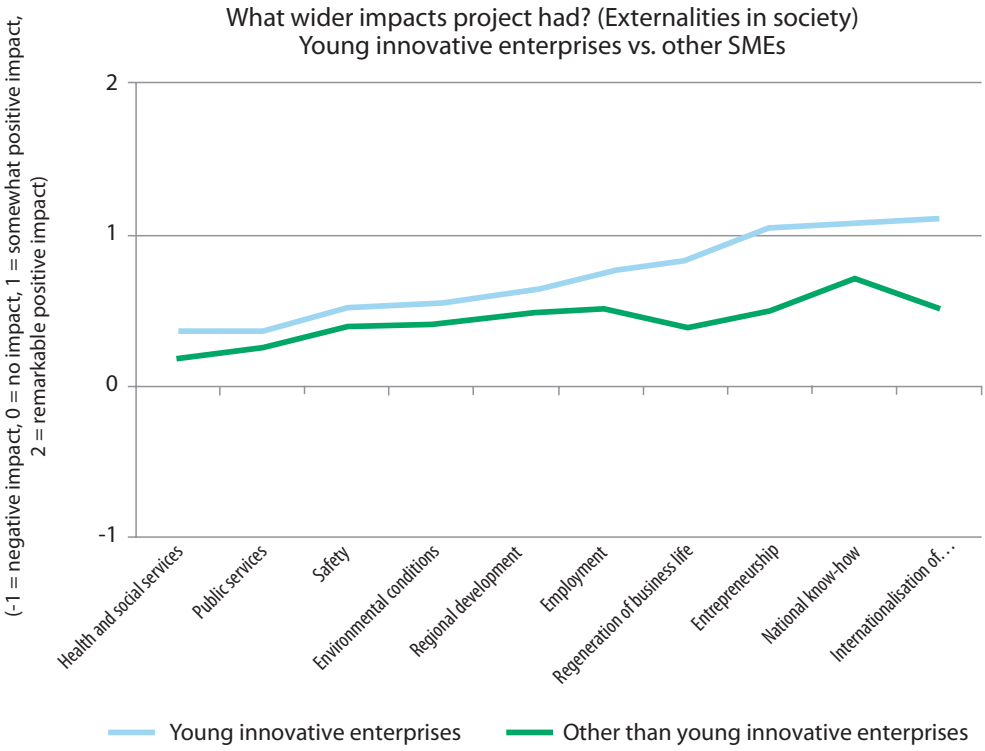
Figure 25. Externalities in economic life (NIYs).



NIY enterprises report consistently higher impacts to economy and society in general. They report a significant impact on collaboration with other firms, followed by operational innovativeness, deeper relationship with public sector and value added, turnover and productivity in other enterprises. This suggests that the NIYs have implemented highly collaborative projects for mutual benefit between partners.

For impacts on society in general, NIY enterprises report significant internationalisation of innovation, national know-how and entrepreneurship. The latter supposedly refers to the positive effect that the funding has had in the development of the NIY enterprises themselves. Otherwise, it could be argued that NIY enterprises are more likely to network internationally than other enterprises. In addition, the regeneration of business life is highly rated, which indicates that these enterprises view themselves as more innovative than other enterprises.

Figure 26. Externalities in society (NIYs).



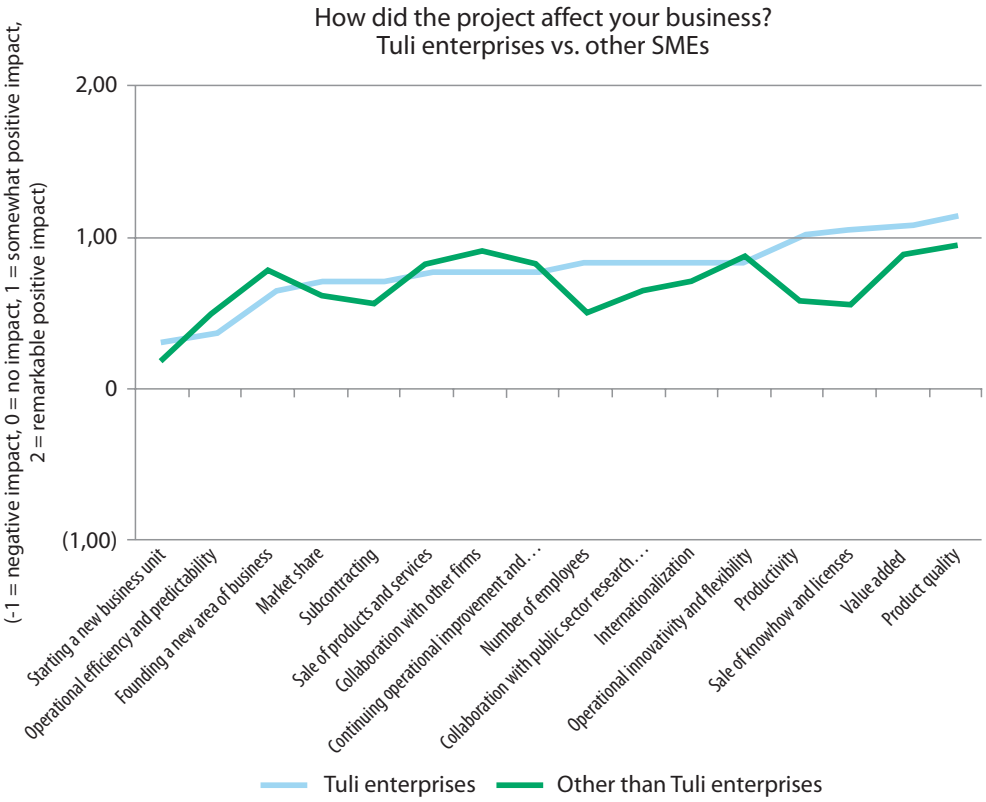
4.2.3 TULI enterprises

The TULI programme (Tutkimuksesta liiketoimintaa, Research into Business) has run for two programming periods. The first TULI programme granted funding in 2002–2005 and the second in the period 2007–2011 to several thousand projects in universities, research institutes, and universities of applied sciences, with an aim to support the commercialisation of research and establishment of new enterprises. A total of 187 spin-off companies were created in the latter TULI programme.

As noted above, TULI enterprises seem to extract more value out of their R&D projects than other SMEs, especially in terms of employment, internationalisation, sales of knowledge, productivity, value added and product quality. The most significant effect was on the latter four dimensions, indicating that the R&D projects have helped the TULI enterprises to develop marketable technology and quality products. This is to say that the effect of funding on renewal at the enterprise level is not significant in the case of TULI enterprises. However, as with NIY, it follows from the fact that they are by definition new enterprises; the existence and survival of TULI enterprises contributes to industrial renewal.

Compared with the NIY enterprises, the TULI enterprises that noted a significant effect on productivity most commonly noted an effect on the number of employees, value added and sales of knowledge, followed by internationalisation, market share and product quality. However, the percentages are much lower than in the NIY-group. In practice, one out of ten productivity-increasing projects had significant other additionality.

Figure 27. Project's effects on business (TULI enterprises vs. SMEs).



TULI enterprises are also consistently above others in their ratings of externalities. Their top externality is a deepening relationship with other enterprises as well, but the remaining externalities are in a different order, starting from turnover, product development and number of jobs in other firms. Thus, TULI enterprises see more direct output additionality in other firms, meaning that they have a relationship that differs from that of NIY enterprises or that they view the impacts differently.

The societal impacts are similar to NIY, although in a slightly different order of importance. However, the impacts are also less marked, with the most significant being entrepreneurship and internationalisation of innovation, followed by national know-how and employment. This seems to indicate that TULI enterprises more readily network internationally than others and that R&D projects have enabled the development of new knowledge and growth.

Figure 28. Externalities in economic life (TULI enterprises).

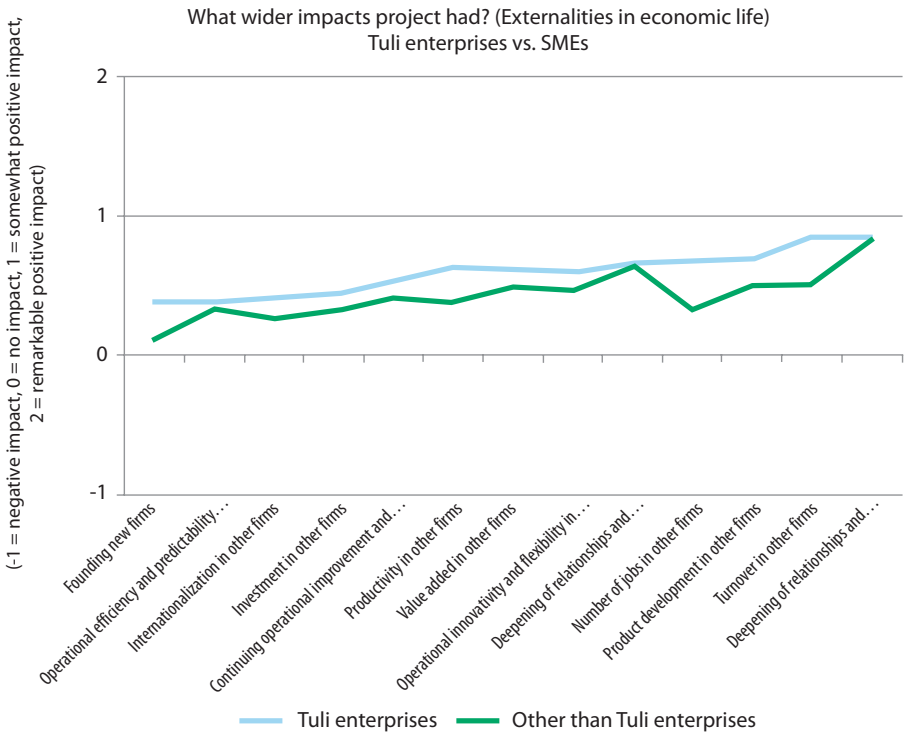
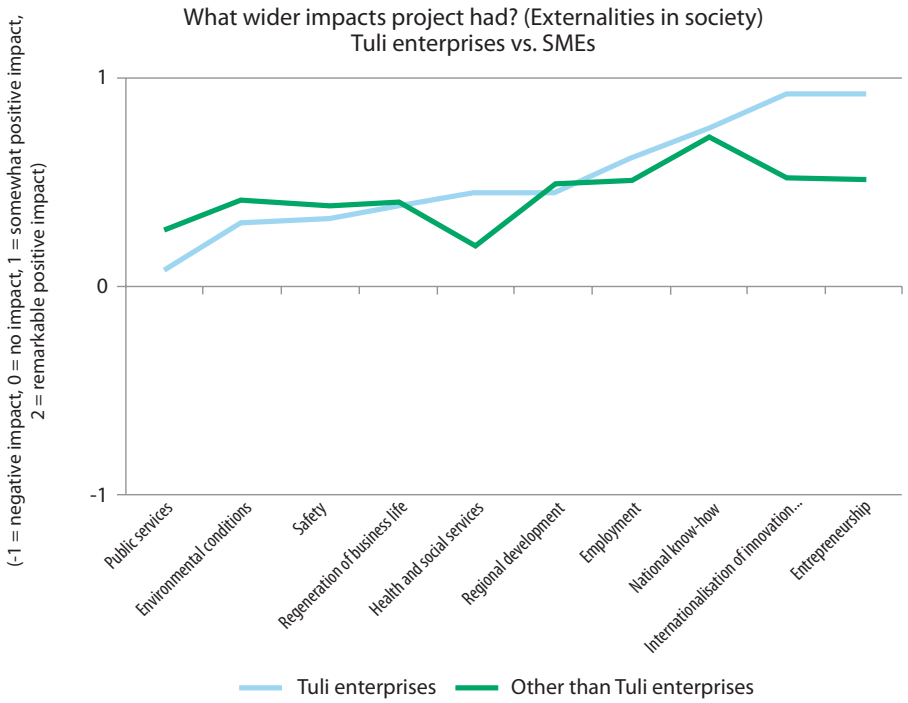


Figure 29. Externalities in society – What wider impacts did the project have (TULI enterprises).



4.2.4 Summary of findings from project self-evaluations

The Tekes special interest groups, SMEs, NIY enterprises and TULI enterprises, gain (on average) more additionality from Tekes-funded projects than the 'baseline' large enterprises. Especially NIY and TULI enterprises see a significant impact on dimensions regarding technology and product quality and productivity. In other words, the greatest additionality is output additionality, i.e., better technologies and products.

Examining the responses of different types of enterprises, the general picture is that each Tekes-funded R&D project has a relatively small, incremental impact, mostly in terms of output additionality followed by behavioural additionality. As discussed above, the average project does not rate significant or notable impact on most of the dimensions of the questionnaire. Of note, the enterprises that lag behind competition in technological and innovation capability seem to gain more in terms of renewal, whereas the leaders seem to benefit less in terms of behaviour and more in output and spillovers.

However, the special interest group NIY enterprises seem to be, on average, more successful in gaining from the projects. Furthermore, the NIY enterprises gain significant behavioural additionality, indicating that funding for NIY enterprises contributes to renewal at the enterprise level. Regarding the other enterprises, including SMEs in general, aspects of behavioural additionality are among the top benefits from R&D funding, but the overall rating is not significant, on average.

Findings on renewal at the level of industry and economy are considerably more tentative. As a summary of externalities or spillovers in the industry, the beneficiaries of Tekes funding categorically rate that the main benefit is deepening collaboration with other enterprises and subcontractors, and in the case of NIY enterprises, operational innovativeness. Of the social externalities, national know-how is the most important. Altogether, it can be hypothesised that insofar as knowledge is created, it is spread through the stronger connection between enterprises, effectively creating a possibility for renewal of enterprises within the value network of the beneficiaries. It is also notable that NIY and TULI enterprises represent the renewal of industries. Especially considering that NIY enterprises experience the greatest benefit from funding, it can be argued that even though the average impact of the funding intervention is quite low, there are quite significant impacts that are masked by the averages.

4.3 Case studies

The case studies were conducted to examine the behavioural additionality of funding and triangulate the findings from other data sources. The mode of inquiry was explorative and the template for the case studies was based on the additionality framework and operationalised impact model presented in Section 3.2. The key observations from the case studies are summarised below. The individual case studies are described in Appendix 2.

Starting from the impact of funding on behavioural additionality, there seems to be a clear distinction between early stages of enterprise life-cycle and the established phase. In the start-up phase, the knowledge and technology base is relatively concentrated and product variety is narrow. The enterprises report that Tekes funding does not steer the path of development; rather, it enables development to the fullest potential. This is also evident from TULI enterprises' additionality profile (above), which was tipped towards output additionality. However, the interviewees noted that business development funding had an effect on market knowledge and, thus, indirectly on the R&D path.

For more established firms, R&D funding seems to have a greater impact on strategy, as funded projects diversify the knowledge base by enabling the development of knowledge outside the current core. Considering company D, which clearly represents an established medium-large enterprise, there are relatively clear signs of behavioural / 2nd order additionality in the form of the introduction of new thinking and management practices as well as output additionality in the form of new technologies and products as well as production processes and systems. Additionally, the R&D projects have broadened the use of outside expertise and networks and created partnerships. Thus, one of the main effects seems to be that R&D funding enables more profound and rapid development of new technologies, which open up new business possibilities.

It seems that start-up and small enterprises extract the most benefit or additionality from 'general budgetary support'-type instruments and funding that supports market studies and business development such as the NIY instrument and venture capital investments. These instruments seem to have the minimum of overhead and thus maximum business impact. Overall, the NIY-funded companies state that the funding has enabled a market presence, which has had a significant effect on the development of the business. The specific additionality of NIY and TULI instruments seems to be that they enable the development of market and customer insight during early research

and development, which improves reception of the products when ready. The funding also seems to have a general enabling component, as it improves the financial position of the firm and enables recruitment of new talent.

In fact, Tekes funding is an important enabler of enterprise development for SMEs in general. Paraphrasing one interviewee, "all the funds are in the same account in any case", and receiving any form of funding is of assistance to cash flow/liquidity constrained enterprises. At least in some of the cases, enterprises would not have been established without funding, which suggests that R&D funding has an enabling function. However, teasing out the actual additionality, i.e., what the enterprises have achieved with the aid that they would not have achieved without it, is more challenging.

One explanatory factor behind this enabling component of Tekes funding might be the structure and liquidity of the private capital/equity market. Two of the cases touch upon this issue. One of the interviewed entrepreneurs stated that "investors expect that Tekes will pay half of development", which can be interpreted that private investors are reluctant to take the full risk of financing a start-up and seek investment targets that have public funding. Furthermore, according to other interviews, Tekes funding is also beneficial for securing private investments because it can be interpreted as a signal that others (Tekes) see the value of investing in the company and technology. From an investor's point of view, public subsidies can be a means of lowering technological and financial risk. Another entrepreneur called for stronger public equity investments rather than R&D project funding, referring to Finnvera and Teollisuussijoitus as possible actors. This suggests that the volume or terms and conditions for private equity investments do not meet the needs of the entrepreneurs. From a start-ups perspective, Tekes funding can be viewed as an opportunity to support R&D, but to secure other funding as well. This is an interesting finding concerning the function of the capital market. The literature refers to the crowding out effect as a negative externality of public funding, meaning that strong public investment marginalises private investment. However, here, we have anecdotal evidence of a *crowding in effect*, i.e., public subsidies drawing private investments.

A related issue is that while the clients are generally satisfied with Tekes funding and in general public funding can be regarded as an important enabler, project grants are not unanimously praised as a funding instrument for start-ups. To paraphrase one interviewee, "the whole enterprise is one large project in the start-up phase and everyone is trying to work to keep the momentum towards the market". In this situation, the overhead of project application and reporting requires the time of the people who develop the core business; thus, the project grants may be viewed as a minor aid for business development. Correspondingly, R&D loans were rated as the least desirable funding form for an enterprise that is cash flow/liquidity constrained. They require at least some certainty of future cash flow and pose a great risk for funded SMEs with poor liquidity. This comment also reinforces the finding about the suitability of general budgetary support-type instruments for start-ups.

Concerning the internationalisation of enterprises, Tekes funding supports networking nationally for enterprises that are inclined to do so. Especially the NIY funding and in one case, TULI-funding was used for international networking and market development, which was viewed as an important factor in business development. However, Tekes R&D grant terms and conditions do not enforce networking. In one case, in direct comparison with EU FP7, Tekes funding had a less direct impact on international networking or internationalisation.

Regarding the interaction between Tekes and other actors in the innovation system, especially the start-ups work typically with ELY-centres and public and private investors. However, the public subsidies from other actors are relatively small compared with Tekes grants, whereas equity investments are significant. An interesting question, especially when comparing productivity between Tekes-funded enterprises and their nearly exactly matched counterparts, is the slim additionality of R&D funding to productivity (see below). This opens a discussion on what drives the enterprises to Tekes funding, i.e., whether enterprises turn to Tekes to substitute equity funding with other instruments or genuinely undertake R&D.

The other explanation for the productivity dilemma is that enterprises that are publicly funded have improved productivity but because the comparison group constitutes a moving target, they have not surpassed the others. This would suggest that private investors have better information than Tekes in choosing investments, enabling them to 'cherry pick' the targets with the most potential, leaving the runners-up for public subsidy. This explanation is, to some extent, in conflict with the further analysis of productivity, as evident below.

Comparing the findings from the cases to the quantitative analysis of the relationship between productivity and funding, it is not surprising that the impact on productivity is limited. Especially the SME cases exhibit a tendency to satis-

fice on profitability and productivity and invest in growth in the short term. Typically, the turnover and profitability of the firm have remained relatively stable over a long period, but personnel number has been reduced quite significantly. In effect, productivity has grown as the same volume is produced with less personnel. Continuing from the summary of findings from the project evaluations, it seems that a common feature in the successful cases is that the R&D projects are aligned with corporate business and R&D strategy.

To summarise, the overall finding regarding the additionality of Tekes funding is that the behavioural additionality is more easily traceable in established enterprises, as they clearly exhibit the markers for both behavioural and output additionality. In start-ups, it is more difficult to distinguish how much of the effect is technically behavioural additionality or output additionality. It seems that Tekes funding has the effect of drawing private investments, which can be considered as input additionality. However, in the start-up phase, the enterprises seem to believe that project funding introduces too much overhead compared with GBS-type or equity funding. It is also clear from all of the data sources in this study that this type of funding is quite beneficial for the growth of SMEs. However, the success of NIY enterprises cannot be attributed to the instrument terms and conditions alone, as NIY funding is specifically limited to business development, not R&D, and the enterprises are also carefully screened for the program. This raises the question of whether the enterprises should be screened as a whole for other Tekes funding as well.

An interesting suggestion from one of the interviewees was that Tekes could achieve more business impact with a more application and/or problem-oriented approach to R&D funding, following the so-called DARPA model[91] of setting a challenging and relevant problem and funding R&D to solving it. Presently, there seems to be a risk, even if a minor one, that the technical level of ambition rises during R&D, while the enterprises could enter the markets with a 'satisficing[92]' technology before perfecting it. This approach could also have a stronger or more immediate impact on productivity, as the investment period would be shorter.

4.4 Summary of findings concerning renewal

Considering the average self-evaluation of the R&D projects, one can interpret that the projects are either relatively minor incremental innovation projects or risky projects that were not "hits to the bull's eye" within three years of project completion. For example, in the case of NIY enterprises, three out of five productivity-raising projects and nine out of ten of the others had insignificant additionality. In both cases, the success stories are hidden in the average project. Pulling the case findings together with the other data, it appears that many of the Tekes-funded R&D projects have some behavioural additionality. This indicates that the funding contributes to the renewal of enterprises.

As for externalities, there are some suggestions that knowledge is developed in the projects. Furthermore, the reported deeper connections with the partners and impact to partners' value added suggest that knowledge is exchanged within the networks, indicating spillovers. This may indicate that the projects contribute to the renewal of industries. In terms of contributing to society at large, the firms seem to contribute mostly through their own growth, internationalisation and knowledge generation rather than through spillovers.

The question of additionality also concerns serial funding. The literature has reported that first-time funded enterprises learn most from their projects, at least in terms of behavioural additionality. This proposition has some support from the finding that enterprises that are behind competition in terms of technology experience the greatest behavioural additionality, but is not directly supported by the cases. Although NIY more often reported that their R&D had an impact on internal processes as others, case enterprises of all sizes and project numbers reported that the R&D projects had an effect on their internal processes. Furthermore, case D, a large company with multiple sequential projects, reports the best results from the last projects. This may suggest that although the there is a decreasing marginal behavioural additionality from multiple successive projects, the output additionality tends to cumulate over multiple projects.

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91 See, e.g., Dubois, L.H. 2003. DARPA's Approach to Innovation and Its Reflection in Industry. In: United States National Research Council, Chemical Sciences Roundtable. Reducing the Time from Basic Research to Innovation in the Chemical Sciences: A Workshop Report to the Chemical Sciences Roundtable. Washington (DC): National Academies Press (US); 2003. Available from: http://www.ncbi.nlm.nih.gov/books/NBK36337/

92 Satisficing is a term coined by H.A. Simon, meaning that, e.g., a satisficing technology performs at or above the 'aspiration level' or expectation according to the criteria set for its evaluation. In technical terms, a satisficing solution is 'good enough' (a local optimum) rather than the best imaginable (global optimum) (e.g. Simon, 1996).

5
Analysis of productivity development

This section presents an econometric analysis of the impact of Tekes funding intervention on the productivity of recipient enterprises, compared with closely matched enterprises that have not received funding. The goal of our econometric analysis is to identify a causal relationship between R&D subsidy and the productivity of enterprises. With regard to Tekes special interest groups, some additional analyses have been carried out to complement the econometric study.

5.1 Challenges in assessing the impact of funding

The central question in policy program evaluations is how to measure the causal effect of a policy tool, such as R&D subsidy, on policy-relevant outcomes such as firm productivity. If the causal relationship is known, it is possible to use different policy tools in the most efficient way. The problem is that researchers and policy makers observe only one outcome, whether the firm receives the subsidy or not, i.e., both outcomes cannot be true at the same time. This is called a "fundamental problem of causal interference"[93].

As subsidies are not randomly distributed, a firm's observed and unobserved characteristics correlate with the probability of receiving the subsidy. For example, more productive firms might receive the subsidy with higher probability than other firms (i.e., productive firms might be skilled in the application process). If so, then successful program evaluation must take into account firm selection into the subsidy program. Otherwise, a simple comparison of group means of those who do and do not receive the subsidy will likely lead to inaccurate conclusions.

Determining the causal impact of R&D subsidy to firm productivity is not a simple empirical question for several reasons:

1. If public R&D subsidy crowds out private R&D in equal amount (and this is not controlled), then the measured impact is not a causal effect. This is not a problem according to the existing literature.[94] There are also indications that public R&D subsidies stimulate private R&D spending.[95]
2. The positive effect of R&D on productivity comes with lags.[96] This should also apply to R&D subsidies. As researchers typically have only a limited period of data, the productivity effect might not be observed. In this study, we use data over a five-year period after the subsidy year.

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93 Holland, P.W. (1986). Statistics and Causal Inference. Journal of the American Statistical Association 81, 945–960.

94 Aerts, K. & Schmidt, T. (2008). Two for the price of one?: Additionality effects of R&D subsidies: A comparison between Flanders and Germany. Research Policy 37, 806–822; Ali-Yrkkö, J. (2004). Impact of public R&D financing on private R&D: Does financial constraint matter? (No. 943). Helsinki: The Research Institute of the Finnish Economy (ETLA); Hussinger, K. (2008). R&D and subsidies at the firm level: an application of parametric and semiparametric two-step selection models. Journal of Applied Econometrics 23, 729–747; Lach, S., (2002). Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel. The Journal of Industrial Economics 50, 369–390.

95 González, X. & Pazó, C. (2008). Do public subsidies stimulate private R&D spending? Research Policy 37, 371–389; Meuleman, M. & De Maeseneire, W. (2012). Do R&D subsidies affect SMEs' access to external financing? Research Policy 41, 580–591.

96 Rouvinen, P. (2002) R&D-Productivity Dynamics: Causality, Lags, and "Dry Holes", Journal of Applied Economics, Universidad del CEMA; Ali-Yrkkö, J. & Maliranta, M. (2006). Impact of R&D on Productivity - Firm-level Evidence from Finland (Discussion Paper No. 1031). The Research Institute of the Finnish Economy.

3. R&D subsidies might have externalities through many different channels. Basic estimations may yield downward biased estimates (this might be one reason why no positive effect is found). However, it is difficult to identify these effects and measuring externalities empirically would require a significant amount of time and research resources.
4. Heterogeneity problem. Typically only the mean impact is estimated, even though there might be differences between different firms. To consider the possibility of heterogeneous effects, we estimate results for different groups.
5. Firm survival. According to economic theory, non-productive firms should decline in size and exit the marketplace, whereas productive firms should grow and gain larger market share. When the researcher is conducting causal analysis using multiple periods (with balanced data), there is a built-in sample selection problem in the study. This sample selection problem increases with the length of the study period.
6. Selection problem. If there are unobserved factors that affect the probability of receiving the subsidy and the future productivity, then results might be biased. Perhaps one of the most important control variables is the firm's own R&D development. If one wants to evaluate the causal impact of an R&D subsidy on firm productivity, then the impact of the subsidy should be evaluated while controlling for the firm's own R&D effort (in this study, we have two proxy controls for firm R&D effort derived from employee educational characteristics). The selection problem can also be minimised by the econometric methods (in this study, we use matching combined with difference-in-differences).

The relationship between firm R&D and productivity has been studied extensively internationally[97] and in Finland[98]. Although there are different results on how fast and why R&D affects productivity, the conclusion is that R&D has a significant and positive effect on productivity. However, there is only a modest number of peer-reviewed empirical research studies on how firm productivity is affected by the public R&D subsidy. Table 7 summarises several recent studies on the causal impact of R&D subsidy on firm productivity.

Table 7. Recent econometric studies on R&D subsidy and firm productivity.

	Data set	Productivity measure	Evaluation method	Results
Harris & Trainor (2005)	Plant-level data in N. Ireland 1983–1997	TFP	IV-GMM	Mixed results
Piekkola (2007)	Finnish firm-employee-level data 1996–2002	TFP	OLS & IV	Significant positive effect
Baghana (2010)	Manufacturing firms in Quebec	TFP	Matching + DID	Positive effect, but ineffective.
Sissoko (2011)	European firms involved in Eureka programme	LP & TFP	Matching + DID	Positive heterogeneous effects
Bernini & Pellegrini (2011)	Southern Italian firms 1996–2004	LP & TFP	Matching + DID	Significant negative impact (year after)
Criscuolo et al. (2012)	UK firm-level panel 1983–2004	TFP	OLS & IV	No effect

97 e.g., Hall et al (2012);

98 e.g., Ali-Yrkkö & Maliranta (2006); Lehto, E. & Böckerman, P. & Huovari, J. (2011). The return to the technological frontier: The conditional effect of R&D on plant productivity in Finnish manufacturing. Papers in Regional Science 90, 91–109.

5.2 Estimation method and data

The econometric analysis examines the causal effect of public R&D subsidy on firm productivity. To minimise this selection bias, we use a combined matching and difference-in-differences method (CDID). With this method, the productivity of Tekes-funded firms is not compared with average firms; rather, for all firms, we construct a similar control group.

The matching method attempts to find as good a comparison group as possible using a wide range of matching variables available in this study. If only the matching method is used, then the causal relationship is based on the assumption that all necessary variables are used in the matching (so-called "selection on observables" assumption). However, as we combine matching with difference-in-differences approach (DID), see e.g., Roy (1951)[99] and Rubin (1977)[100], we can also control unobserved time invariant effects (e.g., industry specific shocks). After matching, the requirement for successful DID evaluation is that the firms that receive the subsidy have a similar trend as other firms (conditional on matched variables). CDID estimation method is a robust method for studying causal effects[101]. For more details on this estimation method, see Appendix 3. For those who are not familiar with the treatment framework, a good place to start is Imbens and Wooldridge (2009)[102] or Blundell and Costa Dias (2000)[103], who surveyed development on program evaluation.

In practise, this means that in the matching phase of our estimation, we use data to determine a propensity score (the probability of receiving a subsidy) for each firm in the control group. The firms in the control group that are similar to subsidised firms receive a higher propensity score than those that are different (a firm that is exactly similar will receive a weight of one). Thus, the firms that have the smallest probability of receiving a subsidy have the smallest impact on results. In essence, the treatment and control groups' performances are compared as weighted averages of similar enterprises, resulting in a robust control for all enterprises, even in sparsely populated regions. If we had only few matching variables (e.g., no regional dummies or firm-specific R&D variables), propensity score matching would place 'wrong' firms close to the subsidised firms measured in propensity score. This is a salient point for the validity of claiming a causal relationship, as the subsidies are not assigned to the enterprises randomly (as exhibited in Table 9, which reveals that several variables we control for indeed have a significant effect on the probability of receiving a subsidy). In this case, it would be highly likely that estimations would be biased, as we would not compare "apples to apples".[104]

In earlier assessments of Tekes subsidies, particularly in the 'visual study' or descriptive analysis presented by ETLA 2012[105], only a few variables were used in the matching phase. If we constrain the analysis and use only a few matching variables, it would not be a causal analysis between subsidy and firm productivity (it would be more like a descriptive analysis with conditions). In short, the less possible variables that have an effect on productivity are controlled, the more prone the analysis is to selection bias, i.e., unfair comparison of enterprises with different capabilities for R&D, and the *post hoc, ergo propter hoc* –fallacy, i.e., mixing coincidental covariation of observables with cause and effect -relationship. As this assessment focuses on a causal relationship, it is central to use a wide range specific matching variables that incrementally

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99 Roy, A. D. (1951). "Some Thoughts on the Distribution of Earnings." Oxford Econ. Papers 3 (June 1951): 135–46.

100 Rubin, D.B. (1977). Assignment to Treatment Group on the Basis of a Covariate. JOURNAL OF EDUCATIONAL AND BEHAVIORAL STATISTICS 2, 1–26.

101 Blundell & Costa Dias (2000).

102 Imbens, G.W. & Wooldridge, J.M. (2009). Recent Developments in the Econometrics of Program Evaluation. Journal of Economic Literature 47, 5–86.

103 Blundell, R. & Costa Dias, M. (2000). Evaluation Methods for Non-Experimental Data. Fiscal Studies 21, 427–468.

104 We use local linear regression in matching, which uses part of the firm distribution to form a control group. Some other matching methods such as nearest neighbourhood matching calculate the propensity score more directly and use only the close neighbourhood to form a control group. During this study, we also evaluate how an alternative matching method affects the results. To assess the robustness of our approach, all of the results are also repeated for trimmed samples with 5 and 10 per cent of the observations removed from the tails. These modifications did not change our conclusions and are not reported here.

105 Rouvinen and Pajarinen (2012). Kehittyykö Tekes-asiakkaiden tuottavuus muita vastaavia yrityksiä paremmin? Visuaalinen tarkastelu. Presentation at Tekes, 18.6.2012.

Table 8. Summary of the control variables (see detailed description in Appendix 1).

Variables
Dependent variable
Productivity*
Treatment variables
R&D subsidy from TEKES*
Firm specifics
Age*
Turnover*
Employees
Group (part of a group, or independent)
Ownership (majority ownership international of domestic)
Foreign trade (Import/export or none)
R&D development
Patents*
R&D personnel (Share of doctorate or equivalent degree in sciences or engineering)
R&D personnel (Share of other personnel with a tertiary/university degree)
Tekes-funded R&D year before
Tekes-funded R&D two years before
Other R&D subsidies (besides TEKES)
Industry classification
Industry code (NACE 2002)
Regional variables
Region (NUTS 3 regions)
Located in single location/region or multiple
Located in regional centre or peripheral area

diminish the probability of the observed effects being random.[106] The assumption of a random distribution of subsidies would preclude conclusions about the net effect of the subsidy to productivity; in essence, it would simply provide evidence on the effectiveness of the selection process. For example, the findings presented by ETLA were based on an analysis that controlled for turnover, age, industry and a 'yes/no' dummy for innovativeness. The following analysis uses 13 additional controls to match the enterprises more closely.

The DID approach has one feature that can affect results significantly. DID uses time periods before and after the subsidy. There is a danger that a firm anticipates that it will eventually receive the subsidy. The productivity may decline before the actual subsidy is paid because the firm has invested in the process of receiving the subsidy. If this artificial "dip" (also called "Ashenfelter's dip") in the productivity occurs before the actual subsidy year (when researcher measures the "base productivity"), then the DID estimations are biased upwards (because DID is calculated by differencing base productivity and productivity after the subsidy). This is one main reason why we perform the matching with characteristics of the year before the firm is granted a subsidy and not when the subsidy is paid to the firm.[107]

The data used in estimation comes from several sources, as follows: *Business Register database* (age, municipality, NUTS3 region, foreign trade variable, sector, industry code at two-digit level), *Financial Statement database* (number of full-time personnel, value added and turnover), *Patent database* (applied patents in Finland and in Europe and granted patents in US), *Concern database* (group variable) and *Statistics on business subsidies* (paid loans, paid subordinated loans and subsidies). Statistics Finland maintains these register-based databases. Firm-level data were combined with *Employee characteristics database* (educational share variables for the firms) created from the Finnish Longitudinal Employer-Employee Data base by statistics Finland. This data set includes firms that have at least ten employees. The Tekes "three year after"-questionnaire data were also matched to the data using firm identity code. Whereas the questionnaire relates to firms whose projects ended during the years 2003–2008, other data sources include yearly data from 2000 to 2010. The analysis uses two previous annual observations to control previous subsidies (years 2000 and 2001).

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106 We noted that the results are biased upwards if only few variables are used in matching. This finding relates to the selection problem (see Figure 29 and Figure 30). Thus, one must be careful in interpreting the estimation results if only few matching variables are used in the analysis.

107 We noted during the estimations that the so-called "placebo effect" (treatment effect year before the actual treatment) was not significant, and we therefore found no evidence that productivity declines in advance of the treatment. We also examined how the results are affected if we match for R&D personnel and for number of patents two years before the subsidy year rather than one year, as done in baseline estimations (e.g., firm might anticipate the subsidy and hire new employees, which could contribute to productivity). This modification did not affect the results and are not reported here.

The sample consists of private sector firms that have 10 to 249 full-time employees and no more than €50 million turnover (or less than 43 million on balance sheet). This is similar to the definition of SMEs by European Commission with the exception that the firms under ten employees are not included in the current study. We constrain the analysis on the balanced five-year panel if not stated otherwise. Thus, firms are granted a subsidy in the period 2002–2005.

This study uses labour productivity as a measure of annual firm productivity.[108] This is formed by dividing annual value added by the number of full-time employees (defined by the Statistics Finland) because hours of work are not available. Matching variables are measured one year before the treatment (the decision of granting a subsidy to the firm). The treatment variable received a value of one if the firm was awarded an R&D subsidy and zero otherwise (for the detailed list of used variables and explanations, see Appendix 3 Table 9).

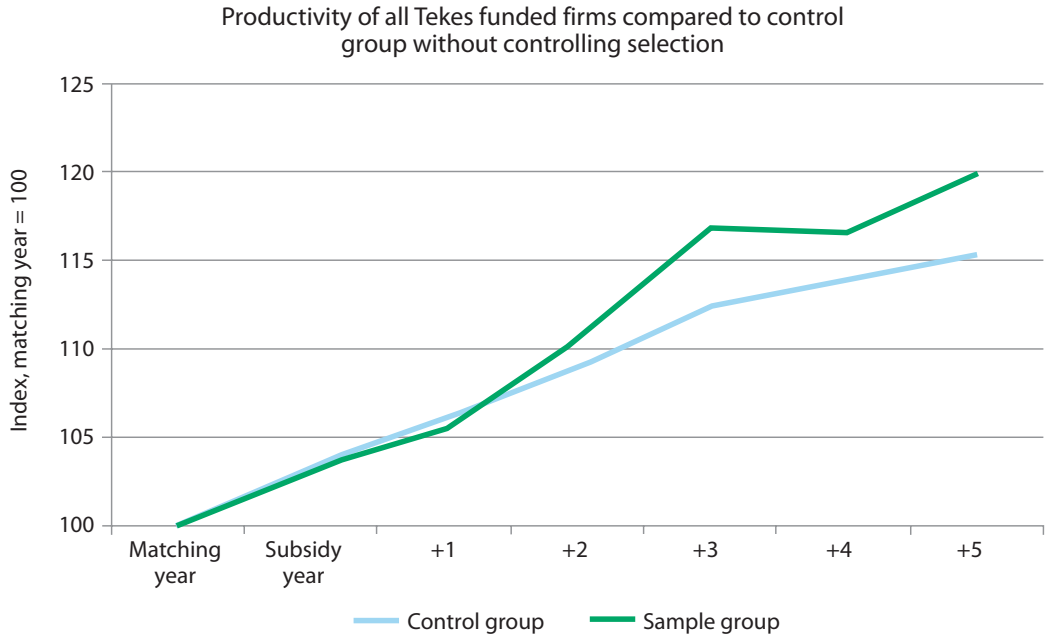
5.3 Estimation results of the impact of Tekes funding

As previously mentioned, when assessing the impact of subsidy, one must carefully consider causality. In particular, the selection problem must be controlled. The question is whether the subsequent productivity growth is affected by subsidy or whether subsided firms are selected in a manner that makes their productivity growth differ from that of the control group.

In the case of Tekes funding, the productivity growth, without controlling the selection issue, seems to be faster on average for Tekes-funded firms compared with the control group (Figure 30). Five years after they have received the subsidy, their cumulative productivity growth is 5 per cent higher than that of the control group.

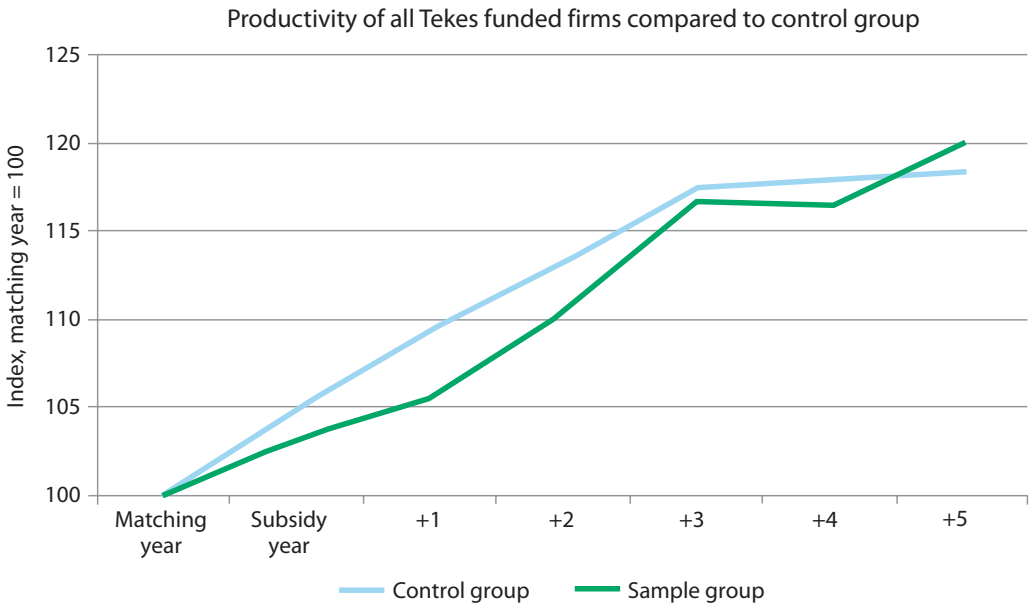
However, the results differ when the selection issue is taken into account (Figure 31). Initially, the subsidy has a nega-

Figure 30. Baseline estimation of productivity, without controlling selection. (The average productivity for the treatment group and for the control group, unweighted average, normalised to 100 in the matching year).



[108] Labour productivity is in logarithm form; thus, negative values of productivity are not defined. For robustness checks, estimations were repeated using non-logarithm form of labour productivity, which had an insignificant effect on the results.

Figure 31. Baseline productivity estimation (The average productivity for the treatment group and for the control group, unweighted average, normalised to 100 in the matching year).



tive effect on productivity growth. One year after the subsidy, funded firms had lower productivity compared to the control group. The accumulated difference was 4 per cent, and the difference was statistically significant. Afterwards, funded firms must catch up. After five years from the time of subsidy, funded firms are equal to the control group. There is no statistically significant difference in the two group's cumulative productivity growth (full estimation results are presented in Table 11 in Appendix 3).

The results raise several questions. First, why does the subsidy have a negative initial effect on productivity? Second, why do the results differ somewhat from earlier assessments and present a more negative assessment of the impact of Tekes funding? Third, do the results state that there are no positive effects from Tekes funding?

The first question is easy to answer. The initial negative effect is not surprising, as the new R&D project might begin by hiring new employees or relocating current employees from the daily business to the development project, with a delay in the potential impact on production. This, by definition, negatively affects the firm's productivity (remember that productivity is measured as the value added divide by the number of employees). This result is also similar to Bernini and Pellegrini's (2011) finding of a statistically significant negative effect year after the subsidy using Italian firm data.[109]

The second question about comparability to earlier assessments by Tekes is mostly related to variables used in the estimations and different methodology. The used combined matching and difference-in-differences (CDID) estimation method is sensitive to the variables used in the matching procedure. The causal interpretation is difficult if the matching procedure does not control all factors that have a significant effect on both the probability of receiving the subsidy and the future productivity. CDID methods are also sensitive to how the sample and before and after periods are defined.

Compared with earlier analysis, the current approach is more prudent. We use many different variables in the matching phase to control the selection bias. Variables that describe

[109] Bernini & Pellegrini (2011).

the firm's own R&D effort are the most important (Table 10 in Appendix 3 reports firm characteristics that affect the probability of receiving the subsidy). The results show that a firm's own R&D and past R&D subsidies are the most important control variables in the selection equation. All R&D variables (especially the variable indicating the share of workers with a doctorate or equivalent level of tertiary education in a field of technology or natural science) obtain positive values, indicating that they increase the likelihood of receiving a subsidy.

Due the data constraints, it is difficult to control firm-specific R&D potential. Optimally, one would accurately control the firm's own R&D resources (for example, using accurate occupational classifications). Otherwise, the causal effect of R&D subsidy is difficult to separate from the firm's own R&D effort that is not caused by the subsidy. Figure 30 and Figure 31 highlight the direction in which the baseline estimations would be biased if firm selection was not taken account in the analysis. Productivity estimates are shown in the figures for the firms that received a subsidy (treatment group) compared with the firms that did not receive a subsidy (control group). Visual comparison shows that if the treatment effect is estimated without controlling firm-specific differences (Figure 30), there is an underestimation of the negative dip after receiving the subsidy while the treatment effect is overestimated for the later years.

The third question is policy relevant, as it seems to suggest that there are no positive effects of Tekes funding on productivity growth. However, the results are not concerning when considering the impact of Tekes funding. The main justification for public R&D subsidies is spillovers from R&D activity, not the productivity growth at the firm level. The method used here does not provide information about spillovers.

At the firm level, it is not reasonable to expect clearly faster productivity from Tekes-funded firms compared with equal firms that did not receive funding. Tekes targets the most able firms. In a well-functioning market economy, their peers should be able to generate above average productivity growth as well. The results and implications are further discussed in Chapter 5.5.

To assess differences in the company sizes, estimations were separately conducted by size. Estimations were repeated for firms with 10–49 employees and firms with 50–249 employees (see Table 14 in Appendix 3). Productivity declines after the treatment in both size groups, but it is larger and statistically significant only for the firms with 50–249 employees. Productivity growth declines 4–5 per cent annually over a three-year period. This might indicate that medium size SMEs invest more clearly in R&D by hiring new employees for the project. The results on small SMEs show no significant effect on productivity.

5.4 The estimation results for special groups

5.4.1 Firms that reported productivity growth on the Tekes questionnaire

The first special group under examination consists of firms that answered the "three year after" -questionnaire and reported a positive productivity impact (firms that reported a remarkable or some impact on productivity). We compare these firms with other Tekes customers and with all other firms. Firms that reported a positive impact experienced faster productivity growth than other funded firms (Figure 32). However, this is not due to subsidy. When firm selection to the subsidy program is taken into account, productivity growth has developed somewhat similarly between the groups (Figure 33). Compared with other Tekes customers and all other firms, results show no significant difference. Still, the CDID results turn positive after the treatment faster than in the aggregate results shown earlier (see Appendix 3 Table 12).

It should be emphasised again that these results do not indicate that Tekes-funded firms did not experience a productivity growth after the R&D subsidy. These results imply that other factors explain the productivity growth better than the public subsidy.

Figure 32. Without controlling the selection, the average productivity of firms that reported productivity growth after Tekes funding compared with other Tekes customers, unweighted average, normalised to 100 in the matching year.

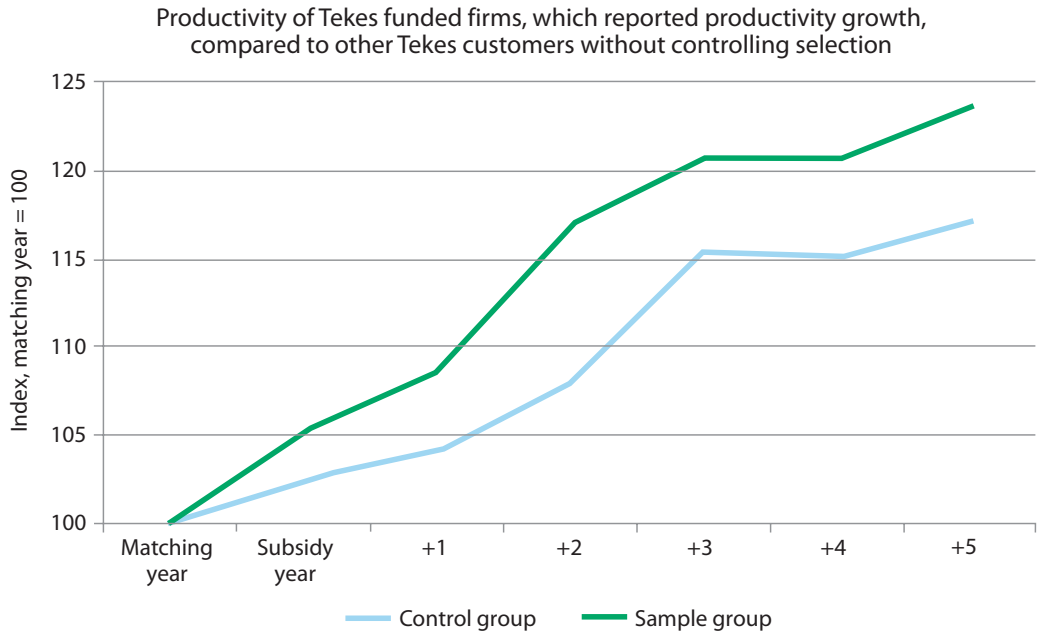
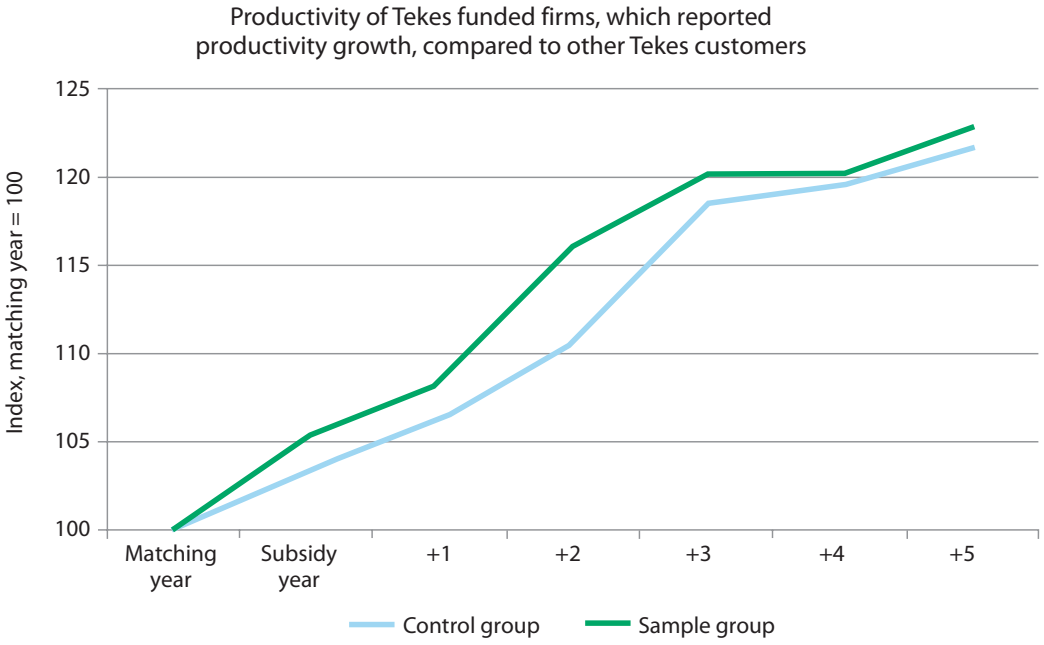


Figure 33. The average productivity of firms that reported productivity growth after Tekes funding compared with other Tekes customers, unweighted average, normalised to 100 in the matching year.



5.4.2 Young Innovative Enterprises

Young innovative enterprises are R&D-intensive SMEs (with a documented R&D spending more than 15% of turnover) that have applied and qualified for the NIY-funding. During the years 2002–2009, nearly 450 young innovative enterprises were established or developed with the help of Tekes funding.

As the sample size of the firms that receive the subsidy is now significantly smaller (in 2003, there were only six firms in this group, whereas 22 firms received this funding in 2009), we constrain the examination to the two-year period after the treatment (as we need before the treatment measure for productivity). Controls for education, NUTS3 region, centre region, past subsidies and industry were also dropped because otherwise, the selection estimator would not converge. This sample also includes firms with 3–10 employees to increase the sample size.

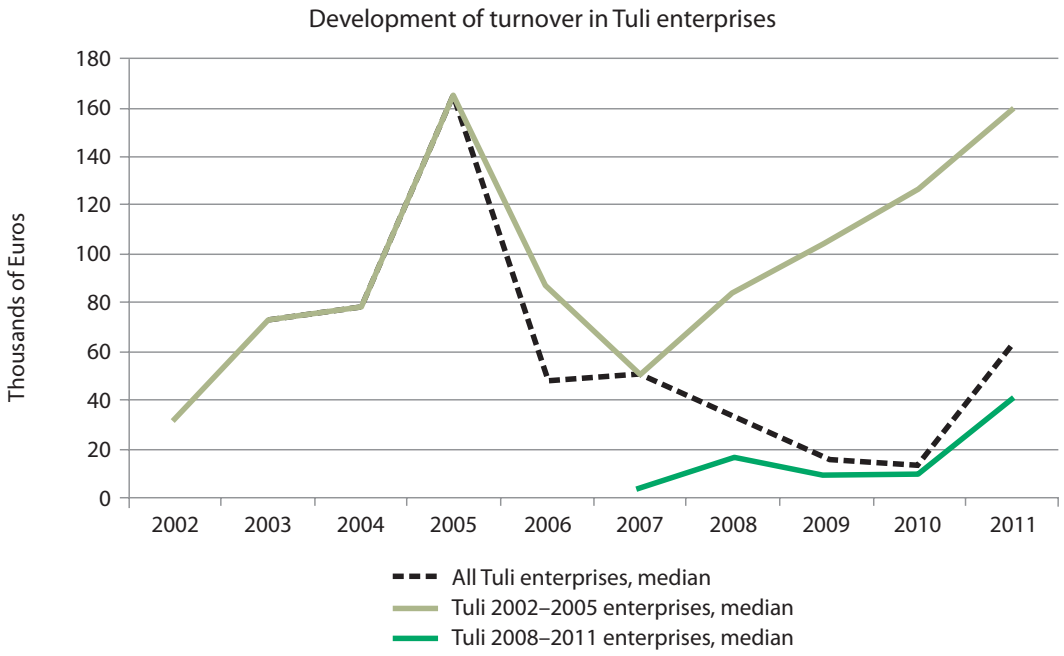
The productivity growth of the young innovative firms seems to be significantly higher in the two-year period after the subsidy compared both with all other firms and other Tekes-funded firms (Results in Table 13 in Appendix 3). However, the effect is not statistically significant. Of note, we do not control for the employees' education or past subsidy; therefore, it is highly likely that these estimates are significantly biased upwards.

Unfortunately, the small sample size prevents from drawing any certain conclusion to this small group of firms. Yet, the results indicate that Tekes funding has a positive productivity impact on young innovative enterprises. It is also notable that, unlike the entire sample, there is no decline in productivity after receiving the subsidy.

5.4.3 TULI enterprises

Productivity analysis is not available for the TULI enterprises. However, analysis regarding turnover and personnel development is provided. The following graph illustrates the development of turnover in TULI enterprises. The shape of the graph for

Figure 34. Development of turnover in TULI enterprises.[110]



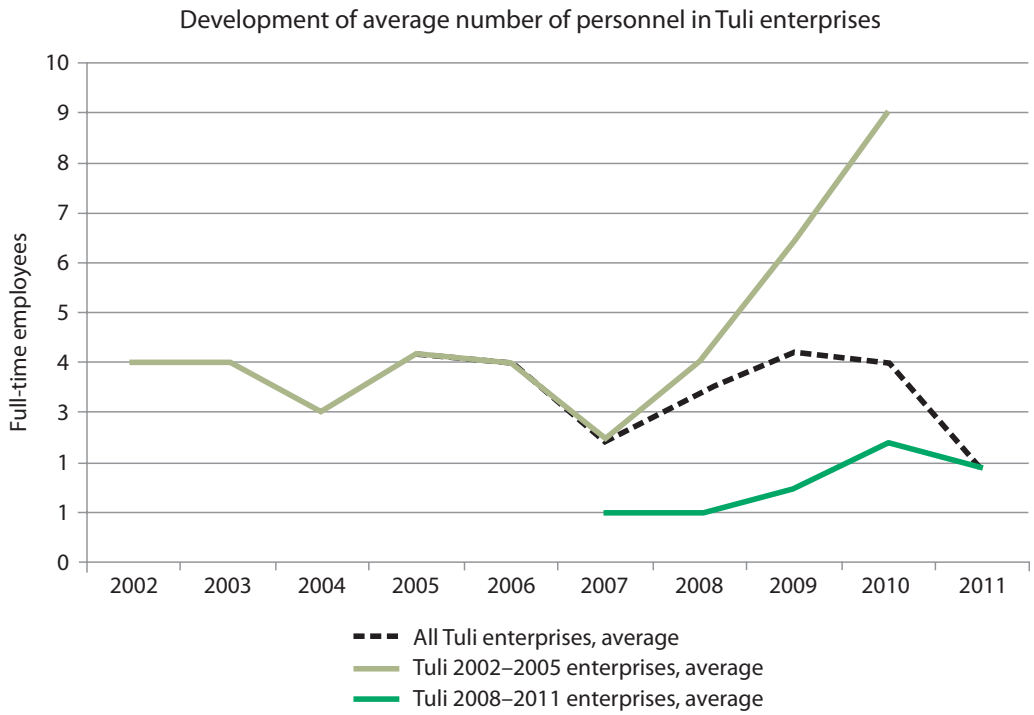
[110] Source: Asiakastieto's Voitto+ database

the first period is explained by the changing number of companies. During 2002, two enterprises reported turnover. In 2005, there were nine enterprises, some of which were already three years old and on a growth path. Examining the scales, much of the variance can be attributed to regular business cycles and the scale of turnover is rather low, which means that having a 'good year' or a 'bad year' is instantly visible as a large difference.

Interestingly, the growth trend starting in 2007 is also mirrored by the increase in personnel. The investments in personnel indicate that although the spike in turnover in 2005 is merely a fluke, the enterprises established in the first TULI period have grown more seriously since 2007.

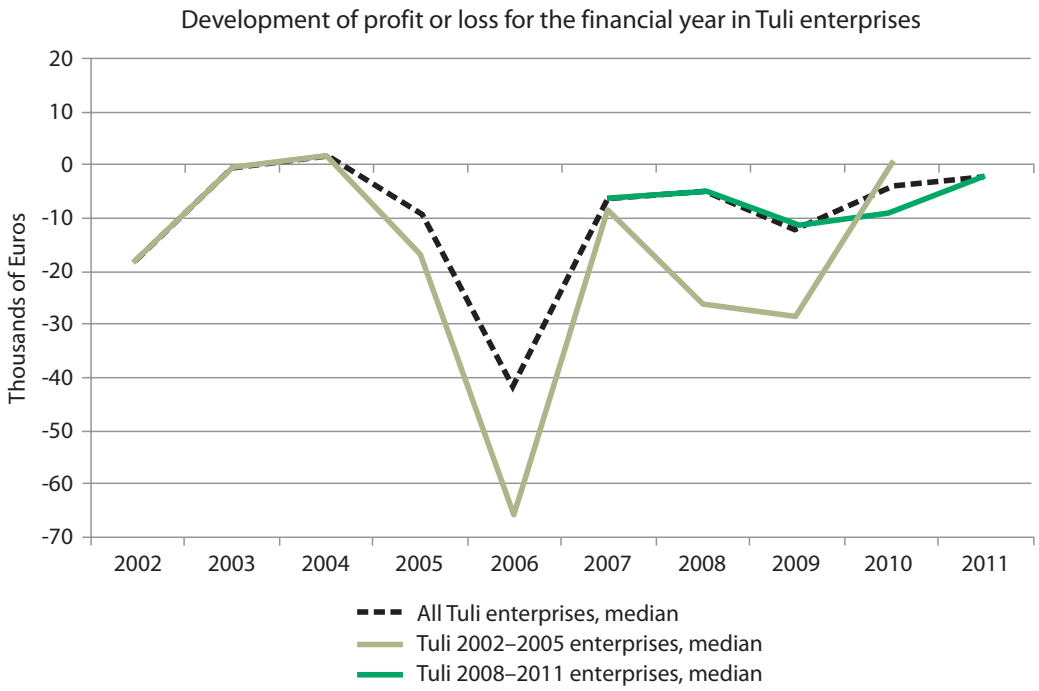
Although not a direct measure of productivity, TULI enterprises had been, on average, unprofitable up until 2010. Together with the growth in employment and turnover, this signals that the earlier period enterprises have been investing into R&D and business development and are entering the expansion stage in their life-cycle.

Figure 35. Development of average number of personnel in TULI enterprises.[111]



[111] Source: Asiakastieto's Voitto+ database.

Figure 36. Development of profit or loss for the financial year in TULI enterprises.[112]



5.4.4 High-growth companies (Gazelles)

For the high-growth companies, estimations of Tekes funding impact on productivity are not available. The gazelles are companies that reach an annual growth of turnover of at least 20% for three years in a row. The number of gazelle enterprises has decreased from the beginning of the decade, and 351 gazelles received Tekes funding in 2010. The number of gazelles financed by Tekes has closely followed the national trend of the number of gazelle enterprises.

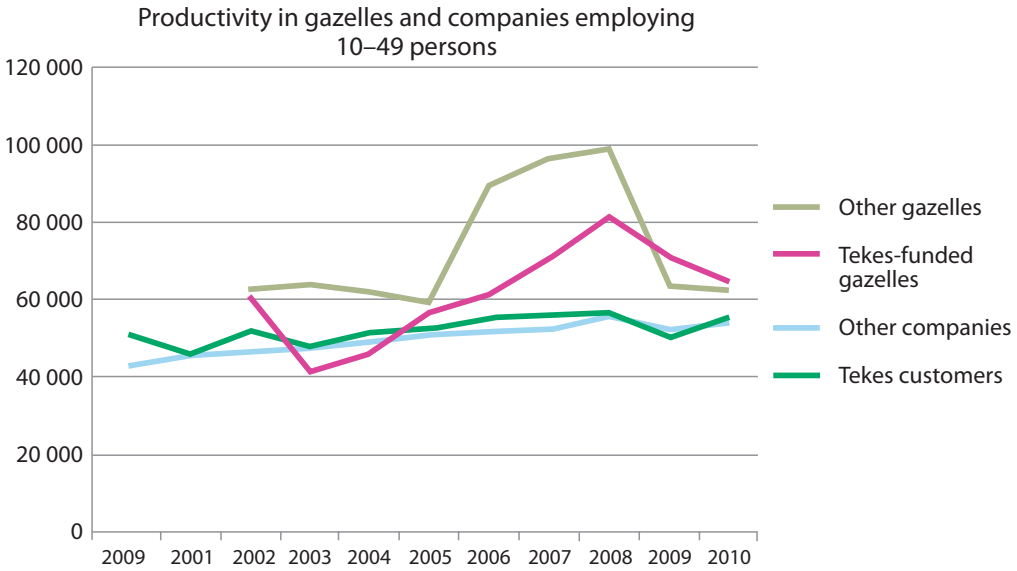
Although a single gazelle grows at a fast pace annually, the average number of employees working for the gazelles has decreased during the past ten years. In 2010, the typical gazelle financed by Tekes employed fewer than 20 full-time employees while the average number of all gazelles was less than five employees. The same is valid for the average turnover, which has decreased in both gazelles that have received Tekes funding and all other gazelles based in Finland. The decrease in both average number of employees and turnover indicate that the average gazelle does not grow for a longer period of time and that the population of gazelles changes constantly, as smaller firms replace larger firms that are not able to grow at the 20% pace. In the following analysis, the "comparison group" of other gazelles has been weighted using the number of full-time employees to produce comparisons that provide information on the productivity development rather than the size differences of the companies in the interest groups.

The average productivity development of gazelles has recently been rather volatile to changes in the economic environment. Both gazelles that have and have not received Tekes funding[113] were able to improve their productivity until the year 2008, which represents the peak year of productivity in the period 2002–2010.

[112] Source: Voitto+ database.

[113] The group of companies that have not received Tekes funding has been weighted using the amount of full-time employees in the comparison.

Figure 37. Development of productivity in gazelles and other enterprises.[114]



In comparison to all SMEs, the productivity of other gazelles has developed along the same trend, although with more variance, whereas the Tekes-funded gazelles' productivity has declined seriously compared with others. However, it is difficult to draw conclusions about gazelles because the population changes constantly as companies grow and mature. Therefore, one cannot determine how the individual company histories have developed. However, the Tekes-funded gazelles appear to invest more heavily than others. The project self-evaluation database did not include gazelles, which may suggest that the Tekes-funded gazelles are subject to instruments other than R&D project grants or have not responded to the self-evaluation.

5.5 Results based on the location of the firm

Estimations were also conducted separately for the firms that are located in the regional centre and those that are located outside of regional centres. The regional centre is defined as centre municipality of the NUTS3 region, with the exception of Uusimaa, where the whole Helsinki capital region is classified as a centre.

This disaggregation affects the result significantly (Figure 38). Firms that are located in a regional centre experience a decline in productivity growth after receiving the subsidy, but the decline is not statistically significant. After three years of the treatment year, the subsidy effect on productivity growth becomes positive, and five years after the treatment, the effect on productivity growth is 5 per cent (see estimation results in Table 15 in Appendix 1).

The results are strikingly different for firms that are located outside of the regional centre (Figure 39). These firms experience a significant decline in productivity growth because of the subsidy, and the negative effect is relatively persistent. One year after the treatment, the negative effect is 4 per cent. Four years after the treatment year, the productivity decline remains negative in comparison with other firms (See Figure 39). As a robustness check, the NUTS3 region of the capital region was dropped (Uusimaa), but this had only a slight effect on the results.

[114] Source: Statistics Finland.

Figure 38. The average productivity of firms that are located in regional centres after Tekes funding compared with the control group, unweighted average, normalised to 100 in the matching year.

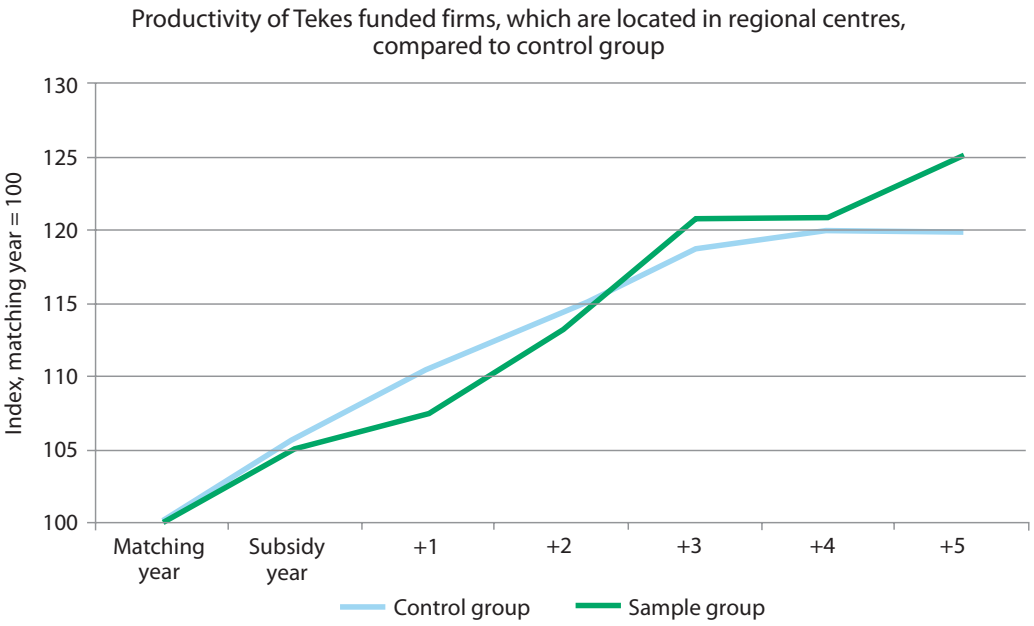
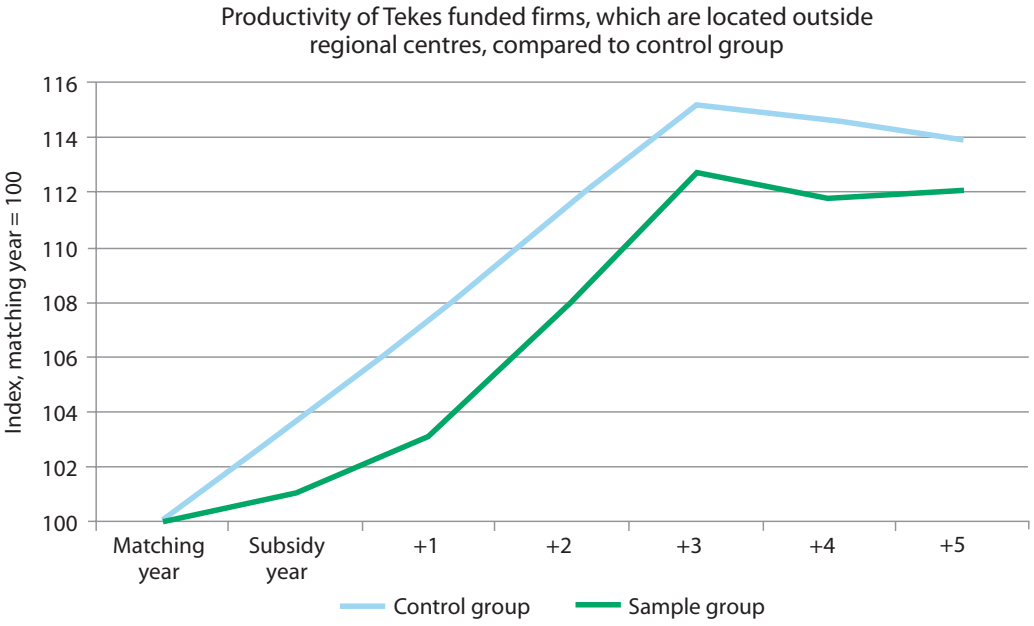


Figure 39. The average productivity of firms that are located outside of regional centres after Tekes funding compared with the control group, unweighted average, normalised to 100 in the matching year.



There are multiple explanations for why the subsidy seems to have a larger positive effect on productivity growth in the central regions, which might complicate our interpretation of the causal effect. First, it might be easier to select the most productive firms for the subsidy program if the firm is located in the central regions (thus, positive selection bias). By contrast, the firms that are located outside of the regional centre might have lower than average productivity in the region (thus, negative selection bias).

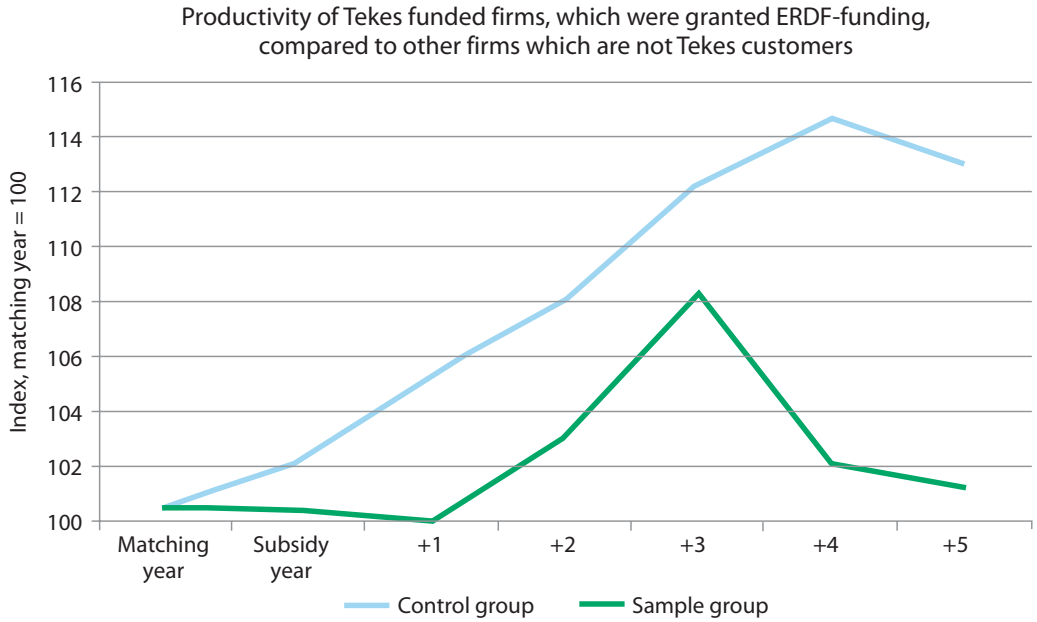
Second, earlier empirical research has shown considerable regional differences in firm productivity related to regional differences in firm renewal (e.g., "creative destruction"[115]). If this is true, then the results might be partly driven by the fact that we only observe firms that survive the five-year period after the subsidy (we are using balanced data). Competition in the regional centres is higher and non-productive firms in these regions might have exited from the sample at a higher rate.

Third, there is evidence that R&D might cause higher returns on the central regions where the distance from most productive firms[116] or distance from technological frontier[117] (Lehto et al., 2010) is smaller. Due to the limited resources, in regions outside of centres, the ambitious R&D projects may less often end successfully.

One reason for more negative results for firms outside of regional centres could be that funding from European Regional Development Fund (ERDF) has a different impact than normal Tekes funding. The criteria for ERDF funding differ from other Tekes funding schemes. This possibility was checked in the present study.

The estimation results for ERDF are strikingly different from the aggregate results. Productivity growth has been considerably lower in firms that received ERDF funding (Figure 40). The results in Appendix 3 in Table 14 indicate that conditional to our matching variables, the subsidy has affected

Figure 40. The average productivity of the treatment group and the control group, unweighted average, normalised to 100 in the matching year.



115 Böckerman, P. & Maliranta, M. (2007). The micro-level dynamics of regional productivity growth: The source of divergence in Finland. Regional Science and Urban Economics 37, 165–182.

116 Piekkola, H. (2007). Public Funding of R&D and Growth: Firm-Level Evidence from Finland. Economics of Innovation and New Technology 16, 195–210.

117 Lehto et al. (2011).

productivity growth negatively when compared with other Tekes customers and other firms. However, it is likely that firms that participate in ERDF program are selected to the program according to background factors, which we cannot observe in our econometric assessment. If there is a factor that correlates strongly with the R&D subsidy and explains why productivity growth in these firms is low, then the observed negative effect of subsidy also reflects this factor.

The ERDF funding does not, however, cause the negative result for firms outside of regional centres. The estimation results do not change significantly when ERDF-funded firms are excluded from estimation. Due to the *small number* of ERDF-funded firms, their influence is limited.

5.6 Summary of the findings on productivity

The econometric analysis examines the causal effect of public R&D subsidy on firm productivity. Although the Tekes-funded firms have faster than average productivity growth after the R&D subsidy, this is not caused solely by the subsidy. The subsidised firms might begin with better productivity growth potential. To minimise this selection bias, we use a combined matching and difference-in-differences method (CDID). With this method, the productivity of each Tekes-funded firm is not compared with an average firm, but with a control group that is as similar as possible.

The results show a clear selection bias upwards in the productivity estimates when firm-specific R&D potential is not controlled in the matching estimation. Firms with a good deal of R&D personnel are more likely to receive Tekes funding than average firms. Furthermore, the number of R&D personnel affects positively the productivity growth. Thus, the firm's own R&D effect must be separated from the subsidy effect.

After controlling the selection bias, it can be concluded that five years after Tekes funding, the productivity of funded firms does not significantly differ from that of the control group. Directly following the subsidy, the productivity declines 3–4 per cent compared to the control group. This is expected and follows when firms invest in R&D. Afterwards, funded firms catch up and the productivity effect turns to slightly positive after five years, but their productivity is not statistically significantly different from that of other firms.

In addition to the whole population, the analysis is repeated with sub-groups. The main result from this disaggregation is that the effect of the Tekes funding is conditional to the location of the firm. Firms that are located in regional centres experience statistically significant faster productivity growth than the control group. Five years after the subsidy, productivity has grown approximately 5 per cent more in the Tekes-funded group in regional centres than in the control group. By contrast, firms that are located outside of the regional centres experience a deeper and long-lasting decline in productivity (3 per cent cumulative productivity growth difference over a four-year period after the subsidy).

The subsidy effect is also conditional to firm size. The results for small firms seem to be slightly more positive than those for medium-size firms. The initial productivity decline is small and not statistically significant for small-size firms, whereas medium-size firms have larger, longer-lasting and statistically significant initial productivity decline. In addition, smaller firms have experienced faster productivity growth compared to control group after five years than medium-size firms. However, the productivity growth difference compared with the control group is not significantly different from zero.

We also studied three special groups, "Young innovative firms", firms that reported a positive impact on productivity in Tekes "three years after" questionnaire, and firms that received funding from European Regional Development Fund (ERDF).

The results indicate that subsidised young innovative firms have much faster productivity growth than other Tekes customers or other firms. The difference is not, however, statistically significant. It is also likely that the results are biased upwards, as it is not possible to control all necessary variables. Unfortunately, the small number of young innovative firms makes it difficult to draw any firm conclusions.

Firms that reported a productivity effect in the questionnaire did not experience a productivity decline or a productivity growth that is significantly different in comparison with other Tekes customers or other firms. These results are likely not affected by sample size, as the point estimates are only marginally positive. Although productivity growth might have been high for these firms, we find no evidence that this is due to the subsidy. This indicates that one should seriously consider the selection problem.

The firms that received ERDF funding seem to have significantly slower productivity growth five years after the subsidy year, compared with other Tekes customers or other firms. However, it is not clear that the subsidy causes the slow productivity growth. There might be some unobserved factors that coincide with the subsidy and explain the slow productivity growth.

Two additional special groups, TULI enterprises and high-growth companies, were also examined. However, for these companies, there were no econometrics analyses to test the impact of Tekes funding. They are, as are young innovative firms, small in number and in a phase of the life-cycle in which productivity cannot even be expected to be high. They are investing in growth and R&D, and the product launch is only in its early stages or to be expected in the future. In the case studies, we found that two TULI enterprises were in the R&D stage around ten years before a product launch.

The results of estimations should be interpreted with the caution. There are multiple limitations to this study that can affect the final conclusions. First, we observe only the firms that have survived over a five-year period after the subsidy, which likely biases the results upwards (as the productive firms are the survivors). There is likely a bias in both the funded and control groups, but not necessarily equal bias. Second, we study the productivity effect of the subsidy over a five-year period. However, productivity effect may appear later. It is more difficult to show causality with a longer lag.

Third, in this study, the econometrical approach assumes that there are no externalities from R&D subsidies. If there are externalities, then the estimations are biased downwards, which might explain the low estimates. This is also crucial limitation of the study because externalities from R&D subsidies are the main justification for the subsidies. This analysis does not provide information about these externalities. Thus, additional research is needed before conclusions can be made. Unfortunately, externalities from R&D subsidies are difficult to estimate.

The other justification for public R&D subsidies is the imperfections in the capital markets. In a case of grave capital market imperfections, empirical results should show higher productivity growth at the firm level due to the subsidy. The current study found little evidence of this.

The conditionality of the subsidy effect on the firm's location raises questions of the effectiveness of the subsidies. The negative effect of subsidy on outside of regional centres is a disturbing finding.

The result indicates that funding could be harmful for productivity for some firms. This could be due to several reasons. It could be related to the intensity of completion, less productive firms survive outside centres, or it could be related to capacity to innovate. It may be more difficult to raise resources for the innovation process in peripheral regions, and an ambitious innovation project could choke an ill-prepared organisation. More research should be conducted on this subject before any conclusions for the funding policy can be made.

6 Summary of findings and recommendations

6.1 Summary of the literature review

In general, public R&D incentives have a positive effect on the volume of private R&D. There also seems to be a link between R&D and productivity, although there is much uncertainty and heterogeneity between firms.

The few studies that also look at the changes in productivity demonstrate mixed results regarding the role of public R&D subsidies. The results also vary in terms of how much of the productivity gains are direct results and how much is gained through spillovers.

The results regarding the type of instruments and the type of recipients are also somewhat mixed. Overall, in many cases, SMEs' growth is more typically observed than an increase in productivity. In large companies, spillover effects seem to be more important than the direct impact on productivity. There is also some indication that direct R&D incentives may be more effective than indirect instruments, such as tax incentives.

Because these various funding channels exist, it is clear that evaluating the aggregate effect of public R&D support is difficult. In addition to the different intervention logic between the instruments, there are different effects of public R&D support on firm R&D according to various firm- or industry-specific characteristics. The empirical analysis in the present study also reveals the following observations:

- Public support has a **complementarity effect** on private R&D for firms
  a. with low technological competence
  b. in industries with high technological opportunities and for firms facing intense market competition
- Firms with high technological competence and firms that have enjoyed fast demand growth in recent years show a **crowding-out effect**.

However, despite several studies, the link between public R&D subsidies and productivity remains somewhat ambiguous. This is partly due to bias in the samples of firms and differences in the various instruments. Many studies on the connection between R&D and productivity seem to have been from the manufacturing sector and established firms. When examining SMEs and/or young companies and the service sector, the picture becomes more complicated. This has much to do with the fact that in small firms and technology-intensive firms, the investment in R&D may consist of a rather large investment at the same time when there might not be any existing markets for the services or products. As a result, the short- or even medium-term effect of R&D on the productivity may be negative (although it is expected to be positive in the long term).

It is also important to note that publicly funded R&D projects are not a one-time affair for many firms. According to Koski and Tuuli (2010), there are strong continuities in participation both within and between different public support programmes and the firms that have once entered the subsidy system actively seek further support from the same organisation and other public agencies.[118] Therefore, in some cases, it is difficult to distinguish the exact effect of each public intervention.

[118] Koski & Tuuli (2010).

6.2 Firm-specific analysis and Tekes main target groups

6.2.1 Renewal

As discussed above in the conception of renewal, Tekes funding can contribute to renewal at the firm level by enabling the development of existing business, diversification and internal processes. Renewal can be additionally approached through changes in industry structures through the creation of new enterprises and markets/industries.

Considering the average self-evaluation of the R&D projects, there is a marked impact on value added, product quality, innovativeness in processes and collaboration with other enterprises. There is a clear product/service focus, but operational innovativeness and flexibility and continuing operational improvement are among the top impacts. NIY firms have recorded, on average, a significant positive effect on founding a new business area. However, the average enterprise's perception of impact is slightly positive. In fact, the enterprises seem to be able to extract relatively little value from individual R&D projects. For average SMEs and large enterprises, the effects of the individual projects are consistently below significant, which is consistent with the relatively small productivity gain. One can interpret that the average project is either a relatively minor incremental innovation project or a risk project that did not "hit to the bull's eye" within three years of project completion. In both cases, the success stories are hidden in the average project. Reflecting on the cases, one of the companies initiated an R&D project to diversify the customer base by varying its core product, but it became apparent that diversification of business was not possible at the given time. Although the project did not result in a product or service with net cash flow, it was a learning experience and, thus, worthwhile for the enterprise.

The main externalities to economic life, as reported by the project managers, are deeper relationships with public institutions and other enterprises, turnover in other firms, value added and product development in other firms. This suggests that networking is indeed facilitated by the projects. However, the effects are not remarkable. Again, NIY-funded enterprises are ahead of others, followed by TULI enterprises. SMEs and large enterprises are on the same level in relation to externalities. The externality of turnover in other firms suggests that either the R&D projects are co-developed with partners' product for mutual advantage, or that suppliers or contractors will have benefitted from the projects. The main social externalities seem to be increase in the national know-how, which can also translate to knowledge spillovers through reportedly increased networking between enterprises, internationalisation of innovation activities, employment and entrepreneurship. However, the average externalities are quite small and should be interpreted with caution, as they are given by project managers of the R&D project. These findings indicate that Tekes funding may also have effects in the form of positive externalities such as learning and knowledge exchange, which are not observable in the current analysis.

The Tekes special interest groups (SMEs, NIY enterprises and TULI enterprises) gain, on average, more value added from Tekes-funded projects than the 'baseline' large enterprises. Especially NIY and TULI enterprises see a significant impact on dimensions regarding technology and product quality and productivity. A general feature of Tekes-funded enterprises is that they are larger in terms of number of employees and volume than SMEs on average.

Pulling the case finding together with the other data, it appears that many of the Tekes-funded R&D projects have little behavioural additionality according to the enterprises' report. However, some special groups, particularly the New Innovative Enterprises, show significantly better results compared with the average. In the case of NIY enterprises, three out of five productivity-raising projects and nine out of ten of the others did not have significant additionality.

Regarding the impact of funding on behavioural additionality, there seems to be a clear distinction between early stages of the enterprise life-cycle and the established phase. In the start-up phase, the knowledge and technology base are relatively concentrated and product variety is narrow. The view is that Tekes R&D funding does not steer the path of development, but rather enables its development to the fullest potential. However, it was noted that business development funding had an effect on market knowledge and, therefore, a supposed indirect effect on the R&D path.

For more established firms, R&D funding seems to have more of an effect on diversifying the knowledge base by enabling the development of knowledge outside of the current core. Considering company D, which represents an established medium-large enterprise, there are relatively clear signs of behavioural / 2nd order additionality in the form of introduc-

tion of new thinking and management practices and output additionality in the form of new technologies and products as well as production processes and systems. One of the main effects seems to be that R&D funding enables more profound and rapid development of new technologies, which opens new business possibilities. Additionally, the R&D projects have broadened the use of outside expertise and networks and created partnerships.

As for the internationalisation of enterprises, Tekes funding supports networking nationally for enterprises that are inclined to do so in the first place. Especially the NIY funding and in one case TULI-funding was used for international networking and market development, which was viewed as an important factor in business development. However, Tekes R&D grant terms and conditions do not enforce networking. In one case, it was found that in direct comparison with EU FP7, Tekes funding has a less direct impact on international networking or internationalisation.

It seems that start-up and small enterprises are able to extract the most benefit or additionality from 'general budgetary support'–type instruments and funding that supports market studies and business development such as the NIY instrument and venture capital investments. They seem to have the minimum of overhead and maximum business impact. Overall, the NIY-funded companies state that it has enabled a market presence, which has had a significant effect on the development of the business. The specific additionality of NIY and TULI instruments seems to be that they enable the development of market and customer insight during early research and development, which improves reception of the products when ready. The funding also seems to have a general enabling component, as the funding improves the financial position of the firm, which enables the recruitment of new talent.

The question of additionality also concerns serial funding. The first-time-funded enterprises learn most from their projects, at least in terms of behavioural additionality. That proposition is not directly supported by the cases. Although NIY more often reported that their R&D had an impact on internal processes as others, case enterprises of all sizes and project numbers report that the R&D projects have had an effect on their internal processes. Case D, a large company with multiple sequential projects, reports the best results from the last projects, which may suggest a decreasing marginal behavioural additionality from multiple projects, but the output additionality tends to cumulate over multiple projects.

6.2.2 Productivity

The econometric analysis of productivity examined the causal effect of public R&D subsidy on firm productivity. To minimise selection bias, combined matching and difference-in-differences method (CDID) was used. With this method, the productivity of each Tekes-funded firm is not compared with average firms but with a control group that is as similar as possible.

The effect of Tekes funding is ambiguous when considering the whole population; however, examination of disaggregation analysis provides greater insight. The main result from disaggregation is that the effect of the Tekes funding is conditional to the location of the firm. Firms that are located in regional centres experience statistically significant faster productivity growth than the control group. Five years after the subsidy, productivity has grown approximately 5 per cent more in the Tekes-funded group in regional centres than in the control group. By contrast, firms that are located outside of the regional centres experience a deep and long-lasting decline in productivity (3–4 per cent cumulative productivity growth difference over a four-year period after the subsidy). Consistently, the enterprises that have received consolidated ERDF funding from Tekes exhibit similar impacts.

The subsidy effect is also different conditional to firm size. The results for small firms seem to be slightly more positive those for medium-size firms. The initial productivity decline is small and not statistically significant for small-size firms, whereas medium-size firms have larger, longer-lasting and statistically significant initial productivity decline. In addition, smaller firms have experienced faster productivity growth compared to the control group after five years than medium-size firms. However, the productivity growth difference compared to the control group is not significantly different from zero.

We econometrically studied three special groups of firms. Two of these groups answered the Tekes "three years after" questionnaire, firms that are classified as "Young innovative firms" and firms that reported a positive impact on productivity. The third group under evaluation received funding from European Regional Development Fund (ERDF). In addition, two other groups, TULI-companies and fast-growing companies, were studied with complementary analysis.

The results indicate that subsidised young innovative firms have much faster productivity growth than other Tekes costumers or other firms. It is, however, likely that results in this

case are biased upwards, as it is not possible to control all necessary variables. In total, there are too few observations over time to make any robust estimation for this group. When considering project self-evaluations, NIY-funded enterprises are able to extract more value than other enterprises from their R&D projects, almost reaching and, in some cases, exceeding marked impact on nearly every dimension.

The ERDF funding seems to have slower productivity growth after five years compared to control group. However, the difference is not statistically significant and the problem here is also small sample size, as we have information only on the firms that answered the questionnaire and had received ERDF funding.

Firms that reported a productivity effect in the questionnaire did not experience a productivity decline or a productivity growth that is significantly different from other Tekes customers or other firms. Although productivity growth is high for these firms, we find no evidence that this is due to the subsidy.

The estimation results for ERDF are strikingly different from the aggregate results. Productivity growth has been considerably lower in firms that were given ERDF funding. The subsidy has negatively affected productivity growth when compared with other Tekes customers and other firms. However, it is likely that firms that participate in ERDF program are selected to the program according to specific background factors, which we cannot observe in our econometric assessment.

The effect of Tekes funding on productivity has been investigated previously, and the effect of funding has been more positive and larger. As discussed, the previous studies have not controlled for R&D intensity or other firm-specific factors as carefully as in the present evaluation. The results show a clear selection bias upwards in the productivity estimates when firm-specific R&D potential is not controlled in the matching estimation. Firms with a significant number of R&D personnel are more likely to receive Tekes funding than average firms, and the number of R&D personnel affects positively the productivity growth. One interpretation is that while Tekes-funded firm exhibit faster than average productivity growth after the R&D subsidy, this may be because the enterprise has better capabilities than the next one rather than the subsidy. The subsidised firms may begin with better productivity growth potential. Another interpretation is that the Tekes funding process works effectively by selecting the firms that are most prone to gain benefit from the funding.

We learned that Tekes typically chooses to fund companies with highly educated personnel, i.e., they invest in the 'best team' to implement the proposed project. It is puzzling that the R&D intensity has not been realised as stronger growth or productivity than other enterprises of the similar size and resources. The attention turns immediately to the large difference between enterprises located in regional centres versus peripherally located enterprises. When the whole enterprise population is examined, the negative impact on productivity in peripheral enterprises cancels out the positive impact on regional centres. However, there are at least two plausible additional explanations elaborated below.

Regarding the productivity of firms belonging to the special interest groups, it seems that Tekes-funded gazelles and NIY-funded enterprises are less productive than the enterprises in general. We hypothesise that R&D has an impact on the productivity and can be viewed as an investment. In the case of gazelles, we do not know the history and life-cycle phase of the enterprises; therefore, examining average yearly productivity might not provide much insight on how individual firms develop. For example, if we consider the cumulative productivity of NIY enterprises versus yearly average productivity, they begin from negative productivity the year that they are established and catch up with other enterprises after some years, all while the average yearly productivity of NIY enterprises seems to be declining. The case studies and analysis of productivity in NIY-funded enterprises suggest that Tekes-funded SMEs invest strongly in R&D activities, which may indicate that the full commercial potential has not been realised. This would explain lower productivity as a feature of the growth/investment stage in the enterprise life-cycle. Thus, the question of when the investments will turn to profit is difficult to answer. In the case studies, we found that two TULI enterprises have been in R&D stage around ten years before the product launch. The same pattern is found in the productivity of NIY-funded firms, as the productivity of those enterprises is below both ordinary SMEs and other Tekes customers for the first 5–7 years, developing steadily upwards.

Another plausible explanation is that Tekes funding has enabled enterprises to upgrade their productivity. The non-Tekes-funded enterprises have had to gather private and public equity funding and/or debt financing to enable their operations. Because equity investments are scarce, and assuming that they are risk averse as well, we may assume that the firms in the control group are the most apparent front runners in

their fields. The cases seem to indicate that at least some enterprises use Tekes funding as leverage to obtain private equity, if not directly as a substitute. Thus, we may speculate that Tekes funding has enabled some of the rougher gems to be cut into shape and upgrade their productivity to match their privately funded counterparts.

Thirdly, if we examine the quantitative analysis and especially the disaggregation analysis, we observe that the location of the enterprise has a significant effect on productivity. Although we cannot determine the exact reason based on the current data, we hypothesise that this may be because of the selection problem or because of more intensive competition and/or network/spillover effects on regional centres. In practice, less productive firms exit faster in regional centres, and those that survive potentially have more peer support and partnering opportunities within and between industries in locales with denser enterprise population. Relatedly, Tekes- and ERDF-funded enterprises were not able to raise their productivity and the evaluation of the Finnish innovation system found that ERDF funding is granted in some cases to enterprises that would not be sustainable without public funding.

6.3 Tekes' strategy, objectives and impact analysis

The literature on the impact of public R&D subsidies has discussed the so-called additionality of subsidies, i.e., R&D funding broadly. Generally speaking, the literature identifies four types of additionality, as summarised in the following table. The types of additionality can be classified according to program theory on the input-activity-output schema. The literature commonly distinguishes input additionality (the effect of public funding on private investment), output additionality (the effect of public funding on new innovations) and outcome or impact (effect on enterprise performance). More recently, the discussion has broadened to behavioural additionality that encompassed the learning and organisational changes that are attributable to the subsidised R&D projects.

The dimension of behavioural additionality opens discussion on the interplay between enterprise characteristics and the effect of R&D funding. That is, according to the literature, R&D funding has an effect on organisations that cannot be fully captured by measuring inputs and outputs in the conventional measurement time frame. In short, behavioural additionality refers to the improved capabilities of the enterprise for innovation and business development as successfully in the future.

The current Tekes strategy and impact model aim to support productivity and renewal of enterprises, with a predominance of endogenous renewal, environment, wellbeing and capabilities. The preceding discussion implies that the commitment to R&D raises the capabilities of an enterprise and provides opportunities for renewal. Impacts on environment and wellbeing seem to be small judging from the project evaluations. This seems to suggest that outside targeted programs for wellbeing and environment, the impacts come through spillovers and income distribution. Regarding spillovers, generally, the enterprises report deeper relationships with partners and contribution to the national knowledge base, as well as to internationalisation in some groups. This suggests a knowledge exchange that can result in both the absorption valuable knowledge from the network and knowledge spillover to other institutions.

At the level of activities, Tekes funding has mostly had an effect on the volume and timing of R&D. In addition, it has an enabling effect on young SMEs. To some extent, behavioural additionality can also be observed in terms of improving processes and management attention to R&D activities. In terms of the outputs, the special interest groups report that the R&D projects have had the greatest impact on quality of products, collaboration and networking with other enterprises and value added. In the case of NIY and TULI enterprises, the projects have also had an impact on internationalisation.

As discussed above, the findings beg the question of whether the observed higher performance of NIY and, to some extent, TULI enterprises is a product of their internal characteristics, the funding instruments, or both. There is evidence of both interpretations. Especially NIY enterprises are hand-picked for the programme, which suggests that they are typically good targets for funding. However, the NIYs also view that the NIY funding has specifically supported business and market development better than other instruments. NIYs also seem to gain more from the R&D projects grants that they receive than do other enterprises. TULI enterprises are a different story, but the cases suggest that TULI funding, which is similar in structure to NIY, has had similar effects on market awareness and presence.

Regarding the impact model, productivity is one of the main success measures set for Tekes. Although it is an important measure from the perspective of national economy and

competitiveness, it seems that it is not as relevant (in the short term) to Tekes special interest groups. Young, fast-growing enterprises tend to invest most of their cash flow. Before R&D is completed to the extent that they have a product and/or service to the market, in some cases this phase is up to ten years, they create little added value. In addition, although productivity arguably measures renewal of enterprises, as a sustained increase in productivity demands keeping up with competition, other measures better represent endogenous renewal. Possible measures to complement productivity are, for example, growth percentage of the enterprises, survival rate in different age cohorts, and measures of innovativeness, such as the number of spin-offs, new business areas and number of new (new-to-firm/network and new-to-market) and radical (new-to-network and new-to-the-world) innovations,.

The results of the current impact assessment suggest that the impact model of Tekes is logical and follows from the basic mission, but is perhaps missing the underlying operationalisation of the objectives to SMARTER[119] indicators and elaboration of how the different instruments contribute to the objectives. The development of intervention logics and indicators alone would enable the collection of more focused monitoring data and thus sharpen programme/instrument evaluation while making it easier and more inexpensive. Additionally, one of the main rationales for R&D funding, especially for large enterprises, is the supposed spillover to industry and society at large. Presently, Tekes monitoring at the project level does not capture data on the amount and nature of spillovers, other than the perception of spillovers from project managers through the ex-post self-evaluation questionnaire.

6.4 Discussions and recommendations

When considering the results at a glance, it may seem that the average Tekes funding intervention has a relatively small impact on the productivity and renewal of the enterprise. However, a deeper analysis reveals that Tekes funding has a significant impact on productivity and, by extension, on the renewal of firms that are well positioned to use the outputs of the R&D funding. The averages also hide the great heterogeneity among innovation projects. Although there are several projects with low observed success and, consequently, low impact, the successful projects appear to produce promising additionalities.

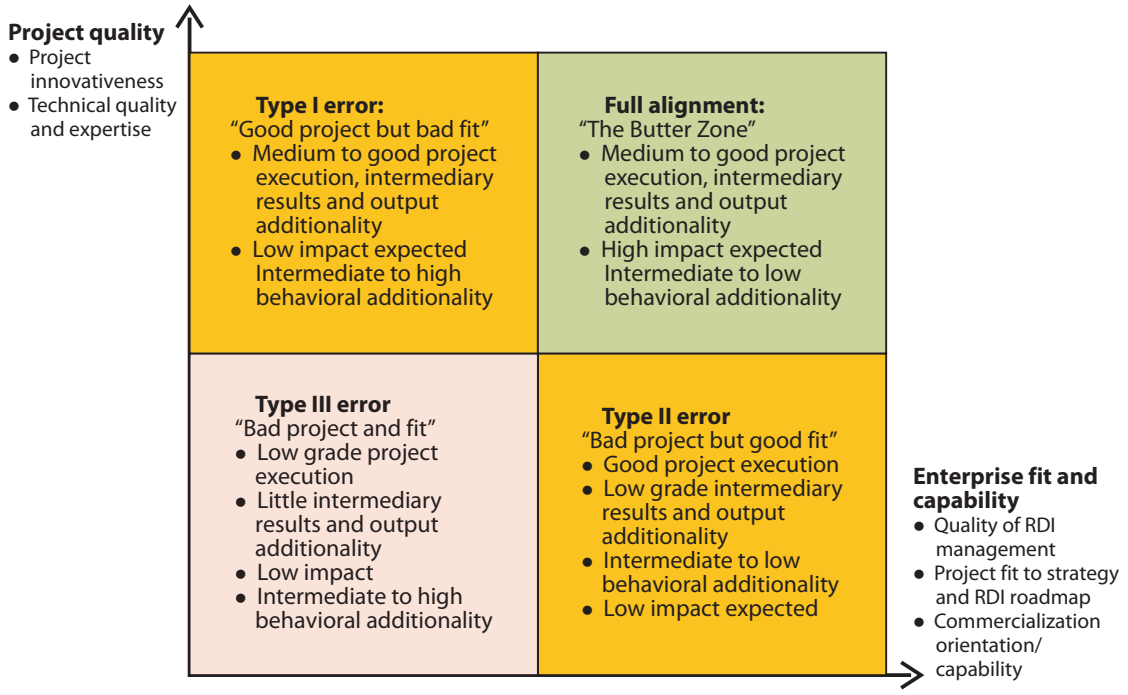
Significant factors that contribute to the effectiveness of the funding seem to be both exogenous and endogenous to the firm. The importance of exogenous factors is exemplified by the regional disaggregation of productivity analysis, as we observe that centrally located enterprises benefit more from the funding. This may be because of their better network connections, more intense competition that enhances selection, which forces weaker enterprises to exit, better availability of labour and/or stronger local demand. An examination of the special interest groups provides evidence of endogenous factors, as we observe that groups that extract more benefit out of funding interventions. Especially NIY-funded enterprises report significant impact. We hypothesise that this is because they are commercialisation and internationally oriented and the R&D projects that they undertake are aligned with business and R&D strategy. However, NIY enterprises have the benefit of public business development funding and R&D project funding, as well as typically private investments, which makes it difficult to distinguish the actual net effect of Tekes funding.

Thus, the first recommendation is for additional research that investigates why peripherally located enterprises either suffer a downright setback as a result of R&D funding or experience a significantly longer payback period than other Tekes-funded enterprises. This research could also give more definitive answers to the question of how to best steer public R&D investments for the benefit of the whole economy.

However, if we further consider the finding that the NIY enterprises are the most successful in terms of performance, one of the key differences in NIY-funding process to the R&D grant process is that NIY enterprises are evaluated as a whole during the funding decision, not solely based on project proposal or other application. This seems to be a salient point, as it suggests that the characteristics of the enterprises are a key determinant in the impact of the funding. As trite a notion as it may sound, we must concede that enterprises are not homogenous in their make-up, intentions, level of information about the markets and capabilities. Consequently, their ability to extract commercial value from R&D activities is also not homogeneous. Although this is common sense, it suggests that if one seeks maximum impact to value added from R&D funding, it is best granted to enterprises that are capable of commercially exploiting the results.

The following figure illustrates the problem space for R&D funding. The first dimension is the quality of the application, work programme and the capabilities of the consortium to

Figure 41. Illustration of problem space for R&D project funding decisions.



deliver the project. The other dimension is the fit of the project to the enterprises' strategic agenda and capabilities. These dimensions provide a two-dimensional problem space, in which the funding decision can fall into four categories, the 'right' or best decision being that the project and team are excellent and the project fits the enterprises' agenda. Given that one evaluates the project only, it will weed out Type II and III errors that lead to funding projects with little contribution to renewal. However, evaluation of the project and team will not indicate whether the project and its outputs fall onto a fertile ground for further exploitation. This may lead to Type I error, in which the project is solid as such, but may be a 'dead end' in the roadmap of the participating enterprises.

Strategic fit may be one explanation for why the large enterprises report small effects from their R&D projects. There is anecdotal evidence that, due to information asymmetries, vested interests or poor alignment with corporate or R&D strategy, R&D projects become loose ends with little immediate impact on the path of the enterprise. There are propositions that often (publicly funded) R&D projects in large enterprises grow out of the interest and drive of individuals, the literature calls this "intrapreneurship", or internal/corporate entrepreneurship.[119] However, this intrapreneurship can lead to value added only if the results are integrated into new product development and/or spin-off activity. Reportedly, Tekes-funded projects have contributed relatively little to spin-offs or entrepreneurship. Thus, the impact of the project should be realised through the product/service variety at the enterprises, which leads to projects results that lay dormant in the IP portfolio if they are not ahead in performance.

[119] E.g. Pinchot; G, 1985. Intrapreneuring: Why You Don't Have to Leave the Corporation to Become an Entrepreneur. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship. Available at SSRN: http://ssrn.com/abstract=1496196; Morris, M.H., Kuratko, D.F., Covin, J.G., 2010, Corporate Entrepreneurship & Innovation, 3rd Ed., South-Western, CENCAGE Learning, Mason OH.

To summarise, the most ambitious projects and the 'best team' for executing the project are important preconditions for the impact of R&D funding, but the actual impact realised through markets is significantly moderated by the enterprise qualities, orientation and the fit between the R&D project and strategy. In effect, the second recommendation is that to raise the tangible impact of R&D funding, the question is whether the funding candidates should be evaluated as a whole in terms of R&D management capability and fit to strategy in addition to project quality.

Reflecting the findings on Tekes' strategy, we must recognise that the data for the analysis are from the period before the present strategy, which was launched 2011. In the present strategy, the aim of Tekes activities has shifted towards SMEs, as measured by statements and allocation. Regarding the ultimate objectives of renewal and productivity, this orientation supports renewal particularly at the industry level, creating new growing enterprises. On the other hand, existing (large) enterprises are funded to enable renewal from within the enterprise with new products and services as well as business areas. Another rationale for funding large enterprises is the proposition that the subsidy provided for them is distributed through the network and the effects emerge as spillovers. Further, it is proposed that there is a 'slipstream effect' that draws the network to the international markets in the wake of the network engine.

There are two caveats to these propositions. First, if the R&D project is not attached to the strategy of the core actor in the network, the probability of the project result leading to commercialisation is relatively low and there will be no slipstream effect (see the discussion around Figure 40). Second, large incumbent enterprises are reluctant to undertake game-changing innovations to protect their carefully crafted value network and market position, as demonstrated, for example, in the SHOK evaluation.[120] By definition, this limits the impact of the R&D funding on renewal by reserving funding for sustaining projects and keeping the incumbent alive and possibly helping it reinforce a dominant market position.

Thus, we recommend that the impact of R&D funding on large enterprises is investigated with a view on how many tangible results and spillovers come from the projects and how many of them are actually new and radical as opposed to incremental innovations compared with SMEs. The question to be addressed is as follows: should the funding be directed even more toward SMEs and to new instruments, such as NIY? After all, there is ample funding for large enterprises outside of Tekes' programmes. The most notable of these sources are the SHOKs, which are largely self-governed (in practice by large incumbents) and the upcoming EU Horizon 2020 programme with a volume that surpasses any national instrument by an order of magnitude.

Finally, the findings of the impact assessment raise a question of whether productivity is the best indicator at the firm level, especially for R&D and growth intensive SMEs, at least in the short to moderate timespan. It appears that positive project results do not correlate in all cases with (short-term) productivity development in these firms. The evidence from earlier research and the current results suggests that investments in R&D and growth decrease productivity in the short term in many cases. This leads us to suggest that although productivity is a justified objective at the level of the national economy, at the firm level, growth and capability development might be more fitting (intermediary) indicators for the impact of R&D funding.

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Appendix 1. Additional data on renewal of enterprises

Figure 42. How did project affect your business? Share of firms which felt remarkable or somewhat remarkable impact on....

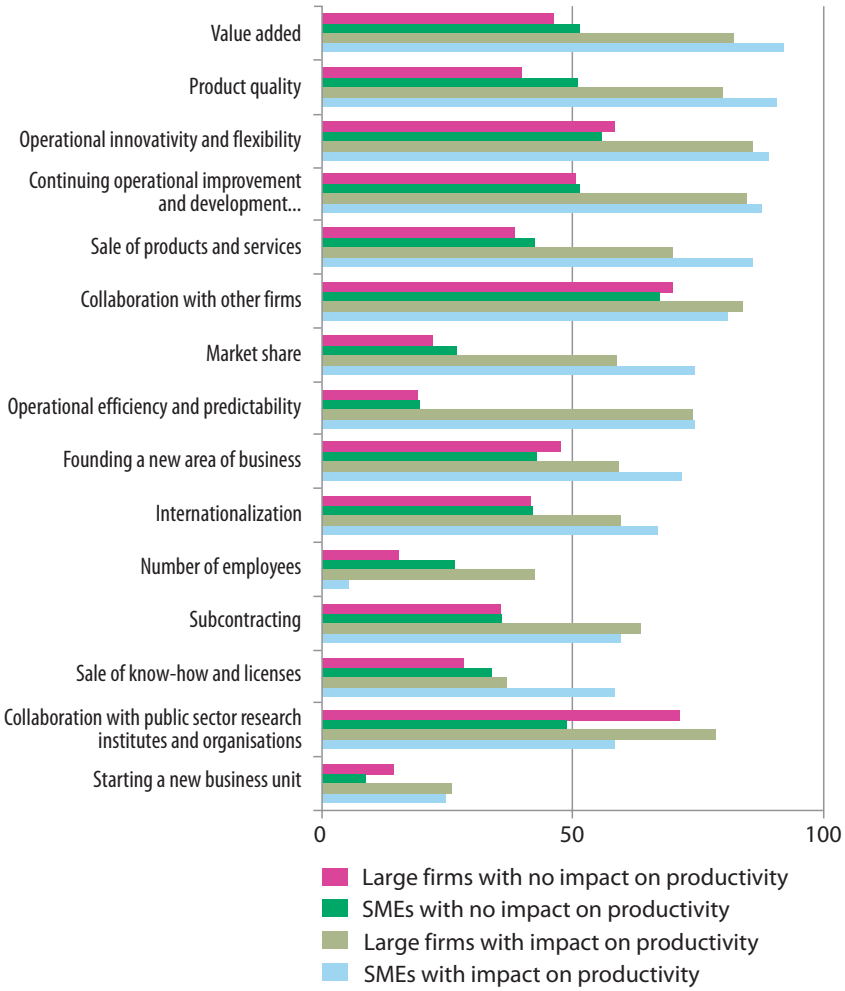


Figure 43. What wider impacts project had? (externalities in economic life). Share of firms which felt remarkable or somewhat remarkable impact on....

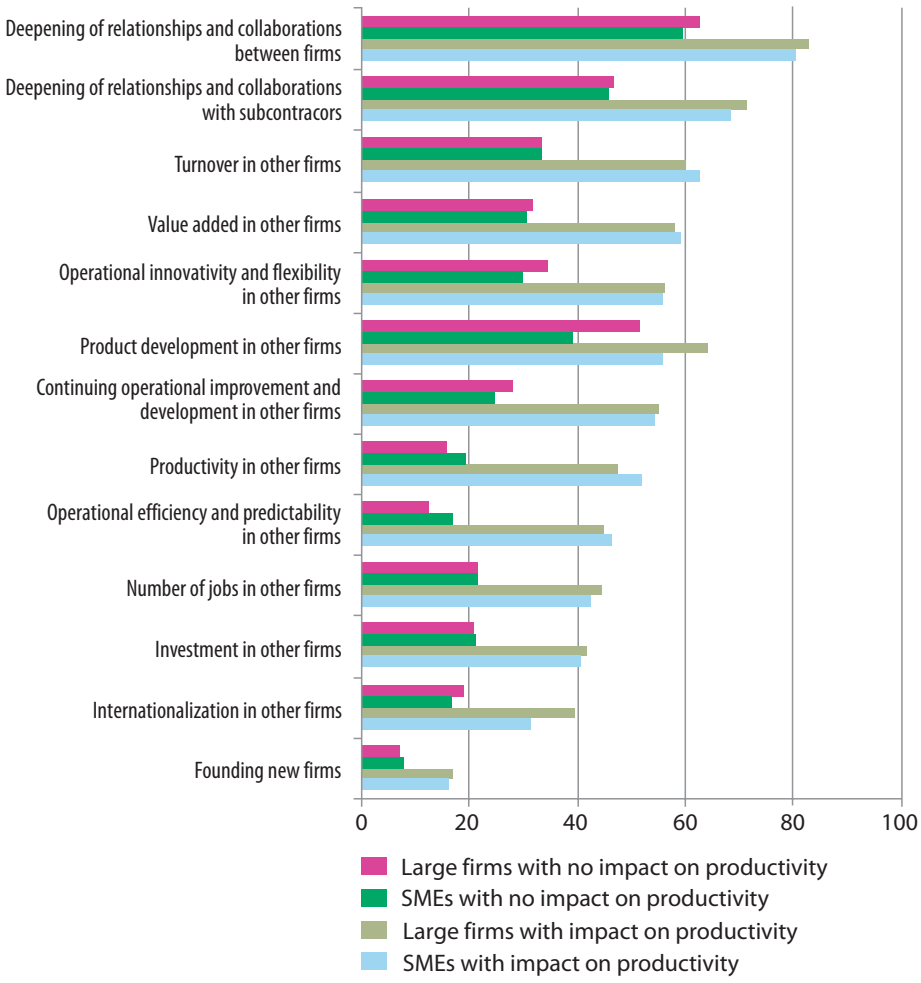


Figure 44. What wider impacts project had? (externalities in society). Share of firms which felt remarkable or somewhat remarkable impact on productivity.

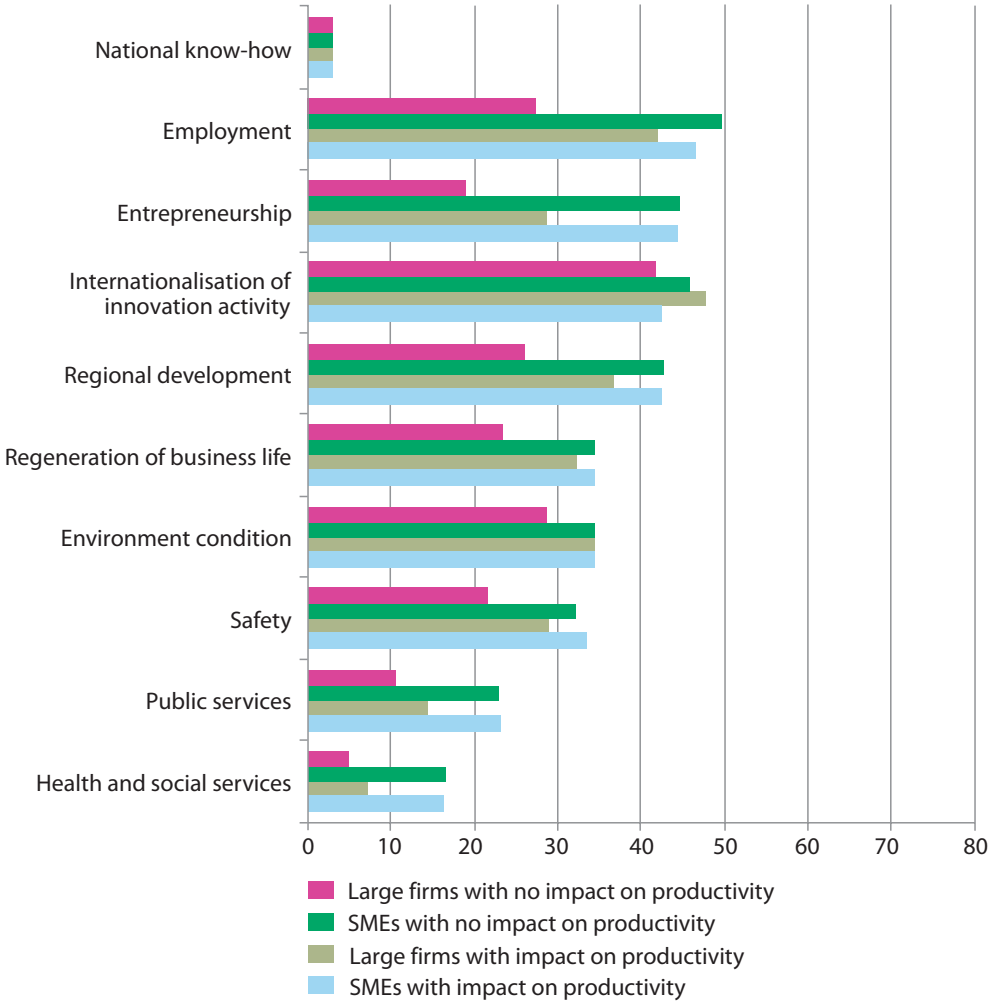


Figure 45. Average turnover per person in Tekes funded enterprises and other enterprises.

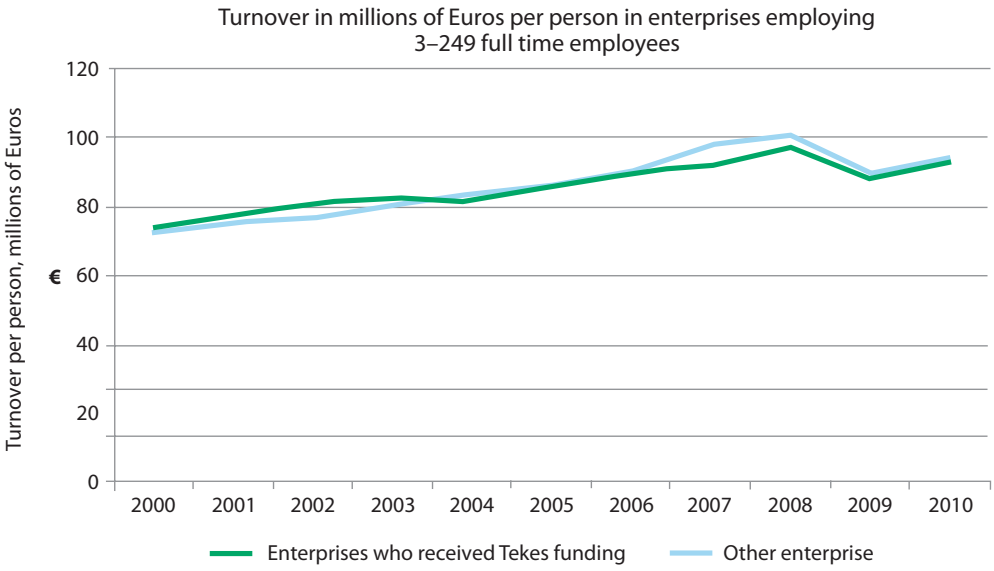


Figure 46. Projects' wider societal impacts; SME's that reported improved productivity compared with other SME's.

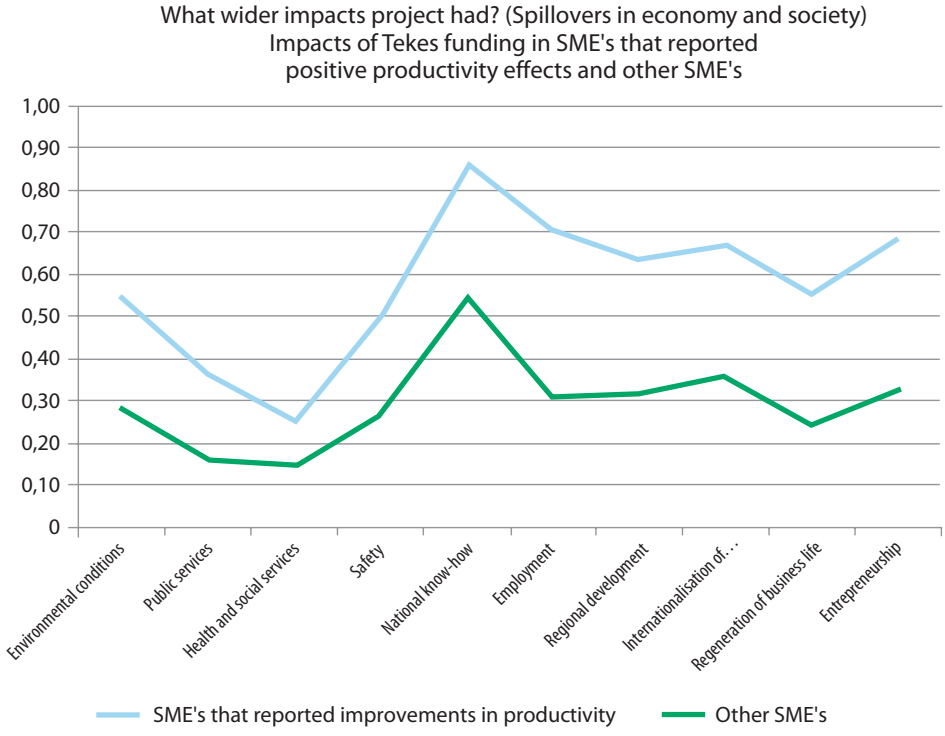


Figure 47. Projects' wider economic impacts; SME's that reported improved productivity compared with other SME's.

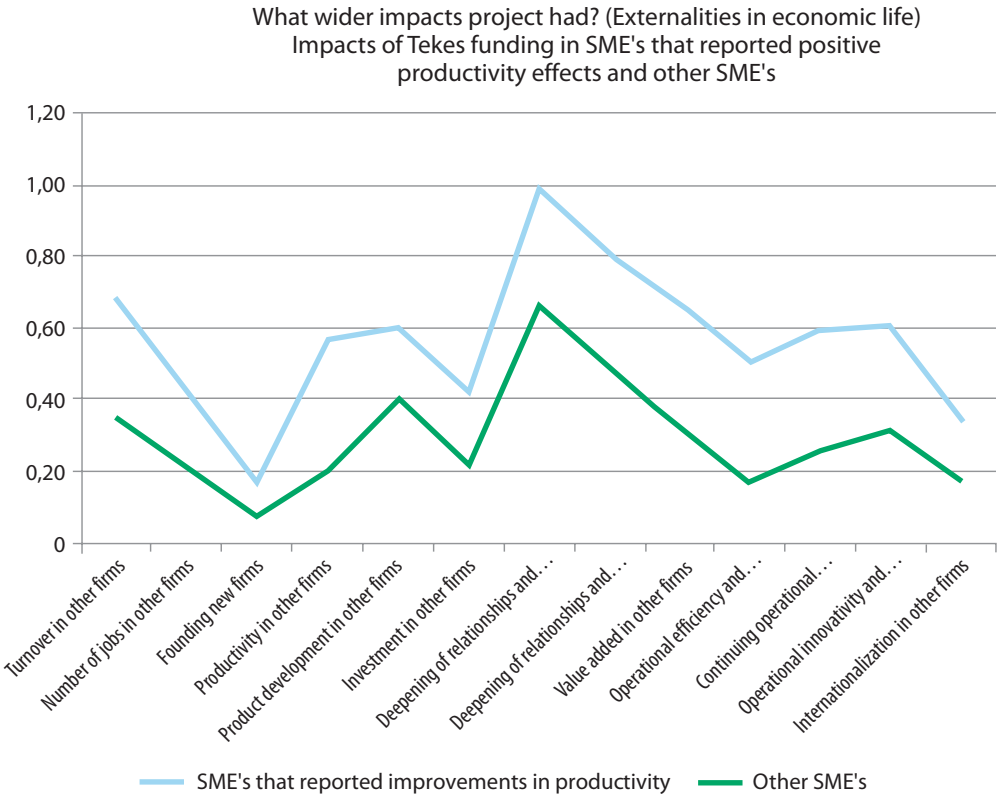


Figure 48. No. of NIY-funded enterprises which felt remarkable or somewhat remarkable impacts.

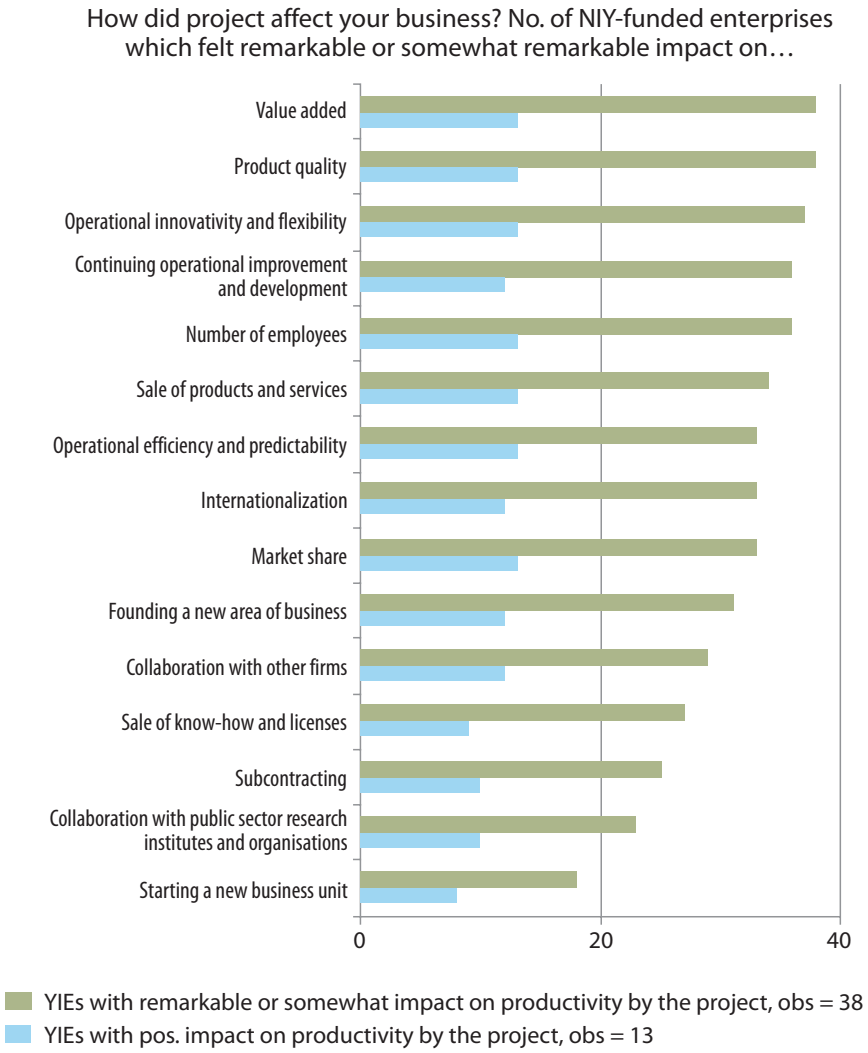


Figure 49. No. of TULI enterprises which felt remarkable or somewhat remarkable impacts.

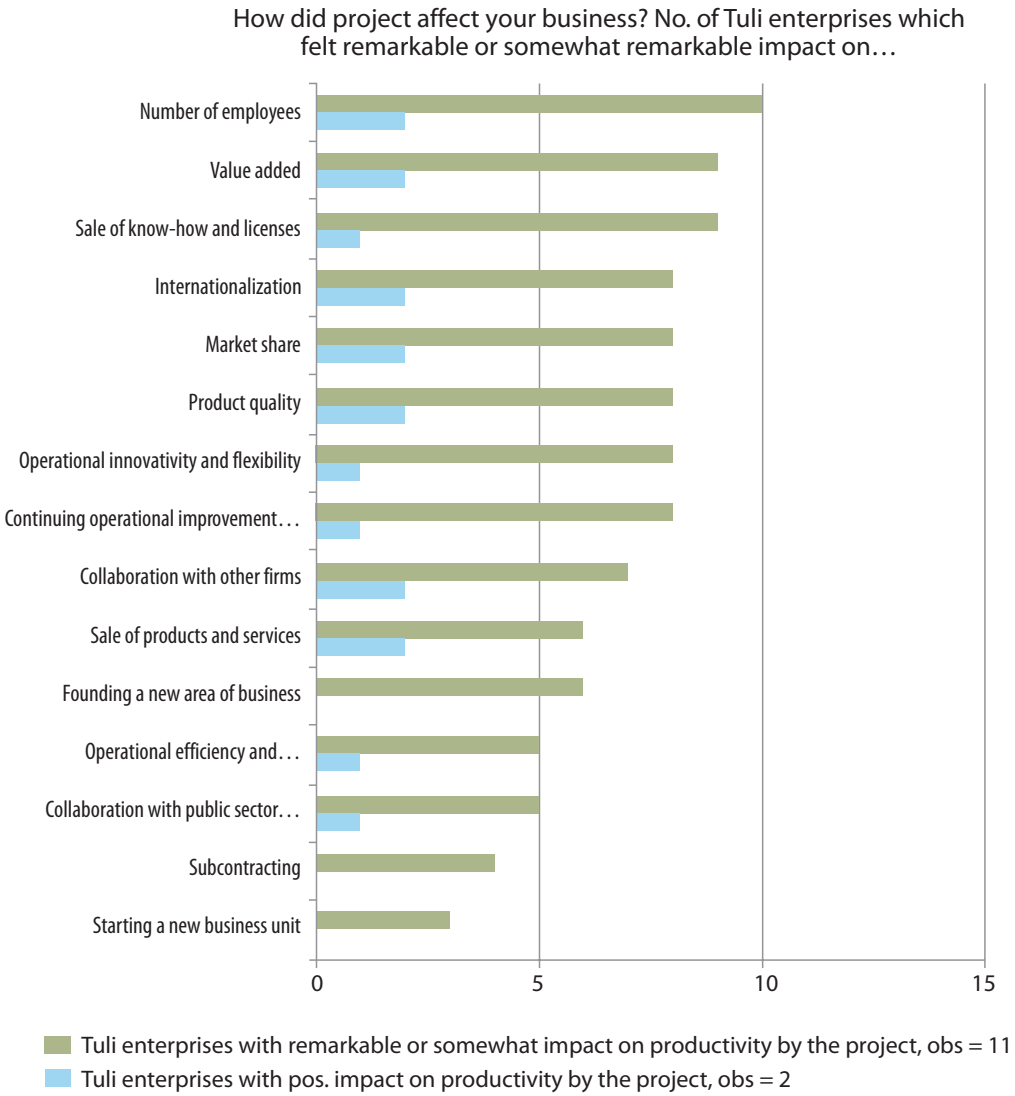


Figure 50. The development of the amount of gazelle enterprises. (Source: Statistics Finland)

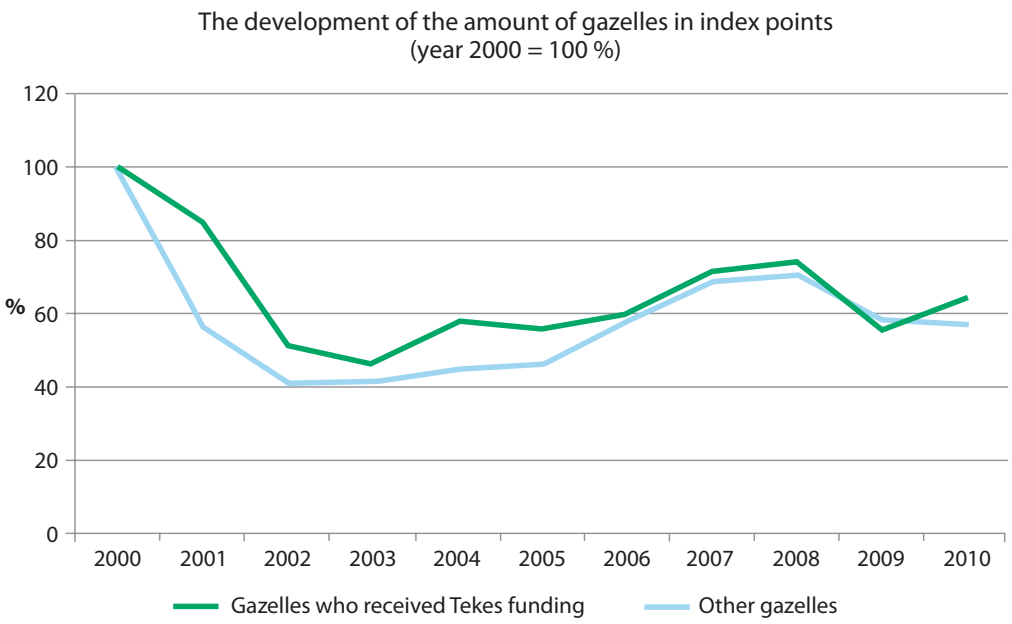
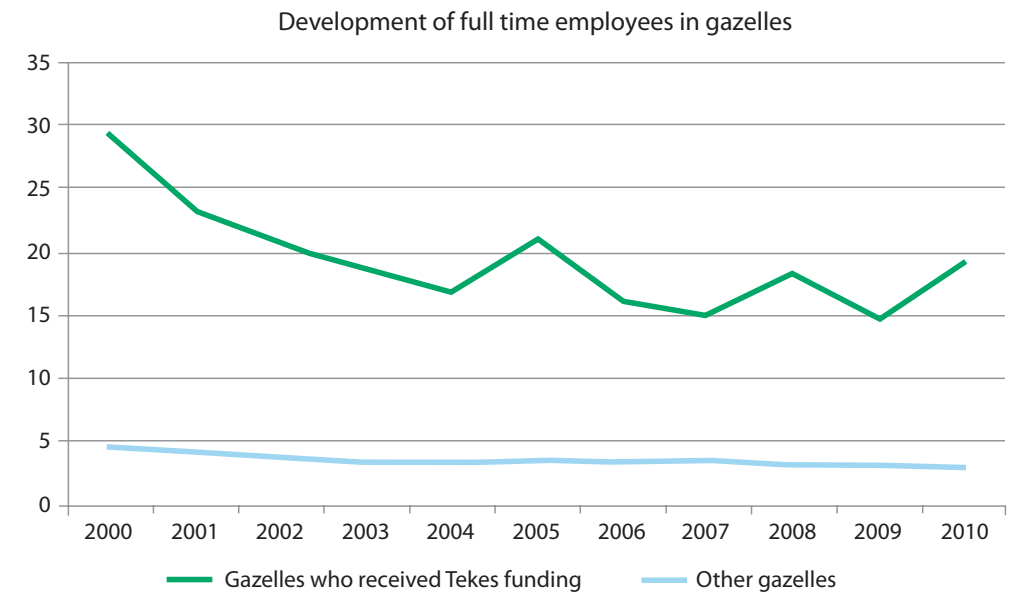


Figure 51. Development of full time employees in gazelles. (Source: Statistics Finland)



Appendix 2. Description of case studies

The cases are presented anonymously with some key background information and coded answers. The key themes are summarized after the individual cases. The coding for the answers is based on the concepts of additionality discussed in section 3.2.

1.1 Case A

Case A is a small company, which develops and manufactures industrial instruments. The company currently employs 17 'highly educated people'. The company was founded based on academic research in mid 2000s after participation in the TULI programme. Since the inception, the company has two Tekes R&D grants, NIY funding and has participated in EU FP7 R&D projects as an RTD partner and as a beneficiary in an SME programme. The findings are summarized below:

Input additionality

- The company would not probably have been founded without Tekes funding
- Tekes funding also brings continuity to the business
- Tekes funding acts as a leverage for other funding sources
- Especially the NIY instrument has enabled recruitment through lowering the risks associated with recruitment in a cash flow constrained enterprise.

Behavioural additionality

- Tekes funding has had relatively little direct impact in networking
- Compared to Tekes funded projects, FP7 projects are more massive and bureaucratic, but at their best they enable creating more contacts, market insight and knowledge
- Knowledge has been created on programmes, but in collaborative projects the partners tend to work on peripheral issues and register IPRs outside the R&D projects
  - This practice seems to be more common in that case of large companies who can invest on their own
- Tekes funding has not inspired joining or founding industry associations or other networks
- The main impact to strategy has been that the R&D projects enable gaining more insight from application areas, customer needs and processes
- Typically the projects start with a broad focus and tend to be narrowed down towards the end
- However, the adverse effect is that during the project it turns out to be a dead end with little business prospects
- Impact to management capability is hard to estimate.

Output additionality

- Tekes funding, especially NIY-funding has enabled developing and launching products
- NIY-funding has been the most important for business/commercial development
- Exact additionality hard to estimate, "all the Euros are in the same account".

General

- Tekes could extract more commercial impact from the R&D funding, if stronger focus on commercial exploitation would be expected from the projects
  - Technical ambition tends to escalate during R&D
  - Strong technology and engineering mindset can lead to daisy chaining R&D projects perfecting a technology that would already be marketable
  - Potentially DARPA-style problem and application-oriented approach[121] would bring commercial results more quickly
- Potentially the R&D tax incentive has a similar effect than the NIY funding, enabling a broader set of innovation activities.

[121] See e.g. Dubois, L.H. 2003. DARPA's Approach to Innovation and Its Reflection in Industry. In: United States National Research Council, Chemical Sciences Roundtable. Reducing the Time from Basic Research to Innovation in the Chemical Sciences: A Workshop Report to the Chemical Sciences Roundtable. Washington (DC): National Academies Press (US); 2003. Available from: http://www.ncbi.nlm.nih.gov/books/NBK36337/

1.2 Case B

Company B is a small enterprise that develops diagnostic equipment. The company was founded originally in the early 1990s. The basic technology was developed over approximately 10 years. After the technology base was fully developed, the present main product line was developed between 2008-2010 and subsequently released. Tekes has granted funding for two projects for company B. Company B houses approximately 20 persons. The findings are summarized below:

Input/output additionality

- Hard to estimate the additionality of funding "the funding has to come from somewhere"
  - Equity funding serves start-ups best, they are cash flow and equity constrained, and cannot afford to take debt.

Behavioural additionality

- The project officers try to spar the applicants but the it was felt that Tekes tries to steer the company
  - "The executive doesn't have time to argue about strategy
- Further, preparing the project applications puts the executives' attention to too small details.

General

- In sum it was felt that funding a start-up through R&D project grants leads to a loss of the big picture
  - Further, because of the administrative overheads, the project grants "vanish like smoke in thin air"
  - Thus the preference order is equity funding/investments, project funding, others.

1.3 Case C

Company C is a small or micro enterprise focusing on industrial equipment. Company C participated in the TULI program in the period in mid 2000s and the company was registered few years later. The knowledge and technology base was developed in a research project and TULI programme funded a market study to evaluate the prospects. Since then C has been granted R&D loans for product development. The findings are summarized below:

Input additionality

- R&d loans have been in a key position in enabling R&D
  - Funding is altogether an important enabler of business development
  - The loans grow R&D volume, enabling more comprehensive development
  - Tekes loans, and funding in general, has an important element of leveraging private funding
    - Tekes funding for R&D is a signal for private investors that the company and technology are worth investing in
    - "investors assume/expect that Tekes pays half of the bills"
- Additionality to networking is hard to distinguish as the technically demanding R&D programme demands networking anyway.

Behavioural additionality

- TULI funding was in key position during inception of the firm, without the market insight, it would have been likely that the company would not have been started
  - TULI funding enabled developing a sound business plan,
  - As well as knowledge and insight about customer needs
- Impact to R&D strategy is expected only when the company has been established and needs diversifying.

General findings

- Market presence and insights to the customers' needs are an important factor in business development
  - Funding for market studies has had an important impact in developing the company
- Business incubation and management training has also had a positive impact in the development of the company
  - Training in basic management skills like accounting, marketing, leadership and business strategy are useful for entrepreneurs who have not studied those subjects
- Officials are used to working with established enterprises, training in small businesses would cut administrative burden
  - For example tax officials routinely require explanations from a start-up about VAT returns and other matters of accounting which are inherent peculiarities of SMEs.

1.4 Case D

Company D designs and manufactures heating equipment. The company has nowadays over 400 employees, 13 of them dedicated to R&D. Company D started production in early 1980s and went public in mid 1990s. The turnover of Company D has been steadily over 50M EUR per year over the last decade, with a peak turnover of approx. 80M EUR and over 750 employees in 2006. Company D works in a relatively cyclical industry, which explains some of the volatility of the turnover. The qualitative explanation behind what appears to be stagnating development are the general economic turndown that has affected demand as well as on one hand recent divestments of non-core business and on the other hand focus on development and introduction of new products in the core business, as documented in the company's yearly reports.

Tekes has granted altogether six project grants for D, which have focused technology development as well as development of production methods and most recently administrative systems. The 13 R&D employees include engineers and designers, and as a function they have a coordinating role in R&D, while other personnel from relevant functions of the organisation participate actively in the R&D projects. The first projects were completed in 2003 and 2004 when D had an SME status, and the rest on 2004, 2005, 2007 and 2012 under large company status. During that period D has grown both organically and through mergers especially after the turn of the millennium. The findings are summarized below:

Input additionality

- R&D funding has enabled growing R&D volume and direct it to new areas, but actual input additionality is not clear
- It is hard to distinguish how funding has affected recruitment, the R&D projects have an overall transformative tendency which affect recruitment qualitatively.

Behavioural additionality

- Funded R&D projects have improved networking
  - Attitudes toward networking have changed significantly
  - Outside expertise is sourced commonly in the projects
  - Some equal partnerships have been developed, where information is exchanged and the partners' products have significant synergies
- Working with industry associations is not specifically related to funded R&D
- Scope of R&D has been changed to some extent
  - The funded projects have enabled more careful examination of new technologies "they offer a possibility to think about thing more carefully"
  - The projects have induced change in thinking
- The impact to strategy poses a "chicken and egg problem"
  - R&D and strategy go hand in hand; strategy steers R&D, but R&D informs strategy by expanding business possibilities
  - "In this kind of company, not much changes in strategy without R&D"
- Management has been developed
  - The funded R&D projects have increased attention to innovation
  - Working with the projects has introduced a wider project culture in the company
  - The experience in the projects has taught about networking and network management
- Market knowledge has been acquired indirectly, the main focus has been on technology and process development.

Output additionality

- Funded R&D projects have enabled development and introduction of successful new products, that are based on new technology
  - The developed technologies have enabled market leading qualitatively product properties
- Funded R&D projects have enabled development production processes and systems
  - The R&D projects have introduced more open and modern thinking, e.g. product modularity
  - The R&D projects have enabled more profound R&D on the selected issues and has speeded up development
- Overall the projects have had a significant impact in the company's development.

1.5 Case E

Company E designs and sells business-to-business analytical software solutions. It was founded in mid 2000s with 6 employees and generated a turnover of 0.13 MEUR. In 2012 Company E employs altogether 19 persons, 13 of whom are permanently in Finland, and their turnover is 2 MEUR, with yearly growth figures between 32 and 60%. During its existence, Company E has received NIY grant, Tekes founding loan in 2007, two project grants for one year 2007–2008 and year and a half 2008–2010 and Tekes innovation services 2008. Company E has an international network of small and large enterprises. The company has worked with a new to the world product, and a new market, which qualifies for a radical innovation. The findings are summarized below:

Input additionality

- R&d funding is an important enabler
  - Funding supports business development
  - Public and private funding support each other
- Especially NIY-funding has enabled recruitment of key personnel
  - Talented personnel with a good track record are costly and thus pose a great risk for a small company, NIY has given financial leeway and enabled taking the risk
- NIY supports growth of a company
  - Traditional Tekes funding is for development of technology, but the technology is not a problem for E
  - NIY enables creating an international presence which is a key for a company aspiring to internationalize
    - Enables visiting trade shows, scoping partners and negotiations, international recruitment and placing account managers in international markets.

Behavioural additionality

- R&d funding as a whole supports networking
  - R&D project grants support recruitment to some extent and sourcing of expertise
  - NIY funding supports partnering in the demand side, e.g. with sales partners, with technology/product partners and ad-hoc partnering for tendering
- R&d funding has had a limited impact to scope of R&D
  - One project was developed to open up a new market as the main market has a long turnaround time and highly cyclical cash flow, but during the project it became evident that the firm has to focus on the main segment
- Funding has not had an impact on strategy, in E strategy has been clear from the start and funding has helped realize it
- R&d funding has raised management and process capability
  - Funding has enabled targeted recruitment, e.g. most recently an R&D director, which has enabled functional specialization of employees and to some extent improved quality management
  - As a result of funded R&D, E have modelled their IPR processes and filed a patent application
- Working with a network of partners have given insights about the application area and markets.

Output additionality

- Funding and ensuing recruitment have enabled faster R&D processes and improved quality
  - Specialisation of employees improves quality
- The same products would have been developed, but results would have been worse
  - Without funding,
    - there would have probably been less software releases, and
    - less features per release.

General

- For a start-up, NIY is an invaluable instrument
  - Originally the company started with the technology and finalizing the product, but
  - Business development had a significant jolt when they recruited a marketing director, developed sales and marketing processes, changed marketing partners and invested in creating an international presence and developing the value proposition for the chosen segment
  - A key factor in learning has been specifically internal market development activity, sourced market surveys would not have given as much insight.

Appendix 3. Description of methodology and data

1.6 Treatment framework and firm selection bias

Following Roy (1951)[122] and Rubin (1977)[123] the causal model presented in the Appendix 1 is defined as a difference between potential outcomes. For those who are not familiar with the treatment framework a good place to start is to see Imbens and Wooldridge (2009)[124] or Blundell and Costa Dias (2000)[125] who surveyed development on program evaluation. Let $Y_i(.)$ be potential productivity of firm i and let S_i to indicate the treatment status of the firm ($S_i = 1$: received subsidy; $S_i = 0$: id not receive subsidy). Then the average effect of R&D subsidy on firm productivity can be formulated as

$$\alpha_{TT} = E\left(Y_i(T)|S_i = 1\right) - E\left(Y_i(C)|S_i = 1\right) \quad (1)$$

where α_{TT} is the average treatment effect on the treated firms, and T and C indicate the potential outcome in treated $Y_i(T)$ or in counterfactual situation $Y_i(C)$. The problem of program evaluation is that one cannot observe counterfactual outcome ($E(Y_i(C) \mid S_i = 1)$). This is solved by using information on firms which do not receive subsidy to form the missing counterfactual outcome. Thus we assume that $E(Y_i(C) \mid S_i = 1) = E(Y_i(C) \mid S_i = 0)$. Resulting formulation of the counterfactual can result selection bias in our estimates of (α_{TT}). Selection bias is zero only if the difference of the potential outcomes in treated and in non-treated situation equals zero. Bias can be negative or positive depending on firm sorting to R&D subsidy program. In practice, there is some bias in results as long as the subsidy is not randomly distributed for the firms.

Now as we have defined potential outcomes framework and the problem of selection bias, we turn to matching and difference-in-differences (DID) methods which have been developed to minimize the possible selection bias. Before going further it is good to remind the reader why potential outcomes framework has a number of advantages compared with other approaches. First, if evaluation would have been done by instrumental variable estimators or selection models, then one would need an exogenous variable which correlates with the probability to get the subsidy, but does not have impact on productivity (so called "exclusion restriction"). Unfortunately, these kinds of variables are hard to find. Second, we do not need to make any functional or distributional assumption a priory. Third, we do not need to assume that the effect of the treatment is constant across the entire population. Moreover, linear regression approach does not show how much missing data points are interpolated, while matching approach apply only to those observations which have enough observations for comparison. In short, potential outcomes framework defines uncertainties and causal relationships in a more transparent way than normal regression based analysis.[126]

1.7 Propensity score matching

Causal analysis of matching estimators is based on the assumption that conditional on observed covariates, the treatment status is random. If we observe all relevant information which affects the subsidy assignment probability, we can compare outcomes of treated and untreated pairs directly. Because this approach is based on the idea that all necessarily information is observed from the data, problematic questions arise which need a careful consideration. Matching the pairs of treated and untreated pairs is data intensive process. But as more variables are added to matching formula, the so-called curse of dimensionality makes the analysis impossible. Rosenbaum and Rubin (1983)[127] showed that this can be solved by reducing matching dimension ($\boldsymbol{x}$) to single assign-

122 Roy (1951).
123 Rubin (1977).
124 Imbens and Wooldridge (2009).
125 Blundell & Costa Dias (2000).
126 see Imbens and Wooldridge (2009).
127 Rosenbaum, P.R. & Rubin, D.B. (1983). The central role of the propensity score in observational studies for causal effects. Biometrika 70, 41–55.

ment probability, which is called the propensity score $e(\hat{x})$. For the causal interpretation to hold, we need basic identification assumptions (Rubin, 1977)[128] also when using the propensity score in matching. The conditional independence assumption (CIA) states that conditional on the propensity score potential outcomes are independent on the treatment assignment (unconfoundedness, **Assumption 1**):

$$Y_i(T), Y_i(C) \perp S_i \,|\, e(x) \qquad (2)$$

Assumption 1 enables one to use expected outcome as a potential outcome; $Y_i(C) \mid S_i = 1, = E(Y_i(C) \mid S_i = 0, e(x))$. This requires that there is enough data to form conditional probability pair from the data for each treated firm for whole covariate distribution $0 < Pr[S = 1 \mid e(x)] < 1$ (overlap, **Assumption 2**)[129].

After calculating propensity scores, general matching estimator requires that non-treated group is weighted appropriately. Let p_i be the probability of firm *i* being treated in treated group and let p_j be probability of firm *j* being treated in comparison group. Then $W(.)$ is a function of weights to be put on the comparison firm *j* while making the counterfactual for the firm *i*. The causal effect of the treatment on the treated is the sum of weighted differences of the paired firms:

$$\alpha_{TT}^{M} = \frac{1}{N_T} \sum_{i=treated} \left(y_i - \sum W(p_i, p_j) y_j \right) \qquad (3)$$

1.8 Conditional Difference-in-differences (CDID)

Causal interpretation of matching estimator is yet based on "selection on observables" assumption whereas propensity score matching enables to control for wide range of variables with a single scalar. However, there might be unobserved macroeconomic or firm-specific changes or shocks that might affect firm productivity. As we have longitudinal data on firms, we can study subsidy effect in differences instead of the levels. Difference-in-differences approach removes time-invariant differences in productivity between firms and is assumed to be more robust tool to program evaluation especially when combined with matching methods[130]. Combining matching strategy with difference-in-differences estimator (= CDID) requires that control group would have evolved from pre- to post-period in the same way than treatment group would have done had they not been treated. If this condition holds, we can use conditional control group to estimate the unobserved counterfactual:

$$E\left(Y_{it}(C) - Y_{it'}(C) | S_i = 1\right) = E\left(Y_{it}(C) - Y_{it'}(C) | S_i = 0\right) \qquad (4)$$

where *t* and *t'* are time periods after and before the R&D subsidy. Main interest is to examine the average treatment effect for the treated, the needed assumptions on similar trends are somewhat weaker than the strong conditional independence assumption (Assumptions 1, equation 2) and common support assumption (assumption 2)[131]. Adding time periods to equation (3), CDID estimator is:

$$\alpha_{TT}^{CDiD} = \frac{1}{N_T} \sum_{i=1}^{N_T} \left[y_{jt} - y_{jt'} - \sum_j W(i,j) \left(y_{jt} - y_{jt'} \right) \right] \qquad (5)$$

where the treatment effect α_{TT}^{CDiD} on the productivity for the firms which received a R&D subsidy, is studied in differences instead of levels. N_T is the number of treated firms (*i*) for whom difference in periods before (*t'*) and after (*t*) the treatment can be formed. Term $W(i, j)$ is the weighting function which is used to form counterfactual from untreated firms (*j*) for each treated firms (*i*). This study uses nonparametric regression methods to determine the weighting function as advocated by Heckman et al. (1998). Local linear matching uses a tricude kernel function (with the default bandwidth 0.8) which is widely used in the literature. Trimming and alternatively matching is also performed to assess the robustness of the results.

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128 Rubin (1977).

129 Also **Assumption 3** should apply: Stable unit treatment value assumption (SUTVA) states that the treatment of one firm should not affect the treatment of another firm. This is

130 see e.g. Imbens & Wooldbridge, 2009; Smith & Todd, 2005; Blundell & Costa Dias, 2000; Heckman et al. 1997, 1998.

131 In DID, Assumption 1 in weaker form is $(Y_{it}(C) - Y_{it'}(C) \perp S_i \mid e(x))$ and Assumption 2 is $Pr[T \mid e(x)] < 1$. Heckman et al. 1996, 1997, 1998.

1.9 Sample

The data comes from several sources. We use firm level data from *Business Register database* (age, municipality, NUTS3 region, foreign trade variable, sector, industry code at two digit level), *Financial Statement database* (number of full time personnel, value added and turnover), *Patent database* (applied patents in Finland and in Europe and granted patents in US.), *Concern database* (group variable) and *Statistics on business subsidies* (paid loans, paid suboR&Dnated loans and subsidies). These mostly register based databases are maintained by Statistics Finland. Firm level data were combined with *Employee characteristics database* (educational share variables for the firms) made from Finnish Longitudinal Employer-Employee Data base by statistics Finland. This sample includes firms which have at least ten employees. The Tekes "three year after" -questionnaire data was also matched to the data using firm identity code. While the questionnaire relates to firms whose projects ended during the years 2003–2008, other data includes yearly data from 2000 to 2010. As it is crucial to control past subsidies, analysis uses two previous annual observations to control previous subsidies (years 2000 and 2001).

Sample consists of private sector firms which have 10 to 249 full time employees and have no more than 50 million Euros turnover (or less than 43 million on balance sheet). These do correspond the definition of SMEs by European Commission with the exception that the firms under 10 employees are not included in the study. We constrain our analysis on balanced five year panel if not said otherwise. Thus, firms are granted a subsidy in a period 2002–2005.

Productivity can be measured by calculating total factor productivity (TFP) via production function or by calculating labour productivity from the raw data. This study uses labour productivity as a measure of annual firm productivity. This is formed by dividing annual value added by the number full time employees (defined by the Statistics Finland), because hours of work are not available in the dataset. Typically, dependent variable is in logarithm form as it levels outliers from the data. Problem is that productivity can take negative values and are unspecified for logarithms. Thus logarithm transformation can have unpleasant effect on the results. Both untransformed and transformed labour productivity measures are used in the analysis to overcome this problem. Matching variables are measures a year before the treatment in order to avoid the possibility that anticipation of the subsidy can affect firm behaviour. Treatment variable gets value of one if the firm was awarded a R&D subsidy and zero otherwise. This study evaluates different treatment variables and how the definitions of the treatment affect the results. Overall we try to avoid the dip in the productivity caused by the firm anticipation which can distort DID estimates. Table 9 holds variable definitions.

Table 9. Variable Definitions.

Variables	Definition
Dependent variable	
Productivity	Value added / number of full time employees
Treatment variables *	
R&D subsidy	Firm was awarded a R&D subsidy = 1, otherwise = 0.
Firm specifics	
Age	Age of the firm in years
Age^2	Age squared
Turnover	ln(Euro/1 000 000)
Employees	ln(Number of employees/1000)
Group	Part of a group = 1, 0 = otherwise.
Ownership	Foreign ownership (majority) = 1, 0 = otherwise.
Foreign trade	Exports or imports or both = 1, otherwise = 0.
R&D development	
Patents	Patents = 1, otherwise = 0.
R&D personnel (Science)	Share of workers with doctorate or equivalent level of tertiary education in a field of technology or natural science.
R&D personnel (Other)	Share of workers with tertiary education. Does not include the same workers than in above R&D variable.
Tekes funded R&D year before	Received money year before the treatment
Tekes funded R&D two years before	Received money two years before the treatment
Other R&D subsidies	Received subsidy before (in a two year period) from other source (e.g. Finnvera) = 1, 0 = otherwise.
Industry classification	(NACE 2002 industry code)
Primary production	Mining and related processing (10–14)
Food industry	Food and drink industry (15–16)
Textile industry	Textile industry (17–19)
Wood industry	Wood industry (20)
Paper industry	Pulp and paper industry (21)
Chemical industry	Pharmaceutical and chemical industry (23v26)
Metal industry	Metal industry (27–28)
Machine industry	Machine industry (29, 34, 35)
Electronic industry	Electronic industry (30,31,32,33)
Other industries	Other industry (22, 36)
Utilities	Utilities (37, 40, 41, 90)
Construction	Construction (45)
Sales	Sales (50,51,52)
Private services for business	Business services (67,72, 73, 74)
Other private services	Other services (55, 60, 61, 62, 63, 64, 65, 66, 70, 71)
Regional variables	
Region	A dummy for each NUTS 3 region
Located in single location	Located only in one region = 1, otherwise = 0
Located in regional center	Located in regional (NUTS 3) center municipality =1, other=0. Capital region is an exception.

* Alternative treatment variables were also tested, while not reported here.

1.10 Estimation results for firm-specific analysis

Table 10. Selection to treatment (Probit model).

Dependent variable: Treatment	(1)		(2)	
	Coefficients (SE)	Marginal effects (SE)	Coefficients (SE)	Marginal effects (SE)
Age	-	-	- 0.008*** (0.002)	- 0.000*** (0.000)
Age^2	-	-	0.000 (0.000)	0.000*** (0.000)
Turnover	-	-	0.039** (0.016)	0.001** (0.000)
Employees	-	-	0.167*** (0.021)	0.005*** (0.001)
Group	-	-	-0.008 (0.021)	-0.000 (0.000)
Ownership	-	-	-0.398*** (0.041)	-0.011*** (0.001)
Foreign trade	-	-	0.254*** (0.027)	0.007*** (0.001)
Patents	0.253*** (0.048)	0.010*** (0.002)	0.093* (0.049)	0.003* (0.001)
R&D personnel (Science)	1.908*** (0.078)	0.076*** (0.003)	1.702*** (0.093)	0.047*** (0.003)
R&D personnel (Other)	0.942*** (0.101)	0.038*** (0.004)	0.969*** (0.112)	0.027*** (0.003)
Tekes funded R&D year before	0.671*** (0.030)	0.027*** (0.001)	0.530*** (0.030)	0.015*** (0.001)
Tekes funded R&D two years before	0.598*** (0.030)	0.024*** (0.001)	0.461*** (0.030)	0.013*** (0.001)
Other R&D subsidies	0.576*** (0.020)	0.023*** (0.001)	0.410*** (0.030)	0.011*** (0.001)
Located in single location	-	-	-0.027 (0.023)	-0.001 (0.001)
Located in regional centre	-	-	0.039* (0.022)	0.001* (0.000)
NUTS3 dummies	No		Yes	
Industry dummies	No		Yes	
Year dummies	Yes		Yes	
Propensity score	0.0295		0.0297	
Log-likelihood	-10114		-9476	
Number of observations	97 912		97 912	

Note: Marginal effects are evaluated in the means.

The results are obtained from conditional difference-in-differences (CDID) estimation All estimations were done with common support option which excludes those treated firms which have too high propensity score compared to highest value in the control group. Additional on showed results matching and CDID estimations were also calculated without logarithm transformation. Estimations were also done for trimmed samples where 5 and 10 per cent of the observations of the tails are trimmed. These modifications did not change the results significantly.

Table 11. Impact of R&D subsidy on firm productivity (CDID).

Dependent variable: log(productivity)		
t	**Diff-in-diff (CDID)**	**95% conf. interval**
All firms		
Treatment year	- 0.018	[-.044; .009]
1	- 0.038**	[-.069; -.007]
2	- 0.028	[-.063; .007]
3	- 0.008	[-.041; .026]
4	- 0.014	[-.051; .023]
5	0.015	[-.023; .053]
Obs	Treated: 1034 Control (off support): 30718 (1)	

Note: All estimations are done with a balanced panel. Standard errors are obtained by bootstrapping (500 reps).
Significance: 10 per cent level (*), 5 per cent level (**) and 1 per cent level (***).

Table 12. Firms that reported positive productivity effect.

Dependent variable: log(productivity)				
t	**Firms which reported positive productivity effect compared with other Tekes customers**		**Firms which reported positive productivity effect compared to all firms**	
	Diff-in-diff	**95% conf. interval**	**Diff-in-diff**	**95% conf. interval**
Treatment year	0.019	[-.038: .076]	- 0.010	[-.052: .032]
1	0.021	[.053; .095]	- 0.019	[-.072; .034]
2	0.054	[-.026; .013]	0.024	[-.027; .076]
3	0.017	[-.056; .090]	0.013	[-.044; .069]
4	0.006	[-.081; .093]	0.004	[-.052; .061]
5	0.013	[-.071; .097]	0.031	[-.029; .091]
Obs	Treated: 293 Control (off support): 727 (5)		Treated: 293 Control (off support): 31032	

Note: All estimations are done with a balanced panel. Standard errors are obtained by bootstrapping (200 reps).
Significance: 10 per cent level (*), 5 per cent level (**) and 1 per cent level (***).

Table 13. Young innovative firms.

Dependent variable: log(productivity)				
t	**Young innovative firms compared with other Tekes customers**		**Young innovative firms compared to all firms**	
	Diff-in-diff (CDID)	**95% conf. interval**	**Diff-in-diff (CDID)**	**95% conf. interval**
Treatment year	0.093	[-.271; .457]	- 0.005	[-.283; .272]
1	0.214	[-.162; .591]	0.101	[-.254; .455]
2	0.203	[-.167; .572]	0.180	[-.076; .435]
Obs	Treated: 34 Control (off support): 2292		Treated: 34 Control (off support): 31259	

Note: All estimations are done with a balanced panel. Standard errors are obtained by bootstrapping (200 reps).
Significance: 10 per cent level (*), 5 per cent level (**) and 1 per cent level (***). These estimations do not control for employees' education, past subsidy two years before, regional variables (NUTS3 & centre dummies) or industry. Sample includes also firms with 3 to 10 employees to increase sample size.

Table 14. Firms that received ERDF funding.

Dependent variable: log(productivity)				
t	Compared with other Tekes customers		Compared to all other firms	
	Diff-in-diff	95% conf. interval	Diff-in-diff	95% conf. interval
Treatment year	- 0.010	[-.075; .056]	- 0.018	[-.079; .036]
1	- 0.064	[-.146; .018]	- 0.053	[-.134; .020]
2	- 0.067	[-.163; .030]	- 0.049	[-.150; .041]
3	- 0.079	[-.184; .026]	- 0.041	[-.145; .053]
4	- 0.147**	[-.278; - .015]	- 0.125**	[-.237; -.025]
5	- 0.141*	[-.307; .026]	- 0.119	[-.264; .012]
Obs	Treated: 59 Control (off support): 754 (2)		Treated: 60 Control (off support): 23 375 (1)	

Note: All estimations are done with a balanced panel. Standard errors are obtained by bootstrapping (200 reps).
Significance: 10 per cent level (*), 5 per cent level (**) and 1 per cent level (***).

Table 15. Impact of R&D subsidy on firm productivity by regional location (CDID).

Dependent variable: log(productivity)				
t	Located in regional centre		Located outside the regional centre	
	Diff-in-diff (CDID)	95% conf. interval	Diff-in-diff (CDID)	95% conf. interval
Treatment year	- 0.008	[-.054; .038]	- 0.026**	[-.050; -.002]
1	- 0.031	[-.087; .025]	- 0.042***	[-.068; -.017]
2	- 0.012	[-.071; .048]	- 0.037**	[-.067; -.008]
3	0.019	[-.035; .074]	- 0.026	[-.057; .005]
4	0.009	[-.053; .071]	- 0.029	[-.069; .012]
5	0.052*	[-.006; .110]	- 0.019	[-.064; .025]
Obs	Treated: 517 Control (off support): 16569 (5)		Treated: 512 Control (off support): 14019	

Note: All estimations are done with a balanced panel. Standard errors are obtained by bootstrapping (500 reps).
Significance: 10 per cent level (*), 5 per cent level (**) and 1 per cent level (***).

Table 16. Impact of R&D subsidy on firm productivity by size groups (CDID).

Dependent variable: log(productivity)				
t	Small SMEs: 10-49 full-time employees		Medium size SMEs: 50-249 full-time employees	
	Diff-in-diff (CDID)	95% conf. interval	Diff-in-diff (CDID)	95% conf. interval
Treatment year	- 0.002	[-.038; .037]	- 0.042**	[-.077; -.007]
1	- 0.028	[-.068; .012]	- 0.046**	[-.084; -.008]
2	- 0.014	[-.062; .034]	- 0.038*	[-.079; .002]
3	0.010	[-.030; .051]	- 0.028	[-.067; .010]
4	- 0.004	[-.052; .044]	- 0.028	[-.074; .019]
5	0.025	[-.023; .073]	0.010	[-.040; .059]
Obs	Treated: 667 Control (off support): 25251 (3)		Treated: 353 Control (off support): 4641 (5)	

Note: All estimations are done with a balanced panel. Standard errors are obtained by bootstrapping (500 reps).
Significance: 10 per cent level (*), 5 per cent level (**) and 1 per cent level (***).

1.11 Note on robustness: How to measure the subsidy?

Measuring the treatment effect can be tricky. When researcher is using CDID estimator, one needs a binary variable which captures the subsidy with right timing. Binary variable does not separate those firms which get a small subsidy from those who receive a large subsidy. The effect of subsidy on productivity might depend on how big the subsidy is. We re-estimated results using a treatment variable, which is one if the paid subsidy is 30 000 Euros or above, and zero otherwise. Thus, we exclude those firms from the treated group which are granted a subsidy, but the actual paid amount is less than 30 000 Euros (in three years after the subsidy decision). But, we found no evidence that results are not distorted by those firms which actually receive only a small amount of subsidy.

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