The Effect of Multiple Participations in the Danish Innovation and Research Support System

CBS
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OPGAVEN

I perioden juni 2015 til januar 2016 har CEBR gennemført dette projekt for Styrelsen for Forskning og Innovation (FI). Formålet med denne opgave har været at analysere effekterne af forsknings – og innovationsfremmeprogrammer under FI for perioden 2002-2013.

Projektet har undervejs været fulgt af en gruppe af personer. Forfatterne vil gerne takke Andreas Blohm Graversen, Thomas Blomgren-Hansen og Henrik Barslund Fosse fra FI for mange nyttige kommentarer og diskussioner. Endvidere ønsker forfatterne endvidere at takke forskergruppen bestående af Lektor Fane Groes for værdifulde input og kommentarer.

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INDHOLD

DANSK SAMMENFATNING

Denne rapport analyserer effekterne af forskning- og innovationsfremmeprogrammer under Styrelsen for Forskning og Innovation (FI).

Styrelsen har i over 15 år uddelt midler til danske virksomheder på ansøgningsbasis via en række forskellige programmer med det formål at fremme forskning, udvikling og innovation til gavn for vækst i det danske samfund. Enkelte af disse programmer er ophørt i forbindelse med etableringen af Danmarks Innovationsfond. Disse programmer eksisterer således ikke længere i deres oprindelige form, men elementer af dem er videreført i nye programmer som f.eks. InnoBooster.

Over årene har et betragteligt antal virksomheder modtaget midler fra FI flere gange - enten flere gange inden for samme program eller gennem flere forskellige programmer. Et vigtigt spørgsmål er derfor, om effekterne er større, når virksomhederne deltager mere end én gang, eller om de eventuelle ekstra produktivitetsgevinster er aftagende ved at deltage mere end én gang. Med andre ord, er det mest effektivt at fordele midler til så mange virksomheder som muligt ved at begrænse adgang til én deltagelse, eller giver det større effekt at koncentrere deltagelsen på færre virksomheder, som kan deltage flere gange? Hovedspørgsmålet i rapporten kan altså formuleres som:

1. Hvad er effekten af at deltage anden gang i en af FIs innovationsprogrammer sammenlignet med effekten efter første deltagelse i samme eller et andet program?

I tilgift til at få større viden om, hvorvidt FI skal fokusere midlerne på at støtte mange virksomheder én gang eller færre virksomheder flere gange, forsøger denne rapport at besvare yderligere tre spørgsmål:

2. Hvad er den gennemsnitlige, årlige effekt på virksomhedernes produktivitetsvækst af at deltage i et af FIs programmer?
3. Hvordan ser de årlige effekter af deltagelse i programmerne ud et, to og henholdsvis tre (eller flere) år efter deltagelse?
4. Har programmerne forskellige effekter for forskellige typer af virksomheder?

Spørgsmål (2) går ud på at undersøge den overordnede (gennemsnitlige) årlige effekt på produktiviteten af at deltage i et FI program. Denne effekt estimeres for alle virksomhederne, som har deltaget, regnet fra deres første deltagelse, og hvor gennemsnittet tages over de efterfølgende år, hvor vi følger virksomheden indtil virksomhedens næste deltagelse. Dette spørgsmål har tidligere været undersøgt for deltagelse i årene 2002–2009, se CEBR(2014). CEBR(2014) estimerede den gennemsnitlige årlige effekt på væksten i totalfaktorproduktiviteten (TFP væksten) for de virksomheder, som deltog én gang, på data for perioden 2002-2009, for de programmer, som havde et stort nok antal deltagende virksomheder til at man kan udføre en økonometrisk analyse. Danmarks Statistiks registerdata på virksomheder er nu opdateret til og med 2013, hvilket udvider rapportperioden med 4 år. Analysen estimerer derfor den gennemsnitlige årlige effekt på væksten i TFP på data for perioden 2002-2013 for hvert af de programmer, som havde et stort nok antal deltagende virksomheder til at man kan udføre en økonometrisk analyse.

Spørgsmål (3) adresserer, hvordan effekterne af deltagelse i programmerne udvikler sig år for år efter deltagelse, i stedet for at betragte den gennemsnitlige, årlige effekt af deltagelse. Disse dynamiske effekter kan blandt andet afdække, om nogle programmer virker hurtigere (langsommere) end andre. Således kan de gennemsnitlige, årlige effekter af to programmer være forholdsvis ens, men dette kan for eksempel dække over, at det ene program virker med det samme, mens det andet først har en effekt efter et par år. Alternativt kunne det være, at en gennemsnitlig, årlig effekt på 0 dækker over, at deltagerne i et program først oplever negativ vækst (f.eks. fordi virksomheden foretager investeringer for at få det fulde udbytte af programmet) for derefter at opleve højere, positiv vækst, dvs. at programmet faktisk virker, men at det blot tager et stykke tid. Med besvarelsen af dette spørgsmål bores således dybere ned i, hvad der ligger til grund for de gennemsnitlige effekter fundet i spørgsmål 2. (og i CEBR(2014)).

Sluttelig undersøges det, om de forskellige programmer virker forskelligt afhængig af, hvilken type virksomhed, som deltager. Konkret betragter vi først yngre virksomheder og derefter mindre virksomheder for at undersøge, om FI programmerne virker forskelligt afhængig af, om virksomhederne er tæt på at være nystartede eller mere etablerede, eller afhængig af, om de er større eller mindre virksomheder.[1]

Resultater og konklusioner

De væsentligste konklusioner fra rapporten er samlet op i boks 1 og beskrevet nærmere nedenfor.

Boks 1:Rapportens hovedresultater

- De positive produktivitetseffekter fra tidligere analyser bekræftes med det større datamateriale
- Der er ikke signifikant forskel i produktivitetseffekt mellem virksomhedernes første og anden deltagelse i innovationsfremmeprogrammerne
- Der er forskel på, hvornår effekterne slår igennem for de forskellige innovationsfremmeprogrammer: Effekter af for eksempel Innovationsnetværk slår igennem allerede i år 1 og igen i år 3, mens effekter af for eksempel Videnkupon først slår igennem i år 2 og 3
- Produktivitetseffekterne for yngre virksomheder er umiddelbart større (end mere etablerede virksomheder) af at deltage i Innovationsnetværk, Videnkupon og Videnpilot, selvom ingen af effekterne er statistisk signifikante
- Produktivitetseffekterne for større virksomheder (målt i antal ansatte eller i kapitalniveau) er større af Innovationsnetværk og Videnpilot (hvor dog effekterne af Videnpilot ikke er statistisk signifikante), mens de mindre virksomheder opnår større effekt af Videnkupon

[1] En yngre virksomhed er defineret som værende mindre end 6 år gammel. En mindre virksomhed er defineret som havende mindre ansatte (eller mindre kapital) end medianen af alle virksomhederne i den pågældende branche.

Analysen er baseret på 3.379 virksomheder, der deltager i FI programmer i årene 2002-2012, hvoraf 631 virksomheder deltager to (eller flere) gange.[2] Om de deltagende virksomheder kan vi sige:

- De er typisk større og mere etablerede (dvs. har eksisteret som virksomheder i længere tid) end virksomheder typisk er i Danmark
- De er sjældent enmandsvirksomheder
- De er overrepræsenterede indenfor industrien og underrepræsenterede indenfor bygge og anlæg sammenlignet med den typiske fordeling af virksomheder i Danmark

Antallet af virksomheder i de forskellige programmer, opgjort for de virksomheder, der kun deltager én gang og de, der deltager flere gange, er vist nedenfor i Tabel 1:

Tabel 1

Antal første- og andengangsdeltagere fordelt på de 10 største programmer

Første program	*Virksomheder, der kun deltager én gang*		*Virksomheder, der deltager to eller flere gange*		*I alt*	
EU's 6	24	1%	15	2%	39	1%
ErhvervsPhD	58	2%	41	6%	99	3%
FP 7	16	1%	20	3%	36	1%
Gazelle Growth	10	0%	5	1%	15	0%
Højteknologifonden	25	1%	17	3%	42	1%
Innovationskonsorti	62	2%	55	9%	117	3%
Innovationsnetværk	1304	47%	277	44%	1581	47%
Videnkupon	587	21%	109	17%	696	21%
Videnpilot	617	22%	74	12%	691	20%
Åbne midler	26	1%	11	2%	37	1%
Andre	19	1%	7	1%	26	1%
I alt	*2748*	*100%*	*631*	*100%*	*3379*	*100%*

Kilde: InnovationDanmark Databasen

Om de virksomheder, der deltager flere gange, kan vi sige:

- 60 pct. af dem har deres anden deltagelse indenfor de første 2 år efter deres første deltagelse
- De fleste af anden gangs deltagerne (ca. 85 pct.) finder sted efter 2009, dvs. vi har højst 4 års data, hvorfra vi kan estimere deres produktivitetsvækst efter anden deltagelse
- Kun tre af programmerne har et stort nok antal deltagende virksomheder til at man kan foretage en økonometrisk analyse af anden gangs deltagelse: Innovationsnetværk, Videnpilot og Videnkupon (se Tabel 1 ovenfor)

Estimationsresultaterne af de gennemsnitlige, årlige effekter på produktivitetsvæksten af at deltage første gang er statistisk signifikant for Innovationsnetværk (3,56 pct.), Videnkupon (4,10 pct.), Innovationskonsortier (5,96 pct.) og Højteknologifonden (-8,0 pct.), hvor det dog skal bemærkes, at dette estimat for Højteknologifonden er baseret på kun 42 deltagende virksomheder, hvor de andre

[2] Mere præcist, så er analysen baseret på private virksomheder med færre end 500 ansatte, som er mindst 2 år gamle (for at vi kan estimere deres produktivitet før deltagelse) og for hvem de nødvendige data (på antal ansatte, branche og værditilvækst) er tilgængelige i de nødvendige år.

estimater er baseret på henholdsvis 1.581, 696 og 117 virksomheder og derfor behæftet med stor usikkerhed. Estimationsresultaterne af de gennemsnitlige, årlige effekter på produktivitetsvæksten af at deltage første henholdsvis anden gang (altså spørgsmål 1 og 2 ovenfor) i et af de tre største programmer er angivet i Tabel 2 nedenfor:

Tabel 2

Årlige effekter på produktivitetsvækst af første og anden deltagelse

Gennemsnitlig årlig effekt på produktivitetsvækst	Gennemsnitlig årlig effekt på produktivitetsvækst	Innovations-netværk	Videnpilot	Videnkupon
Første program	*estimat*	0.0356***	0.0079	0.0410***
	standardafvigelse	*(0.0084)*	*(0.0136)*	*(0.0122)*
	80% nedre grænse	*0.030224*	*0%*	*3%*
	80% øvre grænse	*0.040976*	*2%*	*5%*
	antal deltagere	1573	686	450
Andet program	*estimat*	*0.02035*	*4%*	*-2%*
	standardafvigelse	*-0.01882*	*-7%*	*-3%*
	80% nedre grænse	*-0.0037396*	*-5%*	*-6%*
	80% øvre grænse	*0.0444396*	*12%*	*2%*
	antal deltagere	*175*	*4600%*	*11200%*
	andelen matchet eksakt	*87%*	*91%*	*92%*

Kilde: InnovationDanmark Databasen og Danmarks Statistik

Note: Ved anden gangs deltagelse estimeres effekt uafhængigt af, hvilket program man har deltaget I første gang. Dvs. der er ikke nødvendigvis tale om to deltagelser i samme program.

Tabel 2 har to hovedpointer:

- Ingen af effekterne for deltagelse anden gang er statistisk signifikante, dvs. ingen af dem er signifikant forskellige fra 0.
- Det er højst usandsynligt, at effekterne (selv hvis de var signifikante) ville være forskellige fra effekten af at deltage første gang – dvs. at man ville få en enten højere eller lavere effekt af at deltage anden gang – da dette ville kræve, at konfidensintervallerne for de estimerede effekter af første gangs deltagelse og anden gangs deltagelse ikke overlapper.

Hvis man var villig til at acceptere et ukonventionelt lavt signifikansniveau på 80 pct. (hvor det lavest acceptable normalt er 90 pct.), kan man se af Tabel 2, at konfidensintervallerne for første og anden gangs deltagelse i Videnkupon ikke overlapper, hvoraf man kan konkludere, at der er en lavere effekt ved at deltage i Videnkupon anden gang. Det indikerer at Videnkupon kunne overveje at prioritere midlerne til kun at give virksomheder én deltagelse i deres program. For at kunne opnå en statistisk signifikant konklusion på effekterne af at deltage anden gang skal der enten være meget store forskelle i effekten mellem første og anden gang deltagelse, eller også skal man have en betydeligt større population af første og anden gangs deltagere. Eksempelvis ville selv en fordobling af populationerne af første og anden gangs deltagere kun være tilstrækkeligt til, at man ville kunne opnå en statistisk signifikant forskel mellem første og anden deltagelse i Videnkupon, men hverken for Innovationsnetværk eller Videnpilot.

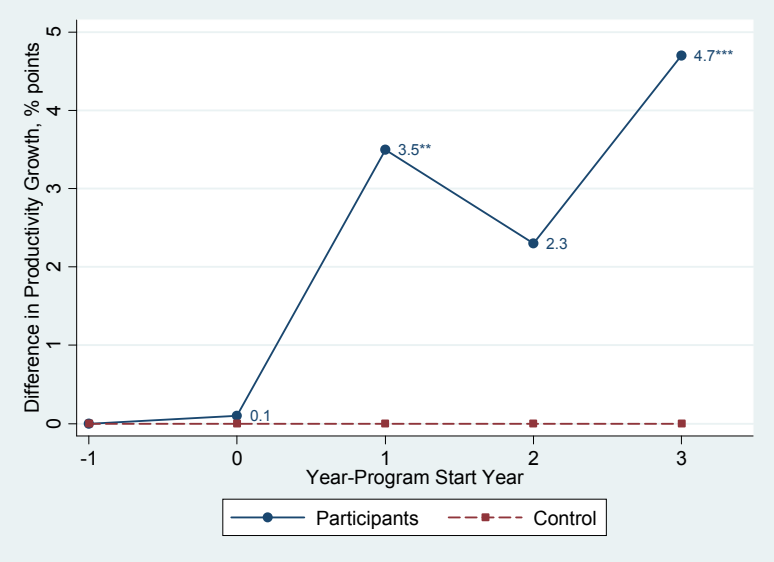
Resultaterne vedrørende de dynamiske effekter 1, 2 henholdsvis 3 (eller flere) år efter deltagelse, samt effekterne for de forskellige typer af virksomheder (dvs. spørgsmål 3 og 4 ovenfor) kan sammenfattes som følger:

- De gennemsnitlige, årlige effekter dækker over store forskelle i, hvornår effekterne indtræder: f.eks. indtræder effekten af Innovationsnetværk med det samme, hvorimod effekten af virksomheds Ph.d. programmet først er positiv (dog insignifikant) efter 2. år:

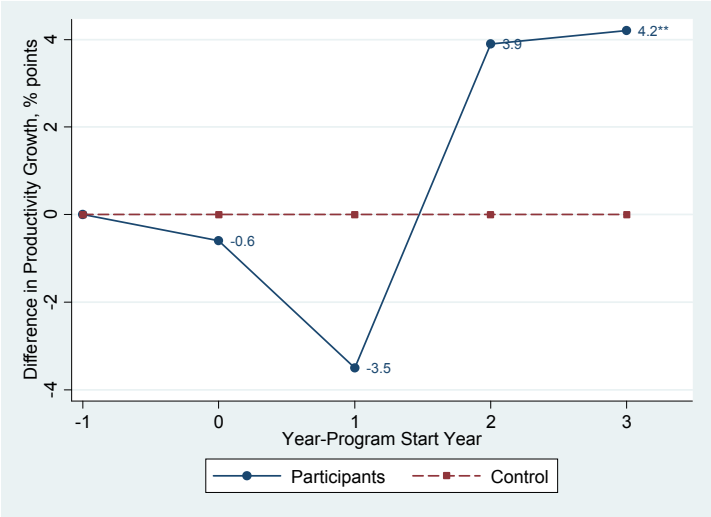
Figur 1

År-til-år forskel i produktivitetsvækst for deltagere i forhold til ikke-deltagere i Innovationsnetværk og Videnpilot

Innovationsnetværk:



Videnpilot:



Kilde: InnovationDanmark Databasen og Danmarks Statistik

Resultaterne angående effekterne for forskellige typer af virksomheder (spørgsmål 4 ovenfor) kan sammenfattes som følger:

- Resultaterne antyder, at yngre virksomheder opnår større effekt (end mere etablerede virksomheder) af at deltage i Innovationsnetværk, Videnkupon og Videnpilot, selvom ingen af effekterne er statistisk signifikante
- Resultaterne antyder, at de større virksomheder (målt i antal ansatte eller i kapitalniveau) opnår større effekt af Innovationsnetværk og Videnpilot end de mindre virksomheder, mens de mindre virksomheder opnår større effekt af Videnkupon (hvor dog effekterne af Videnkupon ikke er statistisk signifikante)

Som det fremgår, er det ikke muligt med det nuværende datagrundlag at svare entydigt på spørgsmålet om, hvorvidt FI skal fokusere midlerne på at støtte mange virksomheder én gang eller færre virksomheder flere gange, idet populationerne af anden gangs deltagere ikke er tilstrækkelige store. Det er dog muligt at bekræfte de tidligere fundne positive, statistisk signifikante gennemsnitlige effekter af første gangs deltagere. Det er desuden muligt at belyse, at effekterne af de forskellige programmer lader til at være forskellige over de forskellige år umiddelbart efter deltagelse, og at det lader til, at forskellige typer virksomheder oplever forskellige effekter.

Metode og data

Når man evaluerer en indsats som FIs innovationsfremmeprogrammer, er man nødt til at sikre sig, at den eventuelle effekt, man finder, med nogenlunde sikkerhed kan tilskrives indsatsen og ikke stammer fra andre forhold. Hvis man kun betragtede de deltagende virksomheder og estimerede forskellen mellem deres produktivitetsvækst før og efter deltagelse, ville man ikke kunne tage højde for påvirkningen fra f.eks. makroøkonomiske chok som den finansielle krise: hvis krisen falder sammen med de år, hvor virksomhederne deltager, vil en før-og-efter estimation se ud som FI programmerne har haft en negativ effekt på væksten, når den negative effekt i virkeligheden kommer af krisen, som for øvrigt har bevirket, at *alle* virksomheder (og ikke blot deltagerne) har lavere vækst. Det spørgsmål, man i virkeligheden ønsker at besvare, er "hvad ville produktivitetsvæksten have været for de virksomheder, der deltog i et FI program, hvis de *ikke* havde deltaget?". Dvs. man ønsker at sammenligne produktiviteten før og efter deltagelse for de deltagende virksomheder, sammenlignet med deres produktivitet før og efter deltagelse, i den kontrafaktiske situation, at de *ikke* havde deltaget.

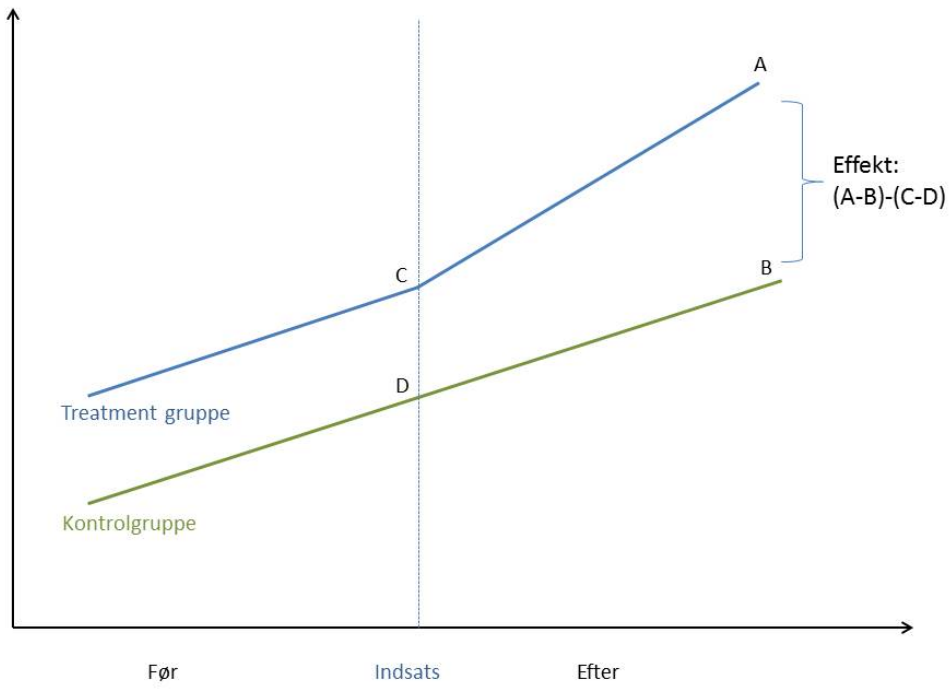
Eftersom en virksomhed i sagens natur ikke både kan *deltage* og *ikke deltage* i et program på samme tid, er man derfor nødt til at sammenligne de deltagende virksomheder med nogle virksomheder, der ikke deltog, men som ligner de deltagende virksomheder på afgørende parametre (en kontrolgruppe). Hvordan skal disse to grupper af virksomheder så ligne hinanden? Eftersom vi er interesserede i at måle på produktiviteten før og efter deltagelse, skal gruppen af deltagende virksomheder og kontrolgruppen have samme produktivitetstrend i tiden før deltagelse; hvis de ikke har samme trend, men de deltagende virksomheder for eksempel har højere produktivitetsvækst, kan man ikke udlede, at en efterfølgende højere produktivitetsvækst stammer fra programmet – det kunne simpelthen være, at det blot var de mere produktive virksomheder, der deltog.[3] Forudsat, at gruppen af deltagende virksomheder og kontrolgruppen følger samme trend i produktivitetsvæksten ledende op

[3] Derudover skal kontrolgruppe virksomhederne også operere i den samme branche som den deltagende virksomhed, de agerer kontrolvirksomhed for.

til tidspunktet for deltagelse, kan effekten af programmet estimeres økonometrisk ved Difference in Difference metoden.[4] Dette er illustreret nedenfor:

Figur 2

Illustration ad difference in difference effekter



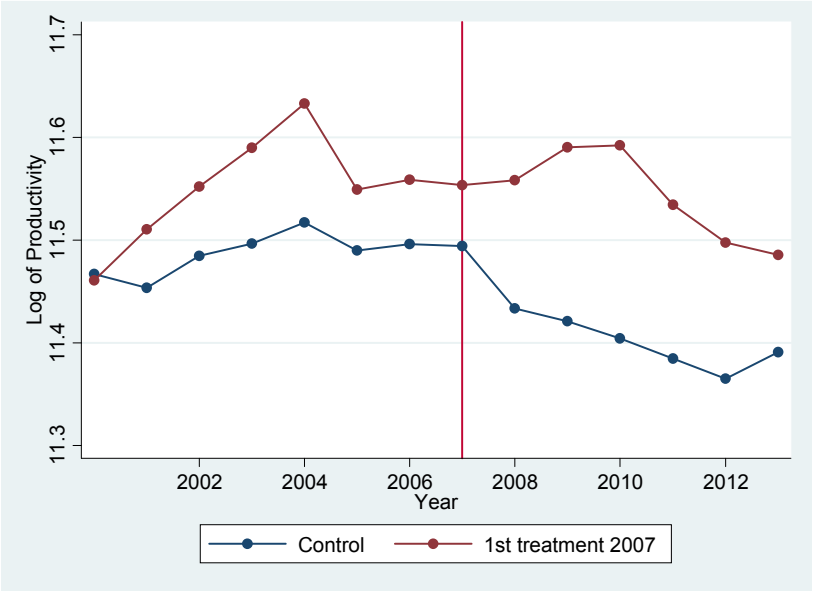
Kilde: CEBR

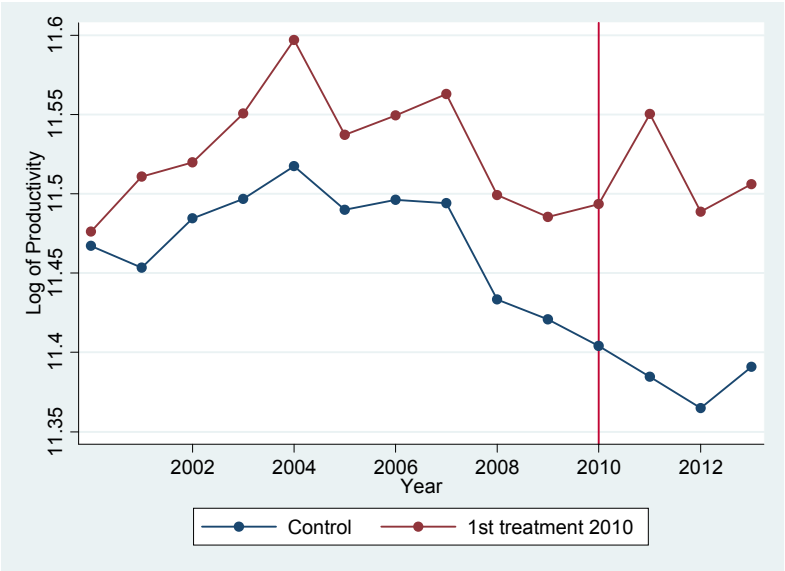
Analysen er baseret på virksomheder, som er private virksomheder, som deltager for første gang i perioden 2002-2013, har mindre end 500 ansatte, er mindst 2 år gamle (for at vi kan estimere deres produktivitetstrend før deltagelse) og for hvem de nødvendige data (på antal ansatte, branche og værditilvækst) er tilgængelige i de nødvendige år. Dette resulterer i en population på 3.379 deltagende virksomheder og 162.597 virksomheder i kontrolgruppen. Et par eksempler på grafer, der viser, at produktivitetstrenden for deltagere og kontrolgruppe ikke er alt for forskellig, er afbilledet nedenfor (for deltagelse i årene 2007 og 2010, for resten af årene, se Appendiks 3):

Figur 3

Eksempler på produktivitetstrenden for deltagere og ikke-deltagere

[4] Produktivitet estimeres både ved Levinson-Petrin og Fixed Effects Difference-in-Differences. Der kontrolleres i alle estimationer for andre forskelle mellem virksomhederne.





Kilde: InnovationDanmark Databasen and Danmarks Statistik

Ud af de 3.379 virksomheder er der 631 (dvs. 19 pct.), som deltager to eller flere gange i et FI program, og 60 pct. af disse deltog anden gang indenfor 2 år efter deres første deltagelse. Vi undersøger effekten af at deltage anden gang (udover effekten af at deltage første gang) ved at sammenligne de virksomheder, der deltager anden gang med virksomheder, som kun deltog én gang og som ydermere deltog i det samme program som den virksomhed, de er kontrol for i det samme kalenderår. Forskellen mellem de to grupper estimeres med en Fixed Effects difference-in-differences estimator. Det skal bemærkes, at populationerne kun er store nok til at foretage en økonometrisk analyse for fire af programmerne, nemlig for Innovationsnetværk (277 virksomheder deltager), Innovationskonsortier (55 virksomheder deltager), Videnpilot (74 virksomheder deltager) og Videnkupon (109 virksomheder deltager).

EXECUTIVE SUMMARY

This report provides the first descriptive statistics on multiple participation and seeks to:

1. Estimate the effect on TFP growth of second time program participation

In addition, we also seek to:

2. Estimate the effect on TFP growth of first time program participation (i.e. update CEBR, 2014), by using 4 more years of participants)
3. Understand how quickly these programs affect TFP growth
4. Investigate the heterogeneous effects of program participation

As this report is also partly intended as an update and extension of CEBR (2014) it uses the same sample selection of firms to facilitate comparison between the two reports: the main estimation sample thus contains all firms with less than 500 employees, who are at least 2 years old, have positive levels of full time equivalent workers, fixed assets and value added and who are found in the Statistics Denmark firm registers. We consider all firms whose first participation occurred between 2002 and 2013, i.e. 4 more years than that covered by CEBR (2014).

When estimating the effect of first program participation, we look only at those firms who participated in just one program during their first participation (94% of total participants). The effects of this participation are calculated in the years following this first participation but before any subsequent program participation. Similarly, the effects of second participation are estimated from firms who only participated in one program in their second year of contact in the years before any subsequent program participation. To be clear, firms are only omitted from the analysis if they participate in multiple programs *in the same year*. For instance, a firm who participated three times in three different years will be included in the calculation of the first participation effect, using only the year observations before their second participation. This firm will also be included in the estimation of second participation effects, using only those year observations that are before the third participation.

General characteristics of the multiple program participation

- 81% of the estimation sample is composed of firms who only participate once. The remaining 19% of firms participated at least one more time in a subsequent year
- 60% of firms who participate in a second program do so within 2 years of their first program participation.
- Approximately 70% and 85% of first time participants and second time participants, respectively, began the program after 2009.

Characteristics of participators relative to non-participators:

- Relative to the firms who do not participate, DASTI programs attract bigger, older firms that are more likely to be in manufacturing and less likely to be in construction and or to be a sole-proprietor
- Second time participants are even older and larger than first time participants and almost 50% of them are involved in manufacturing.

- First time participants of FP7 and Innovation Consortia tend to be larger, older and more likely to be in manufacturing whereas participants in Innovation Assistant and Innovation Voucher tend to be smaller than firms who do not participate.

Below the main results are summarized as follows: Section 4.1 presents the results on the effects of first time participation and compares them with the findings of CEBR (2014). Next, in Section 4.2, the effects of second participation are discussed. Section 4.3 investigates the annual effects, year by year, of first time program participation on TFP rather than the average annual effect on TFP as calculated in Section 4.1. Lastly, Section 4.4 summarizes the heterogeneous effects of first time participation for different types of firms.

1.1 AVERAGE EFFECTS OF FIRST PARTICIPATION

Table 1 presents the main findings in conjunction with the findings of CEBR (2014). The table presents the effects on average annual TFP growth, in percentage points, of having participated in a DASTI program that is large enough to analyze. The second and third columns present the effect of first program participation; the fourth column presents the effects of second program participation. The findings are:

- The average annual effects on TFP growth of Innovation network, Innovation Voucher and Industrial Ph.D. programs are relatively stable: despite the inclusion of four more years of participants, a substantial increase in sample size and a different estimation strategy, the estimates of TFP growth are exceptionally similar to that obtained by CEBR (2014) for these 3 programs: a statistically significant 3.6 and 4.1 percentage point increase in TFP growth enjoyed by Innovation network and Innovation Voucher participants, respectively.
- Both studies yielded insignificant effects close to 0 for participants in the Industrial Ph.D. program.
- No average annual effect is found for participants in the Innovation Assistant whereas CEBR (2014) found a marginally significant effect of 2.9 percentage points. The difference may be due to random variation (the current point estimate is within the 95% confidence interval of the CEBR (2014) estimate). As will be seen in Table 2 below, the average effect found for Innovation Assistant masks positive (significant) effects that take time to manifest.
- The effect of participating in Innovation Consortia has more than doubled since the last study to a strongly significant 6 percentage point increase in TFP growth.

Table 1

Effects on average annual TFP growth of program participation

	1st participation				**2nd participation**
	CEBR(2014)		Current Report		Current Report
Participation date range	2002-2009		2002-2013		2003-2013
Program					
Innovation Network	3.6	**	3.6	***	2.0
Innovation Voucher	3.6	*	4.1	***	-1.9
Innovation Assistant	2.9	*	0.8		3.5
Innovation Consortia	2.7		6.0	***	N.A.
Industrial Ph.D.	-1.2		-2.3		N.A.
Danish National Advancement for Technology Foundation	--.		-8.0	*	N.A.
FP7	--.		-0.3		N.A.

Source: InnovationDenmark Database and Statistics Denmark

Notes: The second and third columns display the effects on TFP growth from first-time participation, where the first column shows the program in which that participation occurred. The last column displays the effects on TFP growth from second-time participation where the first column displays the program in which that participation occurred irrespective of what program they participated in the first time. The number of years

from which the average is constructed varies according to the program and the length of time a firm is observed. Across program, approximately 50% of firms are observed for at least 3 years, but could have been observed for up to 11 years. See Table 7 for more detail. When sample sizes are below 30, no reliable estimate is available and N.A: is reported.. *** p<0.01, ** p<0.05, * p<0.1. Estimates rounded to the 10th decimal point.

The negative effects of first participation in the Danish National Advancement for Technology Foundation and FP7 are estimated (they were not included in CEBR, 2014), however these effects should be interpreted with extreme caution. They are based on a small number of firms (42 and 36 respectively).[5] The effects are either marginally significant or insignificant and have very large variances.

1.2 AVERAGE EFFECTS OF SECOND PARTICIPATION

This section summarizes the results on effects from second participation.6 The effects of second participation are estimated from firms who only participated in one program in both their first and second year of contact. Note that the first and second programs need not be the same.

- No statistically significant effects are detected. This is in part due to small sample sizes: Innovation Network (175), Innovation Voucher (112) and Innovation Assistant (46)
- Only the point estimates of the effect on TFP growth of second participations for Innovation Assistant lies above the point estimate of first time participation.
- Only the second participation effect for Innovation Voucher is statistically different from the first program participation effects if one is willing to accept and unconventionally lower level of confidence (80%). In that case, one can conclude that Innovation Voucher should prioritize firms who have not previously participated in a research and innovation program.

1.3 DYNAMIC EFFECTS OF FIRST PARTICIPATION

Rather than calculating the average annual effect on TFP growth over *all periods* after participation, Table 2 presents the annual effects on TFP growth one, two and three years after participation. Intuitively, the estimates presented in Table 1 are a weighted average of the estimates presented in table 2, where the weights are determined according to how many firms are observed 1, 2 and 3 periods after first program participation. As Table 1 combines all observations after participation to estimate an effect, the estimates are more precisely estimated. A drawback of looking at year by year growth is that the number of observations used in each estimate is smaller making it more difficult to estimate statistically significant effects.

Table 2

Dynamic effects on average annual TFP growth of first time program participation

	Effect on Annual TFP Growth						
Time period	t-1 to t	t to t+1		t+1 to t+2		t+2 to t+3 and beyond	
Innovation Network	0.1	3.5	**	2.3		4.7	***
Innovation Voucher	2.7	0.8		7.5	***	5.6	***
Innovation Assistant	-0.6	-3.5		3.9		4.2	**
Innovation Consortia	2.0	4.9		12.7	**	3.0	
Industrial Ph.D.	-3.0	-4.2		-8.1		2.3	
Danish National Advancement for Technology Foundation	-2.7	-9.2		-5.4		-7.1	
FP7	3.3	4.7		-13.2		6.1	

[5] For FP6 and FP7 DASTI (2015) finds insignificant effects on labor market productivity over five years using a sample of 110 initiating participants between 2002 and 2008.

[6] CEBR (2014) considered only first time participators and therefore these results are not comparable to any results therein.

Source: InnovationDenmark Database and Statistics Denmark

Notes: *** p<0.01, ** p<0.05, * p<0.1. t represents the year in which first program participation occurs.

Estimates rounded to the 10th decimal point.

The findings are:

- There are no immediate statistically significant results on TFP growth (i.e. growth from the year before participation to the year of participation) suggesting that the estimation strategy handles differences between firms who participate and those who do not, i.e. the selection of firms into the programs. Significant effects are detected for the largest programs, the top four programs listed, in part due to the more precisely estimated effects.
- Innovation Network displays rather quick effects on TFP growth that are relatively stable over time
- Innovation Voucher and Innovation Assistant take time to affect productivity growth. Effects on TFP growth take time to materialize for those who participate in Innovation Assistant: Growth is only positive from t+1 to t+2, and becomes significant only from t+2 to t+3. This pattern over time reveals why the average estimate in Table 1 was close to 0: the earlier 2 years of negative growth offset the positive growth that take time to manifest.
- Industrial Ph.D. displays increasing negative (but insignificant) effects until t+2 to t+3. If more time periods were available with sufficient sample size, positive and significant effects may be detected.
- Danish National Advancement for Technology Foundation shows consistent negative and insignificant effects and no clear pattern can be detected with participants of FP7. The results are not surprising given that the programs have few participants, 42 and 36 respectively.

1.4 HETEROGENOUS EFFECTS OF FIRST PARTICIPATION

According to the European Commission's State Aid rules, a YIC is defined as a small enterprise, that is less than 6 years old and that has an R&D intensity of at least 15% in the last three years or currently (for start-ups).[7] Following this standard, the effects of participation for those firms who are less than 6 years old are estimated. As 98% of the participants in the estimation sample have less than 250 full-time equivalent employees, the threshold often used to quantify "small enterprise", the effects estimated for the young firms are also the effects for small and young firms. As no information is available on R&D spending, this is the closest measure of a YIC that is possible. The results suggest that those participants that are less than 6 years old reap the largest benefits from first time participation in Innovation Network, Innovation Voucher and Innovation Assistant although the effects are not statistically significant.

As the size requirement of 250 employees is not informative in this sample, an analysis of small firms relative to other firm in the same industry is also conducted. That is, firms are classified as being above or below the median level of employees or capital in their particular industry, where median level is defined as the value of employees or capital such that 50% of the firms have employees or capital above and below. Participants in Innovation Network and Innovation Assistant with above median levels of employees or capital fare better. On the other hand, participants in Innovation Voucher with lower than median level of employees or capital see the largest gains. The dynamic specification shows that the large gains experienced by small firms manifest one year after program participation and quickly drops away, while the productivity growth of larger firms takes time to realize. Two and three periods after participation, firms with larger levels of employment or capital experience large and significant increases in productivity growth. However, the differences in effects between young and old, small or large are not statistically significant. This is not to say that

[7] If R&D intensity of at least 15% in the last three years or currently (for start-ups) is not fulfilled, a company can still be a YIC if it has been "certified' by external experts on the basis of a business plan, as capable of developing products or processes which are technologically new or substantially improved and which carry a risk of technological or commercial l failure, see Schneider & Veugelers (2010) for more detail

differences do not exist, just that we do not have larger enough samples (i.e. small enough variances) to detect a difference.

The rest of the report is organized as follows. Chapter 5 describes and discusses the methods used in the analysis, chapter 6 describes the estimation sample and highlights the descriptive characteristics of program participants and firms who did not participate; chapter 7 presents the results and chapter 8 concludes. A technical description of the methods is reserved for the Appendix, as well as more detail regarding descriptive statistics and variable definitions can also be found in the Appendix.

1. INTRODUCTION

Over the past decades, the US has seen higher growth in productivity than European countries (e.g. Productivity Commission Report, 2014). Seeking to lessen this gap, the Danish Agency for Science, Technology and Innovation (DASTI) and now also the Innovation Fund offer many different innovation support programs designed to increase R&D activities and spur innovation, and thereby the productivity of Danish firms. This is done, for instance, by providing funds for Research and Development (R&D), encouraging collaborative research and by building bridges between private and public R&D.[8] The link between R&D, innovation and productivity is well established prompting these programs to foster R&D so as to increase process and/or product innovation and consequently increase productivity.[9] This report seeks to evaluate the effect on productivity growth of participating in a DASTI program.

Program participation is predominantly by application and some firms have, over the years, participated in several programs (either the same program or different programs).[10] An important question is whether there are larger effects from participating more than once. The policy question is: Should DASTI prioritize awarding the same firm multiple participation opportunities or target new firms who have not yet participated? That is, are there economies of scale in program participation or not? This report also tries to describe and quantify the effect of second program participation in select programs (large enough to study) in order to compare it to the effect of first time program participation in an attempt to answer this question.

Programs may prove more effective for certain types of firms. Perhaps young, small firms realize relatively larger benefits. The heterogeneity of program participation effects will be investigated for the best available measure of young innovative companies (YICs) for those programs where enough firms (both YICs and larger, more established firms) have participated.[11]

In addition, this report updates and extends CEBR's 2014 report titled "The Short-run Impact on Total Factor Productivity Growth". CEBR (2014) estimated the effect of first time participation only, using register data on firms whose program participation was during the years 2002-2009. This report extends CEBR (2014) by considering firms whose program participation was during the years 2002-2013. In addition, the effects of second time program participation is investigated as well as the potentially heterogeneous effects of program participation for different types of firms and how quickly firms realize the benefits of program participation. Following CEBR (2014), this report also considers TFP growth as opposed to labor productivity growth.[12] TFP captures how efficiently a firm transforms inputs such as labor and capital into output as opposed to labor productivity which simply measures the efficiency of labor.

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[8] The reader is referred CEBR(2014) for a thorough description of the specific Danish Agency for Science and Technology initiatives analyzed herein. A list of the correspondence between Danish and English program names is provided in Appendix 3.

[9] See Hall (2011) & Hall, Mairesse, & Mohnen (2009) for reviews.

[10] The exception in Innovation Network

[11] Firm age is defined according to the receipt of a new CVR number, hence a re-organized firm will be considered as a new firm

[12] Thus this analysis of Innovation Voucher differs from Schneider & Sørensen (2015) in two respects: (1) they consider labor productivity, not TFP and (2) they look at the effect on the *level* of labor productivity whereas the focus here is on the *growth* in productivity.

2 GENERAL METHOD

Assessing the impact of first program participation on productivity is complicated by two main issues. First, productivity is not directly observable. That is, we only observe value added, number of employees, fixed assets, materials and the industry in which a firm operates. From this information, we must form an estimate of how efficiently firms are able to transform these inputs into their output good, i.e. the firm's total factor productivity. This process entails first estimating each industry's technology (the way in which inputs are combined to create output), then using this information to back out how efficiently each firm uses this technology, their TFP. A commonly used technique in the academic literature is used for this estimation, Appendix 2 provides details. As TFP is a byproduct of this first estimation of industry technology, it is important that this first estimation is done as accurately as possible. For this reason, technology is estimated within narrowly defined industries.[13]

Second, as program participation is not random, construction of a valid comparison group (one that will enable a causal analysis) is not straightforward. Assume for the moment that true productivity growth is observed. If those who have higher levels of TFP growth ex-ante are more likely to be involved in a program, simply comparing them to firms who did not participate will lead to a positively biased effect of program participation: did the program really increase productivity growth or is this simply a result of the fact that those firms who were participating were already high growth firms?

Given the repeated observation of firms over time, time-invariant differences in productivity growth across firms can be eliminated by using a before and after comparison: subtract growth before program participation from growth after program participation to form an estimate of the effect of the program. The problem with this approach is that changes in macroeconomics conditions coinciding with the implementation of the program would bias the estimates. Consider a large negative macroeconomic shock (i.e. the financial crisis) that manifests in the year the program begins. The before/after comparison would most likely yield a negative effect as any positive effects from program participation would be swamped by the large negative effect of the crisis.

To correct for this problem, an approach called Difference in Differences method can be used (DID), the details of which are presented in Appendix 2. The trend in productivity growth for those firms who do participate is subtracted from the trend in productivity growth for those who did not participate, i.e. difference in differences. This method corrects for selection on time invariant firm characteristics across participants and non-participants and accounts for aggregate time effects. The underlying assumption is that the productivity growth trend of participants would have been the same as non-participants. If this is true, the difference in productivity growth between participants and non-participants can be attributed to program participation. If firms choose to participate based on a time varying characteristic, i.e. a great idea, this estimation strategy will not yield causal estimates. The best way to attain causal estimates in this case is through randomized participation, which is not feasible with the current data.[14]

Figure 1 presents the desired result of this estimation technique visually. For simplicity, the graph is drawn such that the growth rates prior to participation are the same for firms who do and do not participate (and is zero), though it is important to recognize that this need not be the case. In fact,

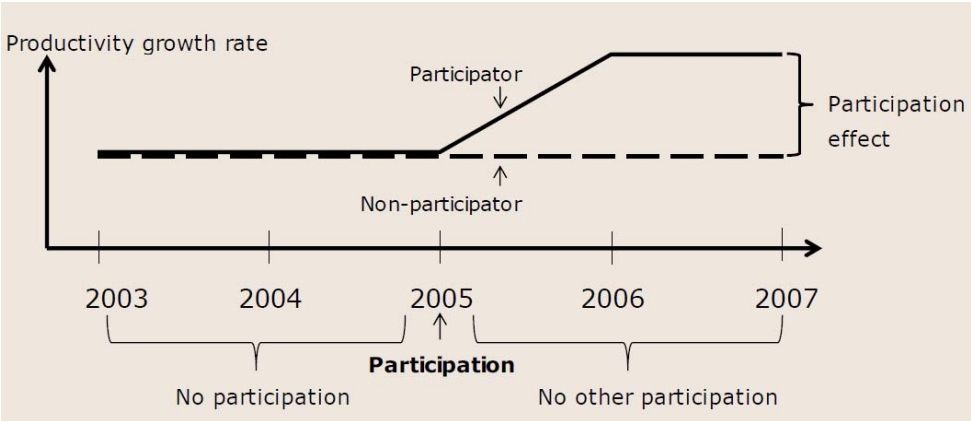
[13] At the 2-digit nace level

[14] Other options to attain causal estimates include estimating a lagged dependent variable model,or instrumental variable estimation. CEBR (2014) uses a simple LDP-approach to estimate a lagged dependent variable model, and an IV-approach following Anderson and Hsaio (1981). No instrument for participation is available See Schneider & Sørensen (2015) for analysis in a lottery setting.

given the voluntary nature of the programs, differences between participators and non-participators are expected. The estimation technique removes such differences. In this example, program participation occurs in 2005. Obviously, we do not observe the TFP growth rate they would have had had they not participated. Therefore in 2006 and 2007 we need to make a comparison to firms who never participate. Assuming that the trend in TFP growth of participators and non-participators is the same both before and after the program participation date allows this comparison to be made. [15] This assumption is reflected by the fact that the slope of the productivity growth of participators and non-participators is the same (in the illustration, this trend is 0).

Figure 1

Illustration of participation effect



Notes: reproduced from CEBR (2014)

An implicit assumption of Figure 1 is that the effect of the program is immediate and permanent: in 2006 productivity growth is immediately affected and remains at that higher level in 2007. There is no need to make such a strong assumption. Perhaps TFP growth increases gradually, increasing from 2006 to 2007. Therefore a model that estimates a single one time permanent increase in TFP growth will be estimated along with a model that allows TFP growth to evolve over time. Appendix A.2.2.2 provides the econometric details. If interest lies only in the effects of first time participation, using the more parsimonious model would suffice to yield the average annual effect on TFP growth after program participation. The advantage to this approach is that it pools all periods after program participation to estimate one parameter (the single and permanent effect on TFP growth) and in so doing "increases the sample size". The disadvantage of this approach is that it may mask important dynamics in the evolution of firm productivity over time. In particular, this dynamic component of TFP estimation must be considered when estimating the effect of second program participation. Finally, a similar estimator, the difference in difference in differences (DIDID), will also be used to isolate the effects of program participation on young and small firms. Conceptually, the de-trending described above is performed within a particular group. That is, small/large firms who participate are compared to small/large firms who did not participate and young/old firm are compared to young/old firms who did not. The details of this estimation are elaborated in Appendix 2.

[15] This is the classical problem of constructing a counterfactual: the program evaluation question is in fact whether the firms who participated do better than had they not participated. Since a firm cannot be both participate and not participate at the same time, an estimation technique must be chose to construct a valid counterfactual.

The DID estimate can be implemented in a variety of ways. The most common implementation uses linear regression techniques. Similar to CEBR (2014) which uses linear regression, this estimation strategy will be used to estimate the effects of first time program participation. The number of full time employees, the capital level, firm age, firm ownership type, and industry will also be included in the regression to address compositional differences between participants and non-participating firms.[16]

One of the analytical questions in this report is to look at the (relative) effect of multiple program participation. The estimation above is necessary in order to calculate the effectiveness of first time program participation for each program to which estimates of second time participation can be compared.[17] The trend after the first participation is assumed to be the same for those who participate once and those who participated twice. In reality, for a given second program, firms could have participated in one of several first time programs. This makes the issue of isolating the effect of second program participation more difficult than that of first time participation. First, the effects for the first time participation need to be removed, and then the effect of the second participation can be calculated. The combination of dynamic effects of program participation, first program participation occurring in multiple calendar years, second program participation occurring after varying amounts of time after the first program participation and the myriad of possible first and second program type combinations makes estimating the effects of second program participation intractable within the linear DID regression framework.[18]

Instead nonparametric DID matching proves to be the much better alternative and is conceptually quite clear.[19] The estimation only considers those who have participated at least once, reducing the sample size dramatically and thereby making non parametric matching feasible. (Due to the large sample sizes, this technique is not feasible for estimating first time effects). A firm who participated twice is exactly (if possible) matched to a firm who did not have a second participation and whose first participation *was in the same year and in the same program* as their own. By matching not only to the same first program, but also to the year in which that program was begun, the evolving productivity growth effects from first time program participation are netted out.

Only those firms who participated once in the first year of contact and either once in a subsequent year of contact or not at all are studied (participating in a 3rd or fourth year is fine). To be clear, we look at all firms regardless of how many times they participated as long as, in a given year, they participated only once. For instance, a firm who participated three times in three different years will be included in the calculation of the first participation effect, using only the year observations before their second participation. This firm will also be included in the estimation of second participation effects, using only those year observations that are before the third participation. A firm who participated in only two programs but participated in those two programs in the same year is not included as the second time participation effect cannot be differentiated from the first time participation effect. Finally, only those firms whose second participation was in Innovation Network, Innovation Voucher or Innovation Assistant are considered due to sufficient sample size.

[16] See Appendix for details.

[17] Another source of multiple program participation is within a year: some firms simultaneously participate in multiple programs in a given year providing another possible source of identification, however sample sizes were too small.

[18] If the objective were to compare the effect of second time participation in any program relative to a particular first time program, this would not be nearly as difficult to nest within the linear model.

[19] As discussed in the appendix, this is matching on the Mahalabobis distance, not on a (parametric) propensity score estimated from a logit/probit. Because of this, the computational burden is large.

3 DESCRIPTIVE STATISTICS

3.1 CREATION OF SAMPLE

Appendix 1 details the creation of the estimation sample. All firms – participants and non-participants - used in the analysis must have met the following criteria to be included in the estimation sample:

- Were private, rather than public institutions
- Matched with the Statistics Denmark register in the year of program participation*
- Had a first program participation year between and including 2002-2013
- Had less than 500 employees*
- Had non-missing information and positive values for full-time equivalent employees, fixed assets, and value added*
- Had non-missing information for industry*
- Were at least 2 years old – a necessary requirement for the estimation strategy*
- Non-participating firms must be in a narrowly defined industry in which at least one participator operates*; that is, firms in industries where no participators are present are dropped

Where * indicates that the same selection criteria was used in CEBR (2014). The firm size restriction is in place to maintain consistency with the earlier report, where it was originally imposed to eliminate firms for whom a valid comparison group would be difficult to find. This restriction drops less than 3% of firms. The remaining estimation sample contains 3,379 program participants and 162,597 non-participants. The sample sizes are considerably larger than those used in CEBR (2014): 1,140 participants and 87,719 control firms. The main reason for this increase is that the current report includes those with program participation dates between 2002-2013 inclusive, as opposed to 2002-2009. This, coupled with increasing enrollment in DASTI programs, yields the larger sample sizes.[20]

3.2 MULTIPLE PARTICIPATION

Tables 3-5 present some descriptive statics regarding the multiple program participation of program participants. Table 3 presents the 3,379 firms that participated at least once, counted in the year during which their first participation occurred. 2,748 of these firms participated only once. 631 firms participated in one program in their first year of contact and subsequently participated in one program during their second year of contact (note that this second year of contact need not be the second calendar year after the first year of contact). The main points are summarized below:

General characteristics of the multiple program participation

- 81% of the estimation sample is composed of firms who only participate once. The remaining 19% of firms participated once in their second year of contact and may have participated again in subsequent years.
- 60% of firms who participate in a second program do so within 2 years of their first program participation.

[20] That is, the current report does not require 2 years beyond the first year of participation in addition to two years before program participation.

- Approximately 70% and 85% of first time participants and second time participants, respectively, began the program after 2009.

Table 3

Multiple program participation

Total Participations	Estimation sample	
Participated only once	2748	81%
Participated (at least) twice	631	19%
Total	**3379**	**100%**

Source: InnovationDenmark Database and Statistics Denmark

Table 4

Time between first and second participation

Number of years between first and second participations		
1	206	33%
2	169	27%
3	121	19%
4	51	8%
5 or more	84	13%
Total	**631**	**100%**

Source: InnovationDenmark Database and Statistics Denmark

Table 5

Distribution of participators by start year

Program Start Year, First Time			Program Start Year, Second Time		
2002	7	0%			
2003	31	1%			
2004	74	2%	Before 2005	6	1%
2005	83	2%	2005	6	1%
2006	159	5%	2006	13	2%
2007	110	3%	2007	12	2%
2008	279	8%	2008	26	4%
2009	393	12%	2009	42	7%
2010	606	18%	2010	108	17%
2011	449	13%	2011	119	19%
2012	508	15%	2012	107	17%
2013	680	20%	2013	192	30%
Total	**3379**	**100%**	**Total**	**631**	**100%**

Source: InnovationDenmark Database and Statistics Denmark

Table 6 describes the distribution of firms across program type for the entire estimation sample (last two columns) and according to whether the firm only participated once (the first two columns) or more than once (the third and fourth columns). 90% of the firms in the estimation sample are involved in one of 3 programs during their first year of contact: 47% participate in Innovation Network, 21% in Innovation Voucher, and 22% participate in Innovation Assistant. Those firms who participate multiple times are more likely to have participated in Industrial Ph.D. or Innovation Consortia and less likely to have participated in Innovation Voucher or Innovation Assistant.

Table 6

Distribution of estimation sample across first program type

First Program	Firms that only participated once		Firms that participated twice		Total Estimation Sample	
EU's 6	24	1%	15	2%	39	1%
Industrial Ph.D.	58	2%	41	6%	99	3%
FP7	16	1%	20	3%	36	1%
Gazelle Growth	10	0%	5	1%	15	0%
Danish National Advancement for Technology Foundation	25	1%	17	3%	42	1%
Innovation Consortia	62	2%	55	9%	117	3%
Innovation Network	1304	47%	277	44%	1581	47%
Innovation Voucher	587	21%	109	17%	696	21%
Innovation Assistant	617	22%	74	12%	691	20%
Open Funds	26	1%	11	2%	37	1%
Other	19	1%	7	1%	26	1%
Total	**2748**	**100%**	**631**	**100%**	**3379**	**100%**

Source: InnovationDenmark Database and Statistics Denmark

This table provides the distribution of firms across first program type in the year of first participation. Firms are differentiated here according to whether they only participated once (first two columns) and firms that participated twice (including those that may have participated 3 or more times).

Almost half of all firms participating a second time do so through the Innovation Network program. Almost 80% of second time participants are involved in one of three programs during their second participation: Innovation Network, Innovation Voucher or Innovation Assistant. Almost half of second time participators had a first program of Innovation Network, 12% and 10% were involved in Innovation Consortia and Innovation Assistant respectively.[21]

As described in Table 3, the estimation sample contains 3379 firms with non-missing information around the year of first participation, 631 of these firms participate a second time. Panel (A) of Table 7 provides more details regarding the length of time firms are observed by first program type. The column labeled "Immediate" lists the number of firms for whom we observe non-missing growth, from the year before program participation to the year of program participation, as well as non-missing covariates. The column total is the full estimation sample. A subset of these firms , 2588 or about 75%, have all requisite information in the year following first participation, 1965 firms or about 58% two years following the first year of participation, and 1609 or about 48% are observed 3 or more years after the year the first program began. It is important to recognize that these drops in sample size are for the most part expected. Table 5 provides the distribution of firms over their program start year. For instance, 680 of the 3379 firms start their program in 2013, therefore we observe them immediately but cannot observe them one year later as our dataset only extends to 2013. In other words, we would expect to see 2699 firms one year later. As the second column in Panel (A) shows, we see only 2588, or 111 less firms. These 111 firms may have closed, changed ownership type, or become too small to be included in the register. As discussed in Appendix A.2.2., estimation techniques are available to address selection due to exit; however the

[21] Appendix tables A3 and A4 provided a bit more detail, though limited, due to data confidentiality.

register data cannot distinguish which firms exit, are acquired or merge with other firms[22] Reassuringly, relatively few (about 4%) firms are lost.[23]These numbers are important in interpreting the dynamic effects that will be estimated. The immediate impact of the program will be estimated from the full estimation sample, the effect one year out will be estimated from 75% of the estimation sample and the effect two years out will be estimated from 58% of the sample. The average effect after 2 years will be estimated from the 48% of firms observed for that length (in each year that they are observed). This is the sample from which effects of first time participation will be estimated using the difference in differences estimator.

Panel (B) of Table 7 presents the same information for just those firms that participate (at least) twice, by *second program type.* Not all of these firms have non-missing information in the year of *second participation.* That is, they had the needed information to estimate the effect of *first participation,* but no restriction has yet been made on non-missing information in the second year of participation. Panel (C) imposes this restriction, very few records are lost. As is clear from Panel (C), sample sizes are quite small for many of the programs. For this reason, only effects of second participation in Innovation Network, Innovation Assistant and Innovation Voucher will be estimated. The sample displayed in Panel (C) will be used in the matching analysis to estimate the effects of second time participation.

[22] Determining the reason a firm ceases to exist is difficult, if not impossible, with the given registry data as changes in the CVR are not accompanied by a reason (i.e. closure, bankruptcy, merger, etc).

[23] As this attrition may be due to closure (a bad outcome) or merger, acquisition or sale (possibly good outcomes), we cannot sign the bias this may have on our estimates.

Table 7
Distributions of estimation sample across length of observation

(A) First Program	First year	Last Year	After first participation Non-missing information for first participation			
			Immediate	1 year later	2 years later	3 or more years later
Industrial Ph.D.	2002	2013	99	87	75	71
FP7	2007	2013	36	31	28	26
Danish National Advancement for Technology Foundation	2005	2013	42	35	23	22
Innovation Consortia	2003	2013	117	109	98	87
Innovation Network	2003	2013	1581	1114	896	735
Innovation Voucher	2010	2013	696	549	406	308
Innovation Assistant	2005	2013	691	553	343	265
Other			117	110	96	95
Total			**3379**	**2588**	**1965**	**1609**

Source: InnovationDenmark Database and Statistics Denmark

(B) Second Program	First year	Last Year	After second participation Non-missing information for first participation			
			Immediate	1 year later	2 years later	3 or more years later
Industrial Ph.D.	2005	2013	26	20	16	12
FP7	2007	2013	26	21	11	10
Danish National Advancement for Technology Foundation	2006	2013	27	21	15	10
Innovation Consortia	2004	2012	27	26	22	17
Innovation Network	2003	2013	307	182	153	89
Innovation Voucher	2010	2013	113	88	59	34
Innovation Assistant	2005	2013	77	46	25	13
Other			28	25	20	15
Total			**631**	**429**	**321**	**200**

Source: InnovationDenmark Database and Statistics Denmark

(C) Second Program	First year	Last Year	After second participation Non-missing information for first and second participation			
			Immediate	1 year later	2 years later	3 or more years later
Industrial Ph.D.	2005	2013	25	16	13	10
FP7	2007	2013	25	20	11	10
Danish National Advancement for Technology Foundation	2006	2013	27	20	13	9
Innovation Consortia	2004	2012	27	25	21	16
Innovation Network	2003	2013	302	175	144	83
Innovation Voucher	2010	2013	112	84	57	32
Innovation Assistant	2005	2013	77	46	23	13
Other			27	25	20	15
Total			**622**	**411**	**302**	**188**

Source: InnovationDenmark Database and Statistics Denmark

3.3 SUMMARY STATISTICS

Table 8 presents summary statistics for all variables used in the analysis for first time participators, non-participators, and second time participators respectively. The information is also provided at the program level in Appendix tables A7-A9. [24]The main points of these tables are summarized below:

Characteristics of participators relative to non-participators:

- Relative to the non-participating firms, DASTI programs attract bigger, older firms that are much more likely to be in manufacturing and less likely to be in construction and are less likely to be a sole-proprietor
- Second time participants are even older and larger than first time participants and almost 50% of them are involved in manufacturing.
- First time participants of FP7 and Innovation Consortia tend to be larger, older and more likely to be in manufacturing whereas participants in Innovation Assistant and Innovation Voucher tend to be smaller than firms that do not participate.

[24] These are provided as the estimations are performed at the program level.

Table 8

Variable summary statistics across program

	Number of firms	Measure	Productivity Growth, Lagged	Productivity Growth	Value Added, MM DKK	Number of FTE	Fixed Assets, MM DKK	Age of Firm	% in Business Services	% in Manufactur.	% in Trade and Transport	% in ICT	% in Construction	% Sole Proprietors	% Limited Liability
All first time participators	3379	mean	0,09%	-0,23%	25,8	38	47,7	16	19%	35%	28%	11%	6%	5%	25%
		s.e.	0,89%	0,81%	1,1	1	6,6	0	1%	1%	1%	1%	0%	0%	1%
		median	-0,83%	0,35%	7,7	14	2,7	12							
All second time participotors	622	mean	-0,69%	-1,93%	46,9	60	62,5	19	18%	47%	21%	11%	2%	2%	17%
		s.e.	1,73%	2,12%	6,0	3	11,9	1	2%	2%	2%	1%	1%	1%	2%
		median	-0,13%	1,17%	13,7	25	5,4	16							
Control	162597	mean	0,84%	-0,88%	5,1	9	8,6	12	15%	12%	44%	4%	20%	31%	39%
		s.e.	0,06%	0,06%	0,0	0	0,3	0	0%	0%	0%	0%	0%	0%	0%
		median	0,47%	0,15%	1,8	3	0,9	9							

Source: InnovationDenmark Database and Statistics Denmark

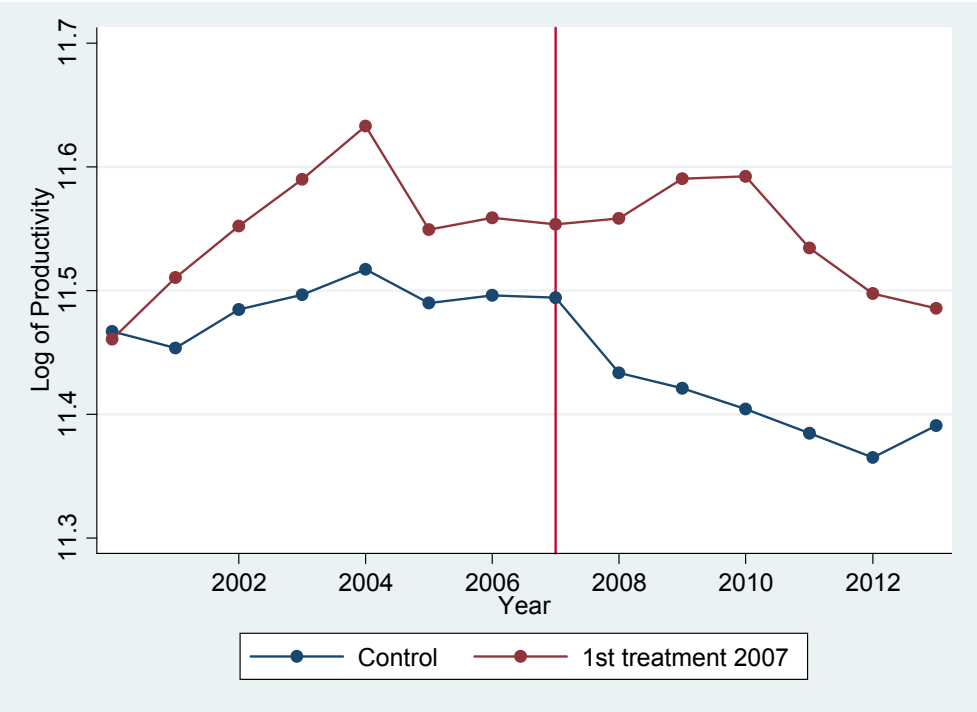
Notes: In cells where the number of firms that can be identified is less than or equal to 5, the value NA is reported. All monetary figures are presented in millions of 2010 DKK. The figures for the firms who did not participate, 162,597 firms, are calculated from all years that they are observed.

The econometric technique that is employed to estimate the effects of program participation eliminates time invariant aspects of firm growth as well as accounts for differences in firm size, age, ownership structure and industry between participators and non-participators.

Figure 2 displays a plot of the raw log productivity for those firm whose first participation occurred in 2007 (the red line) against the raw log productivity for those firms who did not participate in any program (the blue line). Appendix 3 provides the analogous plots for program participants whose year of first participation occurred in other years. Each plot displays the firms who did not participate against firms whose first participation occurred in the labeled year. A vertical line is placed on the year in which program participation began. Note that by definition, the log productivity series for firms who did not participate is the same across all plots. Plots for 2002 through 2004 are not included due to the small number of participants in those years. In addition, the appendix displays plots of raw log productivity growth over time for all firms who did not participate in a program.

Figure 2

Plots of raw log productivity for firms whose first participation was in 2007 against firms who did not participate



Source: InnovationDenmark Database and Statistics Denmark

Notes: For brevity"Control " here corresponds to non-participating firms. see appendix A.2.2.1 for details of the productivity estimation

The figures clearly show that participants generally have higher productivity ex-ante and that, for all firms, productivity is generally decreasing from 2004 onward. Productivity is more volatile for those firms who participate, at least in part due to the smaller sample sizes. The growth in TFP is more volatile than the level of TFP. These are the figures from which common trend assumptions needed for the difference in differences analysis should be checked. Across graphs, the common trend

assumption seems plausible, especially given that these are unconditional plots, i.e. they do not adjust for differences in age, size, firm ownership type or industry. However, an additional check should be performed within the difference in differences estimation to provide additional evidence. Specifically, the effect of the program in the year in which the program began, i.e. the effect on growth from t-1 to t, will be estimated. Given that we are considering TFP growth, we should be worried if we detect an effect so soon – this would suggest that our common trends assumption was not met and selection was not sufficiently handled. The estimation of the pre-participation TFP development shows that there is no significant effect.

4 RESULTS

Chapter 7 presents the main estimation results. First, results on the effect of TFP growth from first program participation are discussed. The average effects are presented in section 7.1.1. and the dynamic effects in section 7.1.2. Section 7.1.3 explores to what extent these effects are heterogeneous with respect to firm size and age. Finally, Section 7.2 presents the effects on TFP growth of second program participation.

4.1 EFFECTS OF FIRST TIME PROGRAM PARTICIPATION

Average effect on annual TFP growth

Panel (A) of Table 9 "Average effect on annual TFP growth", displays the results from the parsimonious model specification corresponding to estimation equation (4) in the Appendix. For ease of reference, Panel (B) provides the estimates found by CEBR(2014). Each column of Table 9 corresponds to the first program in which a firm participated. The row labeled "0" in Panel (A) presents the effect on TFP growth during the period in which the firm began the program. That is, this row presents the effects on TFP growth from the period before program participation to the period in which program participation began. To the extent that firms do not reap the benefits immediately in the year that they begin the program – especially in the form of TFP growth - it is expected that these coefficients ought to be close to 0 and insignificant. In fact, these coefficients serve as a check on our difference in differences identification strategy: If the trend in non-participating firms and participating firms prior to treatment is the same, the difference in differences estimates should be effectively 0 and insignificant in a period in which there is "no treatment". Reassuringly, none of the immediate effects are significant. The point estimates for 2 of the biggest programs, Innovations Network and Innovation Assistant are 0 to the third decimal point. The point estimate for Innovation Voucher is insignificant, but is close to 3. It is important to note that an alternative specification, one that excludes participants in 2008 and 2009, yields a point estimate close to 0 and yet continues to yield positive and significant results, suggesting that the positive results to be discussed below are not driven by participants in Innovation Voucher having higher TFP growths ex-ante. The remaining programs have immediate effects between -3 and 3 percentage points, though none are significant and based on much smaller samples.

Table 9

Average effect on annual TFP growth, fixed Effect difference in differences, effect on tot al factor productivity of first program participation

Average effect on annual TFP growth	Years after particpation	Innovation Network	Innovation Assistant	Innovation Voucher	Innovation Consortia	Industrial Ph.D.	DNATF	FP7
(A) Current Report	0	0.0006	-0.0065	0.0270	0.0209	-0.0294	-0.0274	0.0328
		(0.0138)	(0.0198)	(0.0204)	(0.0442)	(0.0470)	(0.0787)	(0.0729)
	>=1	0.0356***	0.0079	0.0410***	0.0596**	-0.0228	-0.0804*	-0.0029
		(0.0084)	(0.0136)	(0.0122)	(0.0237)	(0.0289)	(0.0486)	(0.0711)
Number of firms		164,178	163,288	163,293	162,714	162,696	162,639	162,633
Number of obser-vations		883,072	873,647	874,464	868,664	868,390	867,928	867,893
Number or participants		1581	691	696	117	99	42	36
(B) CEBR 2014	>=1	0.0361**	0.0292*	0.0356*	0,0274	-0,0124	--	--
		(0.0140)	(0.0149)	(0.0204)	(0.0182)	(0.0392)		

Source: InnovationDenmark Database and Statistics Denmark

Notes: In Panel (A), robust standard errors in parentheses, Not shown, but included in all regressions in Panel (A) are year indicators, lags of the following variables: 3 digit industry dummies, firm ownership indicators, firm age, log of labor, and log of capital as well as 3-digit industry indicators. Growth at time t is defined as tfpt – tfpt-1 . The row labeled "Year after participation 0" refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. The row labeled >=1 displays the changes in average growth rate from t+1 to t+2 and beyond. Panel (B) presents results from column 3 of Table 5.2 from CEBR(2014), Effects for DNATF and FP7 were not estimated in CEBR(2014).*** p<0.01, ** p<0.05, * p<0.1.

The row labeled ">=1" presents the average annual effect on TFP growth over all years after the year the program was joined. The statistically most significant effect of program participation is present for those whose first program was Innovation Network. On average, the annual TFP growth rate increased by 3.56 percentage points. This estimate is exceptionally close the estimate of 3.6 percentage points attained by CEBR (2014) suggesting that the effectiveness of the program is quite stable over time. The largest positive effect of participation is found for those whose first participation is Innovation Consortia. The (statistically significant) effect of participation is about 6 percentage points, more than double the (insignificant) effect of 2.7 percentage point increase found in CEBR(2014). Those whose first program was Innovation Voucher also experienced a significant and positive average 4.1 percentage point increase in TFP growth after participation. This estimate is larger than the 3.6 percentage point growth found in CEBR (2014). On the contrary, those firms whose first program was Innovation Assistant experienced an insignificant increase in TFP growth of 0.8 percentage points, lower than the marginally significant 2.9 percentage point increase reported by CEBR (2014). Consistent with CEBR (2014), those firms whose first program was the Industrial Ph.D. saw a negative and insignificant effect on TFP growth. The only (marginally) significant and negative effect of participation was found for those whose first program was Danish National Advancement for Technology Foundation, the effect of participation being a decrease in average productivity growth of about 8 percentage points. However, this estimate is based on very few firms, 42, and should be interpreted with caution. Those firms whose first program was FP7 experienced no significant change in TFP growth, again, this estimate is based on very few observations, only 36 firms. CEBR (2014) did not analyze either the Danish National Advancement for Technology Foundation or FP7. Appendix Figure A3 presents the results graphically.

Dynamic Effect on annual TFP growth

As mentioned in the general methods chapter, the above average effects may mask important dynamic behavior which is of interest in itself and they are at the same time necessary to consider when estimating the effects of second program participation. Table 10 presents the dynamic effects, a result of estimating equation (5) in the Appendix. The row labeled 0 has the same interpretation as described above. The row labeled "1" presents the effect on TFP growth from the period in which the program began to the following year. This coefficient is estimated from all firms whose first participation occurred before 2013 and who are observed [25]one year after participation, that is, the firms listed in the column titled "1 year later" in Panel (A) of Table 7. The row labeled "2" presents the effect on TFP growth from one year after program participation to two years after program participation and is estimated from those whose first program participation occurred before 2012 and who are observed two years after participation, corresponding to the column titled "2 years later" in Panel (A) of Table 7. The row labeled "3" captures the average effect on TFP growth for all years thereafter and is estimated by firms whose first participation occurred before 2011 and who participated at least three years after participation corresponding to the number of firms listed in the column titled "3 or more year later" in Panel (A) of Table 7. All years after the second year are pooled in this estimate.

Table 10

Dynamic effects on annual TFP growth

Dynamic Effect on annual TFP	Years after particpation	Innovation Network	Innovation Assistant	Innovation Voucher	Innovation Consortia	Industrial Ph.D.	DNATF	FP7
	0	0.0007	-0.0061	0.0268	0.0203	-0.0298	-0.0273	0.0327
		(0.0138)	(0.0199)	(0.0204)	(0.0443)	(0.0470)	(0.0789)	(0.0729)
	1	0.0351**	-0.0349	0.0079	0.0492	-0.0417	-0.0924	0.0468
		(0.0148)	(0.0233)	(0.0264)	(0.0421)	(0.0480)	(0.0827)	(0.1185)
	2	0.0234	0.0390	0.0750***	0.1267**	-0.0813	-0.0535	-0.1317
		(0.0163)	(0.0314)	(0.0245)	(0.0511)	(0.0843)	(0.1550)	(0.1324)
	>=3	0.0469***	0.0419**	0.0559***	0.0301	0.0231	-0.0714	0.0606
		(0.0153)	(0.0180)	(0.0156)	(0.0441)	(0.0378)	(0.0833)	(0.0546)
Number of firms		164,178	163,288	163,293	162,714	162,696	162,639	162,633
Number of observations		883,072	873,647	874,464	868,664	868,390	867,928	867,893
Number or participants		1581	691	696	117	99	42	36

Source: InnovationDenmark Database and Statistics Denmark

Notes: Fixed Effect difference in differences, effect on total factor productivity of first program participation. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Not shown, but included in all regressions are year indicators, lags of the following variables: 3 digit industry dummies, firm ownership indicators, firm age, log of labor, and log of capital as well as 3-digit industry indicators. Growth at time t is defined as tfpt – tfpt-1. The row labeled "Year after participation 0" refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. The row labeled 1 refers to differences in growth from t to t+1 and the row labeled 2 refers to differences in growth from t+1 to t+2. The row labeled >=3 displays the changes in average growth grate from t+2 to t+3 and beyond.

Assuming that the underlying volatility in TFP growth is constant over time, we would expect due to shrinking sample sizes that the standard errors should be smallest in the year of program

participation and increase 1 and 2 years after. Because the estimated effect in the row labeled 3 is actually estimated from all years beyond 2, the size of the standard error is pushed up due to the smaller number of firms but also pushed down due to the repeated observation of firms after the second period.

Turning to the third column of Table 10, the effects of program participation are rather immediate for those firms that participated first in Innovation Network: growth from t to t+1 (t denoting the year in which the program was begun) is a significant 3.5 percentage points higher than those firms who did not participate in any program. The point estimate for the effect on growth from t+1 to t+2 is 2.3 percentage points, but is insignificant. The average effect on annual growth from t+2 and beyond is an economically and statistically significant 4.7 percentage point increase.

The fourth column presents the effects of first time participation for those firms that engaged in the Innovation Assistant program. Interestingly, although the average effect on growth for participating in this program was insignificant in Table 9, Table 10 reveals that there are positive and significant effects – they just take time to materialize. In fact, the average annual effect on TFP growth is economically and statistically significant, a 4.19 percentage point increase from t+3 and onward. That is, the average effect on growth from t+2 to t+3, t+3 to t+4, etc. is large and significant. The insignificant results displayed in Table 9 are a result of the averaging of this effect with the insignificant effect seen in period t+1 and t+2.

Similarly, the estimated dynamic effects for those firms who participated in Innovation Voucher take time to manifest. Significant point estimates appear 2 periods after program participation (i.e. growth from t+1 to t+2 and onward). Growth for participants is a strongly significant 7.5 and 5.6 percentage points higher 2 and 3 years after the start of the program.

Turning to the effects of participating in Innovation Consortia, the dynamic effects reveal a very large effect, almost 13 percentage points, materializing 2 years after participation. This effect is clearly driving the average effect displayed in Table 9.

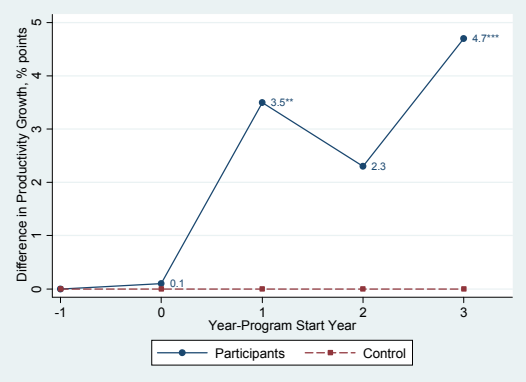
Not surprisingly due to the small sample sizes, no effects are significant for the Industrial Ph.D., Danish National Advancement for Technology Foundation, or FP7 programs. That is, although there are a large number of firm in the regressions, the number of firms participating in these programs is small, leading to large standard errors of the estimated effects. These results are presented graphically in Figure3.

Figure 3

Dynamic effects of first program participation

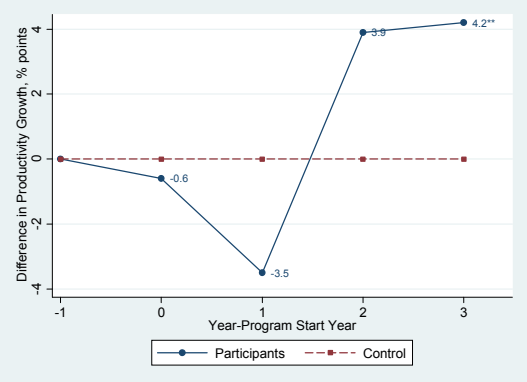
Innovation Network

Number of Program Participants = 1581



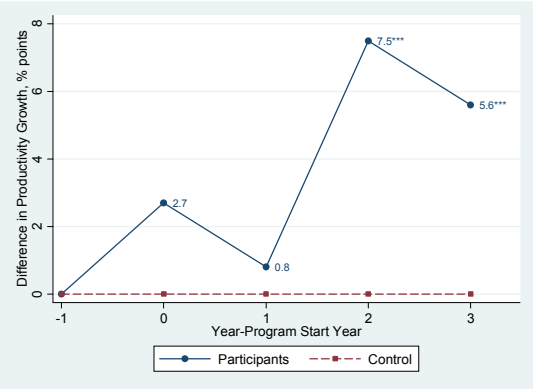
Innovation Assistant

Number of Program Participants = 691



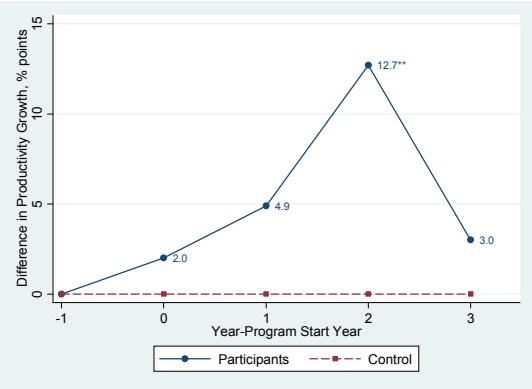
Innovation Voucher

Number of Program Participants = 696



Innovation Consortia

Number of Program Participants = 117



Source: InnovationDenmark Database and Statistics Denmark

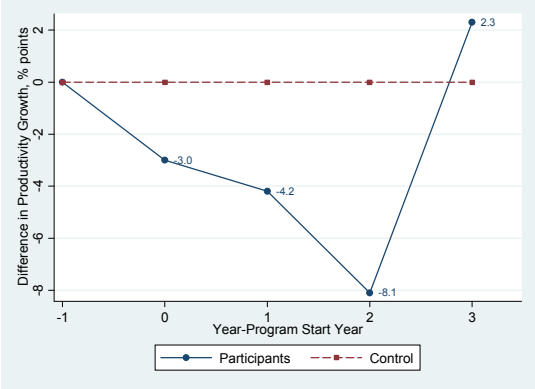
Notes: The figure plots the estimated change in productivity growth resulting from first program participation immediately (0), one year later (1), two years later (2) and the average effect three years and beyond (3). The effects shown for 0, 1, 2 and 3 are estimated from a fixed effect DID. The common trend assumption is reflected in the effect at -1 being zero (i.e. this is the reference period used as "before" in the DID). Growth at time t is defined as tfpt – tfpt-1. For instance, the effect at 0 refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. *** p<0.01, ** p<0.05, * p<0.1. "Number of Program Participants" refers to the number of participants from which immediate effects were estimated. For brevity, firms who do not participate are simply referred to as "Control".

Figure 3 Continued

Dynamic effects of first program participation

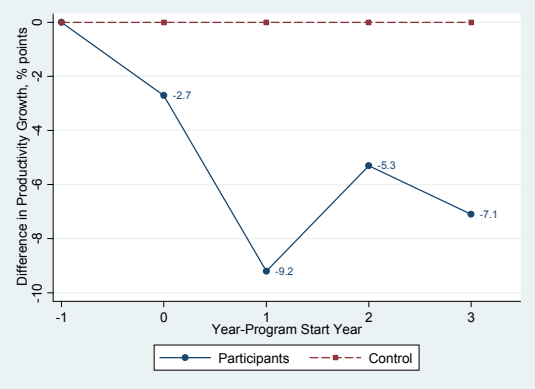
Industrial Ph.D.

Number of Program Participants = 99



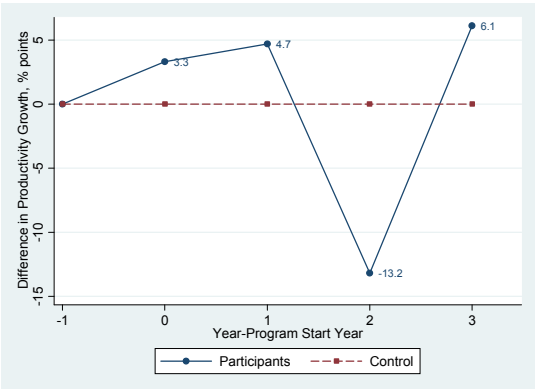
DNATF

Number of Program Participants = 42



FP7

Number of Program Participants = 36



Source: InnovationDenmark Database and Statistics Denmark

Notes: The figure plots the estimated change in productivity growth resulting from first program participation immediately (0), one year later (1), two years later (2) and the average effect three years and beyond (3). The effects shown for 0, 1, 2 and 3 are estimated from a fixed effect DID. The common trend assumption is reflected in the effect at -1 being zero (i.e. this is the reference period used as "before" in the DID). Growth at time t is defined as tfpt – tfpt-1. For instance, the effect at 0 refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. *** p<0.01, ** p<0.05, * p<0.1. "Number of Program Participants" refers to the number of participants from which immediate effects were estimated. For brevity, firms who do not participate are simply referred to as "Control".

Heterogeneity

Tables 11, 12 and 13 present the results distinguished by firm age, number of employees and level of capital respectively. Results are presented in the same format as the main results but with two sets of coefficients: one for those firms who are younger/smaller, and another for those firms who older/bigger.

The average effects of participation according to firm age shown in Panel (A) of Table 11 suggest that younger firms do better: for instance, firms involved with Innovation Network that are less than 6 years old see an effect of 5.17 percentage points on average TFP growth one year after participation (growth from the year of program participation to the year after program participation) as opposed to the 1.77 percentage points increase experienced by firms who are 6 years or older, however the effect for younger firms is insignificant. In part, this insignificance may be explained by the immediate effects. Though insignificant, the immediate effects, growth from one year before program participation to the year of program participation, suggest that the younger firms had lower productivity growth (insignificant -2.5 percentage points) than older firms (insignificant -1 percentage points) prior to participating that was not completely handled by the estimation strategy. In this sense, the estimated effect of program participation for younger firms may be biased downward. A similar pattern is detected for those firms whose first program was Innovation Assistant: young firms realize a (insignificant) 2 percentage point increase in TFP one year after program participation as compared to older firms who experience effectively no effect on productivity growth. Again however, the younger firms were experiencing lower (insignificant -3.6 percentage point) productivity growth prior to program participation relative to older firms (insignificant -1.0 percentage points) leading to the possibility that the effect of first program participation for younger firms is biased downward.

Older firms whose first program is Innovation Voucher realize a statistically significant average increase in TFP growth of approximately 3 percentage points as compared to the more than 4 percentage point increase in TFP growth experienced by younger firms, though the latter estimate is statistically insignificant. As opposed to the two other programs discussed, younger firms whose first program was Innovation Voucher experienced a high level of productivity growth (insignificant 8 percentage points) prior to program participation relative to older firms (effectively 0). Because of this, the estimated effect of first time program participation for younger firms may be overstated and consequently may be lower than for the older firms.

The dynamic specification, shown in Panel (B) sheds additional light: younger firms need time for the effects of participation to manifest. Growth effects are only significantly positive three years after participation. These effects are large: a significant 14, a significant 10 and an insignificant 8 percentage points in the Innovation Network, Innovation Assistant and Innovation Voucher programs respectively, however the difference in these effects with older firms is not significantly different (i.e. the confidence intervals around the estimates for younger firms overlap with the confidence intervals of the younger older firms). The same patterns present in the immediate effects, which are presented Panel (A), are also present in the dynamic specification shown in Panel (B), hence the same caveats apply. Tables 12 and 13 reveal that participants in the Innovation Network and Innovation Assistant programs with above median levels of employment or capital fare better, whereas participants in Innovation Voucher with lower than median levels of employees or capital see the largest gains.

Table 11

Fixed Effect difference in difference in differences, Firm age

(A) Average effect on annual TFP growth	Years after particpation	Innovation Network	Innovation Assistant	Innovation Voucher
Firms 6 years or older	0	-0.0090	-0.0079	0.0039
		(0.0138)	(0.0222)	(0.0190)
	>=1	0.0177**	0.0030	0.0293**
		(0.0077)	(0.0146)	(0.0120)
Firms less than 6 years old	0	-0.0249	-0.0357	0.0835
		(0.0524)	(0.0515)	(0.0881)
	>=1	0.0517	0.0209	0.0421
		(0.0430)	(0.0386)	(0.0577)
Number of firms		164,180	163,290	163,295
Number of observations		883,111	873,686	874,503
Number or participants		1581	691	696

(B) Dynamic Effect on annual TFP growth	Years after particpation	Innovation Network	Innovation Assistant	Innovation Voucher
Firms 6 years or older	0	-0.0069	-0.0079	0.0037
		(0.0138)	(0.0222)	(0.0190)
	1	0.0278**	-0.0217	-0.0011
		(0.0133)	(0.0240)	(0.0282)
	2	0.0110	0.0192	0.0584**
		(0.0167)	(0.0272)	(0.0272)
	>=3	0.0221	0.0232	0.0417***
		(0.0165)	(0.0196)	(0.0153)
Firms less than 6 years old	0	-0.0247	-0.0371	0.0832
		(0.0527)	(0.0515)	(0.0882)
	1	-0.0066	-0.0769	0.0201
		(0.0623)	(0.0650)	(0.0829)
	2	0.0411	0.0601	0.0627
		(0.0573)	(0.0886)	(0.0689)
	>=3	0.1368***	0.1034**	0.0796
		(0.0490)	(0.0477)	(0.0724)
Number of firms		164,180	163,290	163,295
Number of observations		883,111	873,686	874,503
Number or participants		1581	691	696

Source: InnovationDenmark Database and Statistics Denmark

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Not shown, but included in all fixed effect regressions are year indicators, lags of the following variables: 3 digit industry dummies, firm ownership indicators, firm age, log of labor, and log of capital as well as 3-digit industry indicators. Growth at time t is defined as tfpt – tfpt-1. The row labeled "Year after participation 0" refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. The row labeled 1 refers to differences in growth from t to t+1 and the row labeled 2 refers to differences in growth from t+1 to t+2. The row labeled >=3 displays the changes in average growth grate from t+2 to t+3 and beyond. Large/Small firms are firms whose value of capital or labor prior to participation was above/below the median level of capital or labor in their particular industry.

Table 12

Fixed Effect difference in difference in differences, Firm size with respect to labor

(A) **Average effect on annual TFP growth**	**Years after particpation**	**Innovation Network**	**Innovation Assistant**	**Innovation Voucher**
Large Firms, Labor	0	0.0020	-0.0062	0.0122
		(0.0137)	(0.0214)	(0.0251)
	>=1	0.0290***	0.0034	-0.0017
		(0.0080)	(0.0144)	(0.0182)
Small Firms, Labor	0	-0.0728	-0.0328	-0.0448
		(0.0612)	(0.0572)	(0.1056)
	>=1	-0.0262	-0.0128	0.1944**
		(0.0431)	(0.0412)	(0.0946)
Number of firms		164,178	163,288	163,293
Number of observations		883,072	873,647	874,464
Number or participants		1581	691	696

(B) **Dynamic Effect on annual TFP growth**	**Years after particpation**	**Innovation Network**	**Innovation Assistant**	**Innovation Voucher**
Large Firms, Labor	0	0.0012	-0.0042	0.0234
		(0.0137)	(0.0214)	(0.0181)
	1	0.0394***	-0.0330	-0.0281
		(0.0145)	(0.0254)	(0.0236)
	2	0.0101	0.0437	0.0730***
		(0.0154)	(0.0348)	(0.0269)
	>=3	0.0314**	0.0239	0.0436***
		(0.0137)	(0.0196)	(0.0155)
Small Firms, Labor	0	-0.0708	-0.0269	-0.0256
		(0.0606)	(0.0564)	(0.0833)
	1	-0.0952	-0.0393	0.1871
		(0.0651)	(0.0646)	(0.1161)
	2	0.0371	-0.0638	-0.0174
		(0.0819)	(0.0802)	(0.0645)
	>=3	0.0114	0.0517	0.0024
		(0.0761)	(0.0489)	(0.0628)
Number of firms		164,178	163,288	163,293
Number of observations		883,072	873,647	874,464
Number or participants		1581	691	696

Source: InnovationDenmark Database and Statistics Denmark

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Not shown, but included in all fixed effect regressions are year indicators, lags of the following variables: 3 digit industry dummies, firm ownership indicators, firm age, log of labor, and log of capital as well as 3-digit industry indicators. Growth at time t is defined as tfpt – tfpt-1. The row labeled "Year after participation 0" refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. The row labeled 1 refers to differences in growth from t to t+1 and the row labeled 2 refers to differences in growth from t+1 to t+2. The row labeled >=3 displays the changes in average growth grate from t+2 to t+3 and beyond. Large/Small firms are firms whose value of capital or labor prior to participation was above/below the median level of capital or labor in their particular industry.

Table 13

Fixed Effect difference in difference in differences, Firm size with respect to capital

(A) Average effect on annual TFP growth	Years after particpation	Innovation Network	Innovation Assistant	Innovation Voucher
Large Firms, Capital	0	-0.0087	-0.0091	0.0350*
		(0.0141)	(0.0231)	(0.0192)
	>=1	0.0248***	0.0090	0.0171
		(0.0085)	(0.0162)	(0.0118)
Small Firms, Capital	0	0.0083	-0.0020	-0.0552
		(0.0405)	(0.0436)	(0.0581)
	>=1	0.0040	-0.0224	0.0648*
		(0.0262)	(0.0296)	(0.0380)
Number of firms		164,178	163,288	163,293
Number of observations		883,072	873,647	874,464
Number or participants		1581	691	696

(B) Dynamic Effect on annual TFP growth	Years after particpation	Innovation Network	Innovation Assistant	Innovation Voucher
Large Firms, Capital	0	-0.0086	-0.0088	0.0348*
		(0.0141)	(0.0232)	(0.0191)
	1	0.0291*	-0.0245	-0.0403
		(0.0153)	(0.0303)	(0.0254)
	2	0.0034	0.0227	0.0764**
		(0.0167)	(0.0423)	(0.0304)
	>=3	0.0385**	0.0395*	0.0421**
		(0.0160)	(0.0208)	(0.0183)
Small Firms, Capital	0	0.0081	-0.0017	-0.0549
		(0.0405)	(0.0437)	(0.0581)
	1	-0.0078	-0.0451	0.1702**
		(0.0428)	(0.0470)	(0.0790)
	2	0.0521	0.0311	-0.0377
		(0.0490)	(0.0601)	(0.0454)
	>=3	-0.0221	-0.0174	0.0114
		(0.0437)	(0.0412)	(0.0359)
Number of firms		164,178	163,288	163,293
Number of observations		883,072	873,647	874,464
Number or participants		1581	691	696

Source: InnovationDenmark Database and Statistics Denmark

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Not shown, but included in all fixed effect regressions are year indicators, lags of the following variables: 3 digit industry dummies, firm ownership indicators, firm age, log of labor, and log of capital as well as 2-digit industry indicators. Growth at time t is defined as tfpt – tfpt-1. The row labeled "Year after participation 0" refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. The row labeled 1 refers to differences in growth from t to t+1 and the row labeled 2 refers to differences in growth from t+1 to t+2. The row labeled >=3 displays the changes in average growth grate from t+2 to t+3 and beyond.

As shown in Table 12, among firms whose first program was Innovation Network, those with relatively high levels of employment experienced an approximate (significant) 3 percentage point increase in productivity growth whereas those firms with lower levels of employment experienced a (insignificant) 2.6 percentage point decline in productivity growth. However, the immediate effect on productivity growth for firms with lower levels of employment was a (insignificant) decrease of about 7 percentage points, suggesting that the average effect on productivity on the average of subsequent productivity growths may be understated. The dynamic effects shown in Panel (B) reveal that the effects of program participation are more quickly realized for firms with higher levels of employment: one period after program participation, the increase in productivity growth is a significant 3.9 percentage points. On the contrary, firms with lower level of employment take more time to increase productivity, not until 2 years after program participation is a (insignificant) 3.7 percentage point increase in productivity detected.

Among those whose first program is Innovation Voucher, firms with lower levels of employment experience a large and statistically significant productivity growth, 19.4 percentage points, one year after program participation, whereas firms with higher levels of employment see effectively no change in productivity growth one year after program participation. This result is not driven by an upwardly biased estimate as the effect on immediate productivity growth is below 0, suggesting that is downward biased if anything. The dynamic specification shown in Panel (B) of Table 12 reveals that this large increase in productivity growth for smaller firms manifests one year after program participation and quickly drops to effectively 0. None of the effects are significant. On the other hand, the productivity growth of larger firms takes time to realize. Two periods and three years after participation, firms with larger levels of employment experience a significant 7.3 and 4.3 percentage point increase in productivity growth respectively.

Similar patterns are present for large firms whose first program was Innovation Assistant: larger firms with respect to employment saw effectively no increase in productivity growth one year after program participation. On the other hand, smaller firms experienced a (insignificant) decrease in productivity growth of about 1.3 percentage points, in contrast to participants in Innovation Voucher. Again, the immediate effects of program participation for smaller firms was an insignificant decrease in productivity growth of about 3.3 percentage points, suggesting that the estimated negative effect of 1.3 percentage points may be understated. Panel (B) of Table 12 reveals that firms with smaller levels of employment need more time to experience productivity growth, not until 3 years later are positive, although insignificant, effects detected whereas larger firms realize positive (insignificant) gains 2 years after participation.

Table 13 reveals that participants in the Innovation Network and Innovation Assistant programs with above median levels capital fare better, whereas participants in Innovation Voucher with lower than median levels of capital see the largest gains. The patterns of effects discussed above for firm size with respect to employment are quite similar to the effect of firm size with respect to the level of capital.

Effects of second time program participation

An important question is whether there are larger effects from participating more than once in an innovation program. Should the research and innovation system favor the same firm multiple participation opportunities or target new firms who have not yet participated? That is, are there economies of scale in program participation or not? The first attempt at answering these questions is provided below.

Table 14 presents the non-parametric matching estimates of the effect of second program participation. The top panel, labeled "First Program" duplicates the results from Table 9 and Table 10 for ease of comparison. Due to the small sample sizes, only average effects after second program participation are estimated (as opposed to year by year dynamic effects). Note that the effects at $t=0$ are not shown as firms are matched on their growth (i.e. the effects would be close to 0). Only the average effect after participation is shown, that is, analogous to the line labeled ">=1" in Table 9. The results for second time participators are shown in the panel labeled "Second Program". Despite

pooling over time, the standard errors are still relatively large. No effects are significantly different than 0, regardless of the second program.

Table 14

Comparison of first and second participations effects on total factor productivity growth

Average effect on annual TFP growth	Average effect on annual TFP growth	Innovation Network	Innovation Assistant	Innovation Voucher
First Program	Estimate	0.0356***	0.0079	0.0410***
	standard error	(0.0084)	(0.0136)	(0.0122)
	80% lower bound	0,0248	-0,0095	0,0254
	80% upper bound	0,0464	0,0253	0,0566
	Participants	1573	686	450
Second Program	Estimate	0,0204	0,0353	-0,0186
	standard error	(0,0188)	(0,0679)	(0,0294)
	80% lower bound	-0,0037	-0,0515	-0,0562
	80% upper bound	0,0444	0,1222	0,0190
	Participants	175	46	112
	exact match rate	87%	91%	92%

Source: InnovationDenmark Database and Statistics Denmark

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Second participation effects are estimated using the Abadie and Imbens nonparametric matching with bias correction with 3 matches. Among first time participants, firms are matched according to first program type, year of the start of first program, TFP growth, lags of the following variables: 3 digit industry dummies, firm ownership indicators, firm age, log of labor, and log of capital. Exact matching was performed with respect to first program type and start of first program. "Exact match rate" refers to how many matches were exact with respect to these variables. To the extent that matching is not perfect – for all variables- local linear regression is used to remove bias.

The point estimates for Innovation Network (2.0) and Innovation Voucher (-1.9) both lie below the corresponding first participation estimates. The effect of second participation for those whose second program is Innovation Assistant is higher than that of first time participants: 3.5 percentage points compared to 0.8 percentage points.

It is important to note that even if these estimates were statistically different than 0, it is very unlikely that they would be statistically different than the first program effects. Intuitively, the confidence intervals for the two estimates would need to be disjoint. This would require that both sets of estimates are precisely estimated, something quite difficult to achieve given the small sample sizes of the second time participators. However, if one is willing to accept an unconventionally low level of confidence, 80%, one can conclude that the Innovation Voucher program should prioritize first time participators over second time participators. Heterogeneous effects were investigated for second time participators, but as expected given the sample sizes, no significant effects were detected.

Assuming that the effects of program participation are stable over time, the analysis may detect statistical differences once sample sizes have the opportunity to grow. Of course, this is a function of the true difference between being a first and second time participator. If those who participate twice see a 1 percentage point lower growth in TFP relative to first time participators, a much larger sample size would be needed to conclude that this is a significant difference relative to a situation in which the true difference was 4 percentage points. Assuming that the effects of first time and second participation are as shown in Table 14, then a doubling of the sample size of both first and second time participators would be enough to detect a difference between first and second time participators in Innovation Voucher at a conventional 95% level of confidence.[26] However, even doubling the

[26] Note that a doubling of sample size halves the standard errors

sample sizes would not be sufficient to detect a difference between first and second time participants in Innovation Network and Innovation Assistant.

5 CONCLUSION

Significant first time effects on annual TFP growth were found for those participants whose first program was Innovation Network (3.6 percentage point increase on average after participation), Innovation Voucher (4.1 percentage point increase on average) and Innovation Consortia (6 percentage point growth). Although the average effect on TFP growth after participation was insignificant for those involved in Innovation Assistant, the dynamic effects reveal that growth takes time to materialize: after 3 periods, participants in Innovation Assistant experience a significant 4.2 percentage point growth. First time participants of Industrial Ph.D. and FP7 generally see negative but insignificant effects, while first time participants in the Danish National Advancement for Technology Foundation see a negative and marginally significant effect of about 8 percentage points. The results for the Danish National Advancement for Technology Foundation and FP7 should be interpreted with caution: only 42 and 36 of the firms in the estimation sample participated in these programs, respectively. The analysis should be repeated for these two programs once more information is available.

The average annual effects on TFP growth of Innovation network, Innovation Voucher and Industrial Ph.D. programs are relatively stable: despite the inclusion of four more years of participants, a substantial increase in sample size and a different estimation strategy, the estimates of TFP growth are exceptionally similar to that obtained by CEBR (2014) for these three programs. Both studies yielded insignificant effects close to 0 for participants in the Industrial Ph.D. program. No average annual effect is found for participants in the Innovation Assistant whereas CEBR (2014) found a marginally significant effect of 2.9 percentage points, the difference may be due to random variation (the current point estimate is within the 95% confidence interval of the CEBR (2014) estimate). The effect of participating in Innovation Consortia has more than doubled since the last study to a strongly significant 6 percentage point increase in TFP growth. The effects of first participation in the Danish National Advancement for Technology Foundation and FP7 were not included in CEBR (2014).

Participants in Innovation Network and Innovation Assistant with above median levels of employees or capital fare better. On the other hand, participants in Innovation Voucher with lower than median level of employees or capital see the largest gains. The dynamic specification shows that the large gains experienced by small firms manifest one year after program participation and quickly drops away, while the productivity growth of larger firms takes time to realize. Two and three periods after participation, firms with larger levels of employment or capital experience large and significant increases in productivity growth. However, the differences in effects between young and old, small or large are not statistically significant. This is not to say that differences do not exist, just that we do not have larger enough samples (i.e. small enough variances) to detect a difference.

Unfortunately, the number of second time participators is not sufficient to yield strong results about the difference between first and second participators. The point estimates of second participation for those whose second program is Innovations Network andInnovation Voucher are below the point estimates of first participation for those with the same program, yet none are statistically different from first time program effects at conventional levels of significance. If one is willing to accept a lower the level of confidence, 80%, one can conclude that Innovation Voucher should prioritize firms who have not previously participated in a research and innovation program. On the contrary, second time participants in Innovation Assistant saw an increase in TFP growth relative to first time participants, though none of the effects are statistically different than first time effects, even at the lower levels of confidence. As explained within the text, given the estimated effects of first and second program participation, a much larger sample size is needed in order to detect significant differences.

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APPENDIX 1: CONSTRUCTION OF THE ESTIMATION SAMPLE

Table A1 presents a description of the sample selection. The first row "private firms as defined by DASTI data" reflects the total number of private firms who first participated between 2000 and 2013. The column titled "Unique firms" corresponds to the total number of firms who participated at least once during this period and which were not public, there were 8,274 such firms. The column titled "unique firms who participate once in first year" is a subset of this group: 7,827 firms participated in only one program during their first year of contact with DASTI. That is, 447 firms participated in more than one type of program in their first year of contact.

The fourth line below this, in red, displays the total number of unique firms who do not match with register or Experian data in the year of first participation, 983 (952 if only firms who participate once in the first year of contact are considered). The three rows above this give some detail as to whether these firms are present in the register or Experian in any year. 356 of the 983 firms were never found in any year; 238 firms were found in a year prior to the year of program participation and 389 were found in a year after their first participation.

After excluding firms who were not found in the register or Experian in the year of program participation, the sample of unique firms is 7,291. As the variables needed for the analysis are taken from the Firm register, records not found on the firm register must be dropped, yielding 6870 firms. The next line in red displays the number of firms that are deleted as their participation occurs outside of the range 2002-2013, a drop necessary in order to construct the necessary lag variables, leaving a sample of 6,735 firms. Those firms who are larger than 500 employees and/or are defined as public institutions on the registers are eliminated resulting in a sample containing 6,246 firms, of which 5,891 participated just once in their first year of contact.

Finally, firms must have complete information from t-2 to t. This limits the sample to firms who are at least two years old when they begin program participation. In addition, firms must have positive levels of labor, capital and value added in these years as the log of these variables is used in estimation. The final sample thus contains 3,400 firms, of which 3,190 participated once in their first year of contact.

Table A2 provides a description of how frequently firms participated multiple times. The rows correspond to how many programs a firm participated in during the first year of contact. The columns correspond to the number of times a firm participated during their second year of contact. The first row total is 3,463 and corresponds to the total number of firms who participated once in the first year of contact shown in Table A1. The first column and first row of Table A2, shown is red, reveals that 3,379 firms (92% of total firms) only participate once in their first year of contact and either do not participate in a second year or participated once. It is this sample of firms that will be used for estimation, i.e. the estimation sample.

Table A1

Construction of sample

Criteria	Min Participation Year	Max Participation Year	Firms	Firms who participate once in first year
Private firms as defined by FIVU data	2000	2013	8274	7827
Number who are never found on register			356	347
Number only found in year prior to first part.			238	230
Number found only in year after to first part.			389	375
Total Number that don't match with register in year of first part.			983	952
Matched with any register or Experian in first participation year*			7291	6875
Matched with Firm Register in first participation year			6870	6471
Minimum 2002 first participation year	2002	2013	6735	6336
Firms less than 500 employees			6523	6155
Private firms identified as public in register			6246	5891
Final estimation sample:non-missing information*			3680	3463

Source: InnovationDenmark Database and Statistics Denmark

*See discussion in the "estimation sample"

Table A2

Multiple program participation, all firms

	Number of programs during second year of contact		
Number of programs during first year of contact	**0 or 1**	**More than 1**	**Total**
1	3379	84	3463
	92%	2%	94%
More than 1	202	15	217
	5%	0%	6%
Total	3581	99	3680
	97%	3%	100%

Source: InnovationDenmark Database and Statistics Denmark

Table A3

Table of first by second program type, summarizing second program type

	Second Program				
First Program	**Innovation Network**	**Innovation Voucher**	**Innovation Assistant**	**Other**	**Total**
Industrial Ph.D.	16	NA	NA	20	41
FP7	11	NA	NA	6	20
Gazelle Growth	NA	NA	NA	NA	5
DNATF	NA	NA	NA	8	17
Innovation Consortia	32	7	NA	15	55
Innovation Network	152	61	25	39	277
Innovation Voucher	63	5	17	24	109
Innovation Assistant	16	29	25	NA	74
Open Funds	NA	NA	NA	NA	11
Total (not all programs shown due to data restrictions)	**307**	**113**	**77**	**134**	**631**

Source: InnovationDenmark Database and Statistics Denmark

Note: rows (first programs) in which no information was available due to data restrictions were omitted. The columns "other" aggregates all other second program types that are too small to report explicitly.

Table A4

Table of first by second program type, summarizing first program type

	Second Program									
First Program	**Industrial Ph.D.**	**FP7**	**Gazelle Growth**	**DNATF**	**Inno-vation Consortia**	**Inno-vation Network**	**Inno-vation Voucher**	**Inno-vation Assistant**	**Open Funds**	**Total (not all programs shown due to data restrictions)**
Innovation Network	8	7	0	7	10	152	61	25	NA	**277**
Innovation Voucher	NA	9	0	7	NA	63	5	17	NA	**109**
Innovation Assistant	0	NA	0	0	NA	16	29	25	NA	**74**
Other	17	9	NA	13	14	76	18	10	NA	**171**
Total	**26**	**26**	**NA**	**27**	**27**	**307**	**113**	**77**	**8**	**631**

Source: InnovationDenmark Database and Statistics Denmark

Note: Columns (second programs) in which no information was available due to data restrictions were omitted. The row "other" aggregates all other first program types that are too small to report explicitly.

APPENDIX 2: METHOD

A.2.1. GENERAL METHOD

Assume that firms *(i)* transform capital (K) and labor (L) into output (Y) at time *t* according to the following Cobb-Douglas production function:

$$Y_{it} = A_{it} L_{it}^{\beta_1} K_{it}^{\beta_2} \qquad (1)$$

where A_{it} represents the total factor productivity (TFP) for a firm *i* at time *t*. A_{it} TFP is a function of several factors: general productivity shocks that affect all firms at a given time, i.e. aggregate shocks; unpredictable shocks to the firm's productivity, i.e. death of CEO; and a persistent firm productivity component, i.e. a well-organized firm. R&D as well as collaboration is expected to affect TFP though innovations in product or process, that is, A_{it} can be thought of as a function of R&D and collaboration:

$$A_{it} = f(RD_{it}, collarboration)$$

The DASTI programs are expected to affect A_{it} through this R&D and collaboration channel .

A typical specification for these shocks assumes that they multiplicatively affect the firm's efficient use of inputs, that is, A_{it} is the product of each of these three types of shocks. Taking the log of equation (1) yields

$$y_{it} = \varpi_{it} + \eta_{it} + \nu_t + \beta_1 l_{it} + \beta_2 k_{it} \qquad (2)$$

where lower case letters represent log values, is ϖ_{it} the log of the firm's productivity, η_{it} is the unpredictable firm level shock and ν_t are the aggregate shocks.[27]

Several techniques can be used to try and uncover productivity. The simplest of these entails estimating (2) via OLS to recover estimates for ν_t, β_1 and β_2, then using these estimates to back-out a proxy for productivity:

$$y_{it} - \hat{\nu}_t + \hat{\beta}_1 l_{it} + \hat{\beta}_2 k_{it} = tfp_{it}^{OLS} = \hat{\omega}_{it} + \hat{\eta}_{it} \qquad (3)$$

However, firms that realize good productivity shocks are likely to alter their factor demands, hence the estimates of β_1 and $\beta_2$are likely to be biased, the so-called simultaneity bias.[28] A TFP measure

[27] See Olley & Pakes (1996), Levinsohn & Petrin (2003)

[28] This is typically called the endogeneity problem. In addition, firms who realize a bad shock are likely to leave the sample, causing yet another source of bias i.e. the selection bias. This OLS estimate of productivity suffers from both biases.

derived from them will also be biased. It is important to note that this proxy for TFP is actually just unexplained output growth (which is quantified using deflated value added).

An extensive literature has focused on how to handle the simultaneity problem in production function estimation. Olley & Pakes (1996), OP, developed a method in which firm productivity is proxied with firm investment: firms with a positive productivity shock are assumed to invest more. Firms who realize a negative productivity shock below a certain threshold exit. This technique has been the standard in the productivity literature since its introduction. The productivity series resulting from the OP estimation can be interpreted as actual TFP. The fundamental drawback of OP is that only firms with positive levels of investment can be used in the estimation procedure.[29] Levinsohn & Petrin (2003), LP, modified the OP procedure by using electricity and/or materials rather than investment as a proxy for productivity. As many more firms have positive values for intermediate goods than investment, this approach avoids dropping a large fraction of the sample.[30] These two methods of productivity estimation are the standard in the academic literature. For a nice survey of different techniques, see Ilke Van Beveren (2012) who also show that the various methods often yield similar productivity series.[31] The method of LP was used to estimate firm productivity at the 2 digit level, that is, a production function was estimated for each 2-digit industry from which firm level productivity series are estimated. Productivity growth is then calculated as $\Delta\ tfp_{it} = tfp_{it} - tfp_{it-1}$.[32]

A.2.2. DETAILED METHOD

A.2.2.1 Productivity Estimation

The Levinsohn & Petrin (2003), LP, method is used to estimate productivity.[33] As value added is used, only one intermediate good is needed for productivity estimation, materials was therefore chosen. A production function was estimated for each 2-digit industry yielding estimated firm level productivity time series'. Productivity growth, $TEPgrowth_{it}$, is then calculated as:

$$\ln(tfp_{it}) - \ln(tfp_{it-1}) \cong \frac{tfp_{it} - tfp_{it-1}}{fp_{it-1}}$$

This approximation is accurate for small changes, say less than 10% in absolute value. As explained in the general method chapter, the estimation of the production function requires taking the log of value added, labor, capital, thus all records with a non-positive value for any of these variables are dropped. In additional positive levels of material are needed. Approximately 65% of the participants had positive values of material which is a sufficient number from which to estimate the production function parameters (capital and labor shares). Once these parameters have been estimated, they can be used to estimate productivity regardless of whether or not materials are observed. That is, as is

[29] If one is willing to assume that coefficients on labor and capital are "stable", these coefficients can be used to back out the productivity of firms with non-positive investment. See DeLoeker(2007).

[30] But LP do not address exit

[31] Each of these methods, OLS 2-step, OP, and LP are inherently 2-step: estimate productivity then perform the program evaluation. A fourth approach is possible, see CEBR (2014). This approach combines productivity estimation with the program effect estimation by directly introducing program participation indicators into the growth form of (2).

[32] CEBR (2014) instead used $\Delta^{+} tfp_{it} = tfp_{it+1} - tfp_{it}$.

[33] The user written stata ado file levpet was used, see Petrin, Poi, and Levinsohn (2004)

standard, the technology within an industry is assumed to be the same (i.e. the production function). The LP method use materials to estimate these parameters using materials as a proxy. Although only a subset of the sample has positive values for materials, it is still assumed that that those with and without positive values of materials, within the same industry, still have the same technology. Because of this, one can use the subsample of those firms with positive levels of materials to estimate this technology, then use these estimates for all firms within the same industry. That is, firms are *not dropped* if they have non-positive levels of materials.

Figure A1 displays plots of raw log productivity over time for all firms who did not participate in a program against firms who did. Each plot displays the non-participating firms against firms whose first participation occurred in the labeled year. A vertical line is placed on the year in which program participation began. Note that by definition, the log productivity series for the non-participating firms is the same across all plots. Plots for 2002 through 2004 are not included due to the small number of participants in those years, see Table 5. The slopes of these graphs can be interpreted as the percent change in growth. Figure A2 directly plots the percent change in growth.

Figure A1 clearly shows that participants generally have higher productivity ex-ante and that, for all firms, productivity is generally decreasing from 2004 onward. Productivity is more volatile for those firms who participate, at least in part due to the smaller sample sizes. Figure A2 illustrates that the growth in TFP is more volatile than the level of TFP. These are the figures from which common trend assumptions needed for the difference in differences analysis should be checked. Across graphs, the common trend assumption seems plausible, especially given that these are unconditional plots. However, an additional check should be performed within the difference in differences estimation to provide additional evidence. Specifically, the effect of the program in the year in which the program began, i.e. the effect on growth from t-1 to t, will be estimated. Given that we are considering TFP growth, we should be worried if we detect an effect so soon – this would suggest that our common trends assumption was not met and selection was not sufficiently handled.

A.2.2.2. Effects of first program participation

The estimating equation for dynamic first program participation effects is:

$$TFPgrowth_{it} = \beta_0 + \lambda part1_i + \left(\sum_{j=0}^{3} \alpha_j part1_i * after1\_j_{it} \right) + \beta_1 l_{it-1} + \beta_2 k_{it-1} + \beta_3 firmage_{it-1} + \theta_1 time\_dum_t + \theta_2 nace3\_dum_{it-1} + \theta_3 firmtype\_dum_{it-1} + c \quad (4)$$

for *i=1, N* firms and *t=2000-2013*; *part1* is a (time) constant indicator variable taking the value of 1 if the firm participated in a program. *After1_0, After1_1,* and *After1_2* are indicator variables that take the value 1 in the period in which the program begins, and 1 and 2 periods after respectively. After1_3 takes the value of 1 in the third period after participation and every period thereafter.

Within the summand are the interaction terms whose coefficients are the DID estimates of program participation. By allowing different intercepts according to how many years after the program participation *(j=0-3)*, we allow the effects of the program to evolve. $\alpha_0 * 100$ is the percentage point change in TFP growth in the year in which the program began relative to the counterfactual growth rate the firm would have had in that same year had they not participated. α_1 multiplied by 100 yields the percentage point change in TFP growth from the period before program participation to the period after program participation relative to the counterfactual growth rate the firm would have had one year after the program was begun. The same logic holds for α_2. Stated differently, α_j, j=0,1,2 captures the per year (0,1,2) effect on the percentage growth, it does not capture the cumulative effect. α_3 multiplied by 100 yields the *average* percentage point change in TFP growth from all years 2 or more years after the start of the program.

In addition, the average annual effect for *all years* after the year of implementation is estimated using the following estimating equation:

$$\Delta tfp_{it} = \beta_0 + \lambda part1_i + \delta_0 part1_i * after1\_0_{it} + \delta_1 part1_i * after1\_1p_{it}$$
$$+ \beta_1 l_{it-1} + \beta_2 k_{it-1} + \beta_3 firmage_{it} + \theta_1 time\_dum_t + \theta_2 nace3\_dum_{it} + \theta_3 firmtype\_dum_{it} + c_i + \varepsilon_{it} \quad (5)$$

where all variables are as defined earlier and *after1_1p* takes the value 1 in the year after the year of first participation and every year thereafter. The interpretation of δ_0 is the same as α_0 above. The interpretation of δ_1 is α_3 above, except that it averages over all years 1 or more years after the start of the program.

This model is estimated from the set of all firms who participated no more than once during their first and second year of program participation or who did not participate at all.[34] An implicit assumption of this model is that the effects of program participation are the same across time.[35] That is, the estimates of the effects of program participation are effectively a weighted average of the effects at different calendar years. Due to the limited sample size, this assumption was necessary. Fixed effects estimation was performed on equation (4) with standard errors clustered at the firm level. Note that fixed effect estimation eliminates all time variables that are constant over time implying, for instance, that λ is not identified in either model.

To investigate the effects on program participation for particular types of firms, a difference in difference in differences (DDD) fixed effect estimation is performed. For ease of exposition, this will be explained in the static case, though the intuition carries through to the dynamic case. For example, assume that interest lies in the effect of the program on young companies. Define a (time constant) variable *young=1* if a firm is less than 6 years old at time of participation and 0 otherwise. The value of this variable for nonparticipating firms is similarly defined, but is time varying as there is not set participation year. The variable young is then interacted with the following variables $part1_i, part1_i * after1\_0_{it}, part1_i * after1\_1p_{it}, time\_dum_i$ in estimation equation (4). This equation is then estimated via fixed effects.

In addition, this DDD estimation is performed to investigate how program participation varies by firm size in the year prior to program participation. The median level of capital and labor is calculated at the 2-digit nace level. If the firm's level of labor/capital is below the median value in the year prior to program participation, a variable low_labor /low_capital is assigned a (time constant) value of 1 and 0 otherwise. Nonparticipants are similarly defined, but the value of these variables can change over time.

A.2.2.3. Effects of second program participation

The matching estimator chosen here is the nonparametric bias-adjusted estimator of Abadie and Imbens (2011).[36] It is particularly robust in comparison to propensity score methods. Each treated observation is matched with one or several control observations according to the Mahalanobis distance of the observables. Three matches are used. In practice, this matching may not be exact. Importantly, as opposed to the more commonly used simple-nearest-neighbor matching, which estimates the ATT as the difference in means of the outcome variables in the matched dataset

[34] Some firms may have begun a program in a year after the year in which they began a second program. These firms are in the sample for years before the year in which they began the third program.

[35] The same assumption was made in CEBR(2014)

[36] The user written command nnmatch was used, see Abadie, Drukker, Herr, Imbens (2004)

(ignoring the lack of perfect matching), the Abadie and Imbens (2011) method uses local linear regression to correct the bias that results from any mismatches. In addition, the method allows for exact matching.[37]

The estimation only considers those who have participated at least once. For each type of second program, a firm who participated twice is exactly (or as close as possible) matched to a firm who did not have a second participation and whose first participation was in the same year and program as their own. Firms are also matched according to their productivity the year before second program participation, lagged values of capital, labor, firm ownership type, nace3 industry codes and firm age. The outcome variable is $\Delta tfp_{ij} - \Delta tfp_{i-1}$, j=0, 1, 2, 3. The difference in growth rates is used so that the estimated effect is the (nonparametric) DID estimator.

[37] It also allows for the calculation of robust (to heterogeneous treatment effects) standard errors although due to the size of the samples, it is not possible to estimate them. Instead, homogeneous effects were assumed.

APPENDIX 3: VARIABLE DEFINITIONS

All variables were taken from the Statistics Denmark register *Firm*. Table A5 provides an association between the real variables described in the General Method chapter and the variables that will be used in estimation. Nominal variables were deflated to 2010 DKK using the manufacturing producer price index if the firm was in manufacturing; otherwise the domestic supply producer price index was used.[38]

Table A5

Variable description

Real Variable	Register Variable Description	Register Variable Name	Nominal
Output , Y	Value Added	vtv	Yes
Labor, L	Full time equivalent	aarsv	
Capital, K	Fixed Assets	aat	Yes
Materials	Materials KRH	krh	Yes
Industry	Industry	Gf_branche_07	

Table A6 links the Danish and English name of the DASTI programs

Table A6

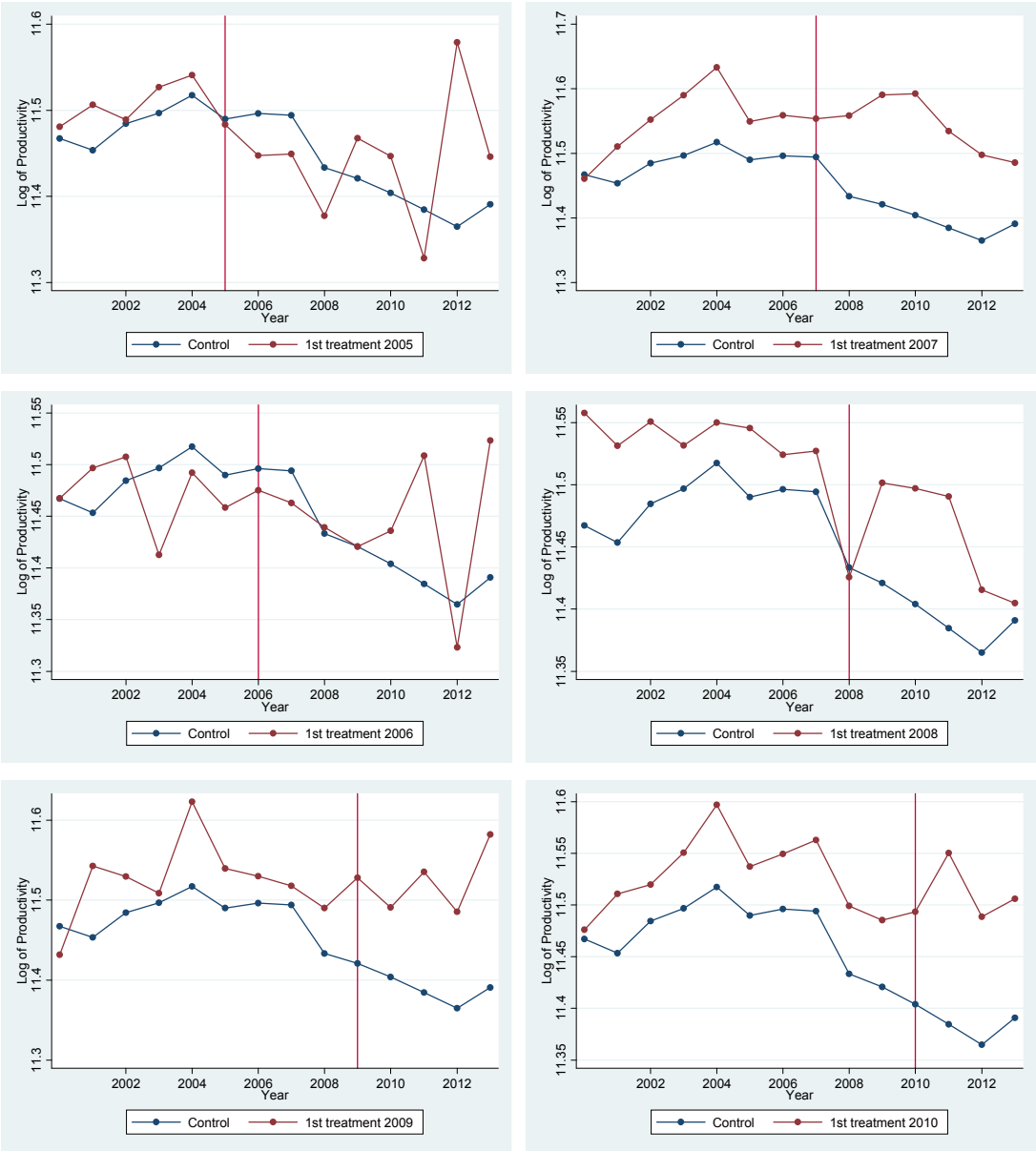
Variable description

English Name	Danish Name
Innovation Network	Innovationsnetværk
Innovation Assistant	Videnpilot
Innovation Voucher	Videnkupon
Innovation Consortia	Innovationskonsortier
Industrial Ph.D.	ErhversPhD
Danish National Advancement for Technology Foundation	Højteknologifonden
FP7	FP7
Open Funds	Åben Midler
Gazelle Growh	Gazelle Growth
EU's 6	EU'S 6

[38] Another source of bias results from using non-firm specific price deflators for non-perfectly competitive firms, see Ilke Van Beveren (2012).

Figure A1

Plots of raw log productivity by first participation year

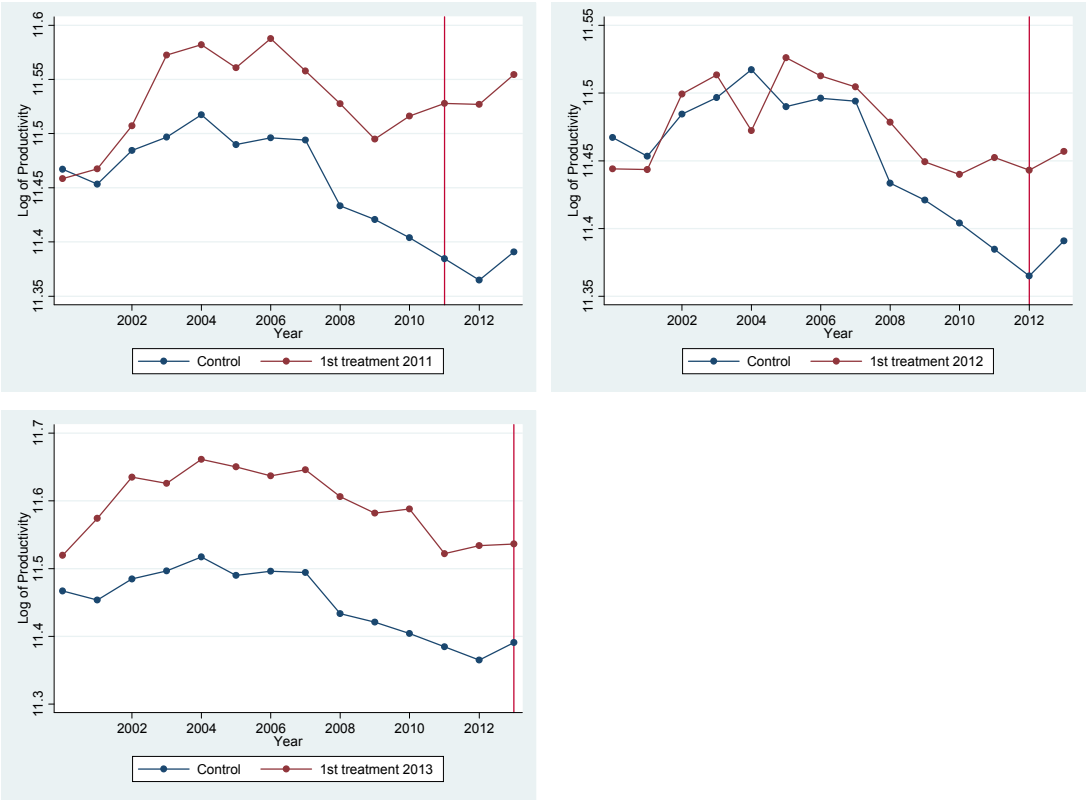


Source: InnovationDenmark Database and Statistics Denmark

Notes: These are plots of the log of productivity, tfpt , produced from the Levinsohn and Petrin (2003) estimation. Each plot depicts the average annual log productivity for those firms whose first participation year was in the year labeled against the log productivity of those firms who never participated in a program, labeled here "Control" for brevity. Note that the series for non-participating firms is the same in each graph by definition. The vertical lines represent the first participation year.

Figure A1 Continued

Plots of raw log productivity by first participation year

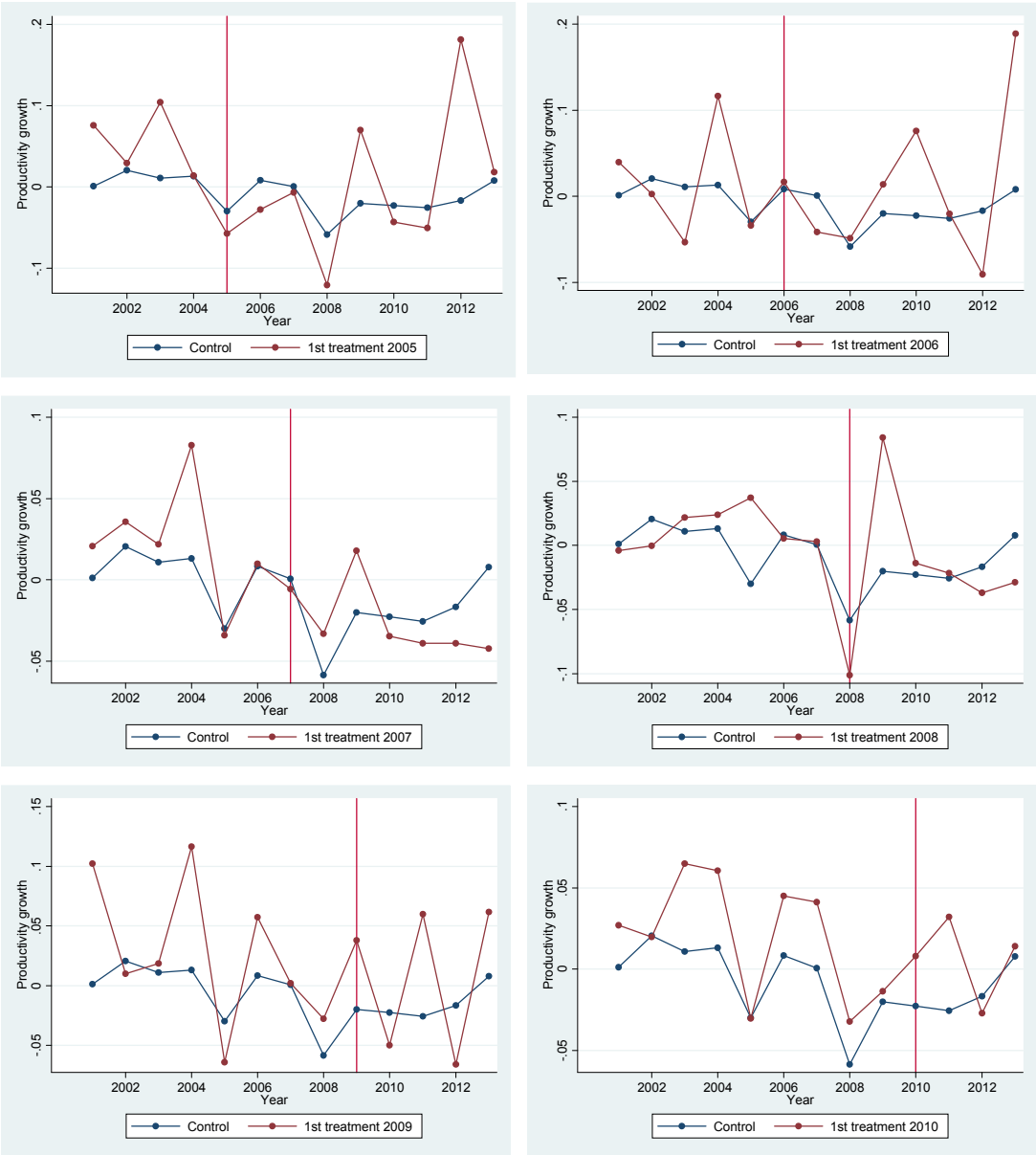


Source: InnovationDenmark Database and Statistics Denmark

Notes: These are plots of the log of productivity, tfpt , produced from the Levinsohn and Petrin (2003) estimation. Each plot depicts the average annual log productivity for those firms whose first participation year was in the year labeled against the log productivity of those firms who never participated in a program, labeled here "Control" for brevity. Note that the series for non-participating firms is the same in each graph by definition. The vertical lines represent the first participation year.

Figure A2

Plots of raw productivity growth by first participation year

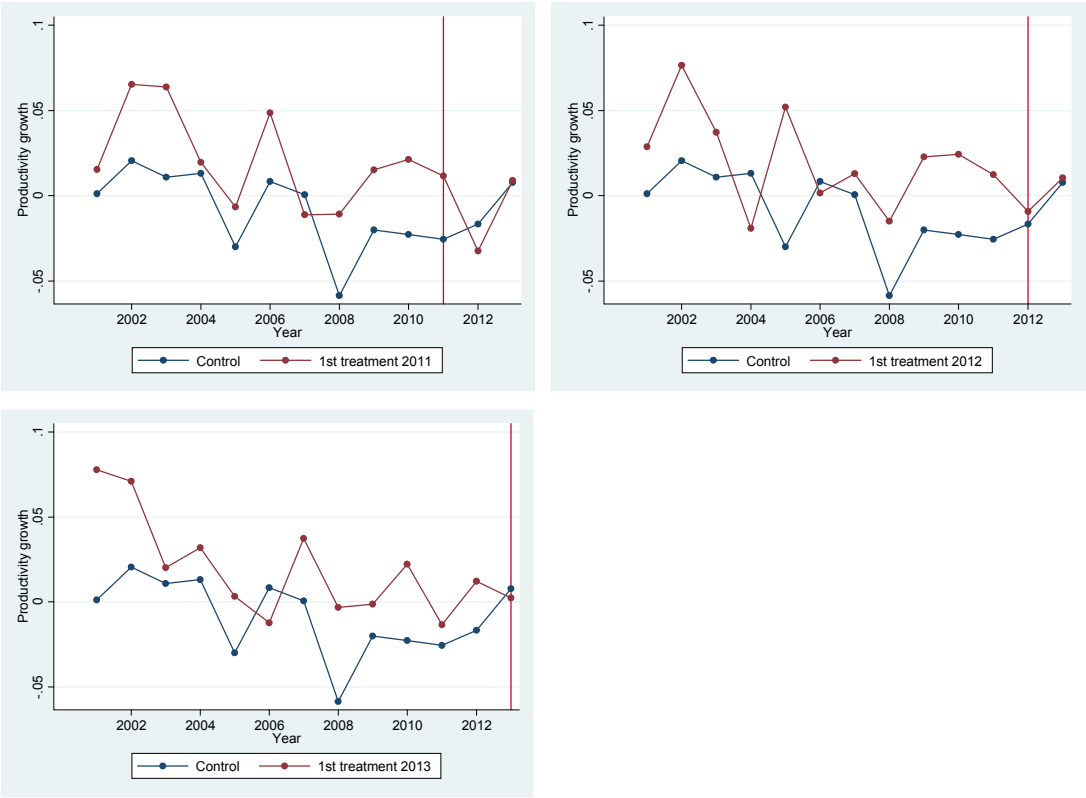


Source: InnovationDenmark Database and Statistics Denmark

Notes: These are plots of productivity growth, tfpt - tfpt-1, produced from the Levinsohn and Petrin (2003) estimation. Each plot depicts the average annual log productivity for those firms whose first participation year was in the year labeled against the log productivity of those firms who never participated in a program, "Control". Note that the control series is the same in each graph by definition. The vertical lines represent the first participation year.

Figure A2 Continued

Plots of raw productivity growth by first participation year



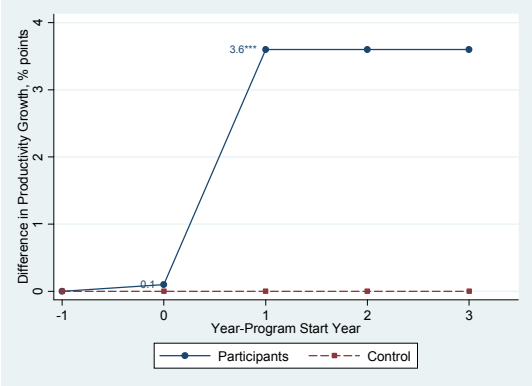
Source: InnovationDenmark Database and Statistics Denmark

Notes: These are plots of productivity growth, tfpt - tfpt-1, produced from the Levinsohn and Petrin (2003) estimation. Each plot depicts the average annual log productivity for those firms whose first participation year was in the year labeled against the log productivity of those firms who never participated in a program, "Control". Note that the control series is the same in each graph by definition. The vertical lines represent the first participation year.

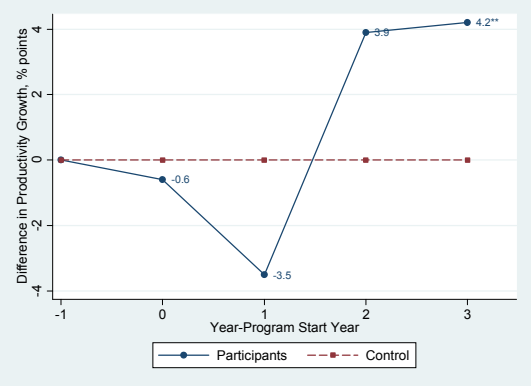
Figure A3

Estimated average effects of first program participation

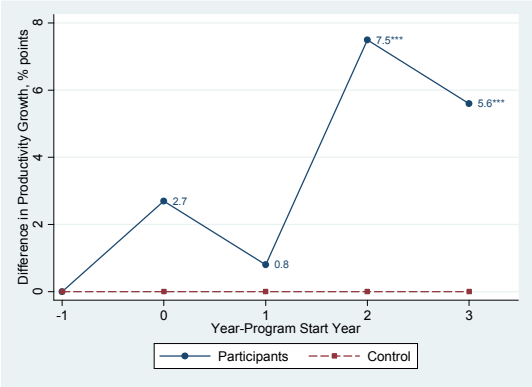
Innovation Network



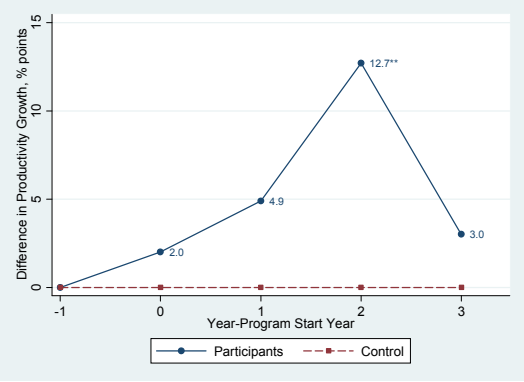
Innovation Assistant



Innovation Voucher



Innovation Consortia



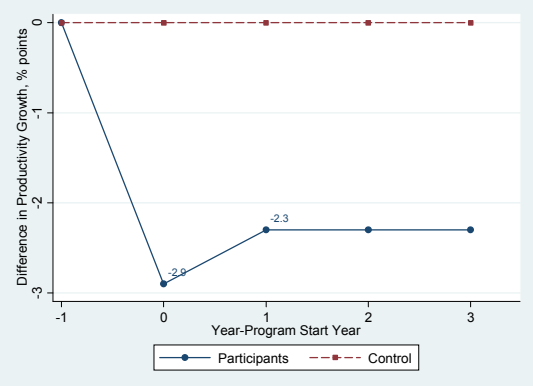
Source: InnovationDenmark Database and Statistics Denmark

Notes: The figure plots the estimated change in productivity growth resulting from first program participation immediately (0=the year in which the program began) and the change in average productivity growth after that, i.e. it is the average change in annual productivity growth one year later , two years later, three years later and beyond. For this reason, the effects shown at 1, 2, 3 are all equal to that average effect. The effects shown for 0 and later are estimated from a fixed effect DID. The common trend assumption is reflected in the effect at -1 being zero (i.e. this is the reference period used as "before" in the DID). Growth at time t is defined as tfpt – tfpt-1. For instance, the effect at 0 refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. *** p<0.01, ** p<0.05, * p<0.1. "Number of Program Participants" refers to the number of participants from which immediate effects were estimated.

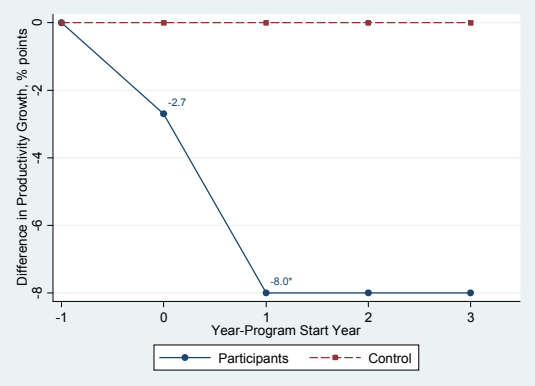
Figure A3 Continued

Estimated average effects of first program participation

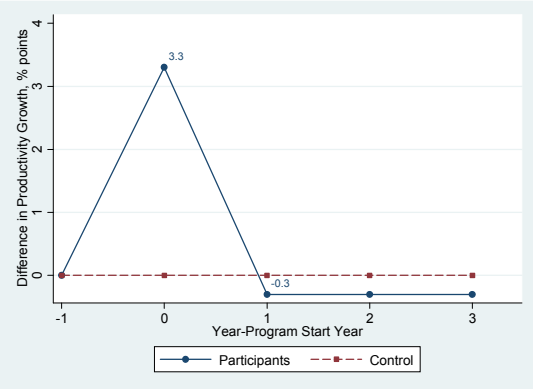
Industrial Ph.D.



DNATF



FP7



Source: InnovationDenmark Database and Statistics Denmark

Notes: The figure plots the estimated change in productivity growth resulting from first program participation immediately (0=the year in which the program began) and the change in average productivity growth after that, i.e. it is the average change in annual productivity growth one year later , two years later, three years later and beyond. For this reason, the effects shown at 1, 2, 3 are all equal to that average effect. The effects shown for 0 and later are estimated from a fixed effect DID. The common trend assumption is reflected in the effect at -1 being zero (i.e. this is the reference period used as "before" in the DID). Growth at time t is defined as tfpt – tfpt-1. For instance, the effect at 0 refers to changes in the growth from t-1 to t where t corresponds to the year in which program participation occurred. *** p<0.01, ** p<0.05, * p<0.1. "Number of Program Participants" refers to the number of participants from which immediate effects were estimated.

Table A7

Variable summary statistics, first-time participators

First Program	Number of firms	Measure	Productivity Growth, Lagged	Productivity Growth	Value Added, MM DKK	Number of FTE	Fixed Assets, MM DKK	Age of Firm	% in Business Services	% in Manufactur.	% in Trade and Transport	% in ICT	% in Construction	% Sole Proprietors	% Limited Liability
Industrial Ph.D.	99	mean	-1,10%	-2,48%	97,2	80	217,1	15	46%	23%	14%	14%	0%	NA	17%
		s.e.	4,71%	4,16%	22,1	11	80,2	1	5%	4%	4%	4%	0%	NA	4%
		median	-0,88%	-1,26%	21,8	32	8,0	11							
FP7	36	mean	-9,06%	1,01%	38,4	65	58,2	20	28%	56%	NA	NA	0%	NA	14%
		s.e.	5,67%	7,18%	7,6	14	21,6	3	8%	8%	NA	NA	0%	NA	6%
		median	-4,34%	0,44%	23,0	38	8,3	17							
Danish National Advancement for Technology Foundation	42	mean	-0,99%	-1,13%	42,7	55	49,5	15	24%	40%	14%	19%	NA	0%	14%
		s.e.	8,53%	7,16%	11,1	11	19,7	2	7%	8%	5%	6%	NA	0%	5%
		median	-1,49%	0,70%	17,0	27	7,4	13							
Innovation Consortia	117	mean	2,14%	-1,62%	62,8	92	103,8	20	10%	52%	28%	9%	0%	NA	9%
		s.e.	3,57%	3,90%	7,5	10	29,6	2	3%	5%	4%	3%	0%	NA	3%
		median	2,31%	-1,22%	27,1	39	15,6	17							
Innovation Network	1581	mean	1,58%	-0,06%	30,9	47	66,3	17	19%	33%	31%	12%	4%	3%	20%
		s.e.	1,39%	1,21%	1,5	2	12,9	0	1%	1%	1%	1%	0%	0%	1%
		median	-1,18%	0,35%	10,1	18	3,6	13							
Innovation Voucher	696	mean	-2,14%	-0,24%	14,1	25	10,9	17	13%	46%	25%	5%	11%	7%	26%
		s.e.	1,56%	1,93%	0,7	1	1,1	1	1%	2%	2%	1%	2%	1%	2%
		median	-0,77%	1,12%	7,4	13	2,4	13							
Innovation Assistant	691	mean	-2,08%	-0,07%	6,6	13	6,2	12	22%	25%	31%	14%	8%	10%	41%
		s.e.	2,01%	1,67%	0,3	1	1,2	0	2%	2%	2%	1%	1%	1%	2%
		median	-1,96%	-0,31%	3,9	7	1,1	8							
Total, all first time participators	3379	mean	0,09%	-0,23%	25,8	38	47,7	16	19%	35%	28%	11%	6%	5%	25%
		s.e.	0,89%	0,81%	1,1	1	6,6	0	1%	1%	1%	1%	0%	0%	1%
		median	-0,83%	0,35%	7,7	14	2,7	12							

Source: InnovationDenmark Database and Statistics Denmark

Table A8

Variable summary statistics, non-participating firms

Number of firms	Measure	Productivity Growth, Lagged	Productivity Growth	Value Added, MM DKK	Number of FTE	Fixed Assets, MM DKK	Age of Firm	% in Business Services	% in Manufactur.	% in Trade and Transport	% in ICT	% in Construction	% Sole Proprietors	% Limited Liability
162597	mean	0,84%	-0,88%	5,1	9	8,6	12	15%	12%	44%	4%	20%	31%	39%
	s.e.	0,06%	0,06%	0,0	0	0,3	0	0%	0%	0%	0%	0%	0%	0%
	median	0,47%	0,15%	1,8	3	0,9	9	0%	0%	0%	0%	0%	0%	0%

Source: InnovationDenmark Database and Statistics Denmark

Notes: In cells where the number of firms that can be identified is less than or equal to 5, the value NA is reported. All monetary figures are presented in millions of 2010 DKK. Table 12 presents the summary statistics for all non-participating firms, 162,597, in all years that they are observed

Table A9

Variable summary statistics, second-time participators

Second Program	Number of firms	Measure	Productivity Growth, Lagged	Productivity Growth	Value Added, MM DKK	Number of FTE	Fixed Assets, MM DKK	Age of Firm	% in Business Services	% in Manufactur.	% in Trade and Transport	% in ICT	% in Construction	% Sole Proprietors	% Limited Liability
Industrial Ph.D.	25	Mean	-5,41%	-4,95%	128,8	140	293,9	22	52%	44%	0%	NA	0%	NA	24%
		s.e.	8,20%	8,57%	38,0	29	184,5	3	10%	10%	0%	NA	0%	NA	9%
		Median	-1,96%	-5,17%	56,6	82	26,3	19							
FP7	25	Mean	-0,06%	-12,96%	23,7	36	24,1	16	24%	52%	NA	NA	0%	0%	NA
		s.e.	8,77%	9,83%	6,1	9	10,5	2	9%	10%	NA	NA	0%	0%	NA
		Median	1,18%	-2,44%	17,0	23	3,7	14							
Danish National Advancement for Technology Foundation	27	Mean	15,95%	9,27%	59,7	62	174,5	19	NA	74%	NA	NA	0%	0%	22%
		s.e.	7,74%	8,13%	22,5	18	130,1	3	NA	9%	NA	NA	0%	0%	8%
		Median	14,69%	5,61%	12,0	25	7,4	12							
Innovation Consortia	27	Mean	-3,77%	-14,50%	59,5	86	89,2	22	NA	63%	NA	NA	NA	NA	NA
		s.e.	8,96%	22,18%	15,1	21	39,1	4	NA	9%	NA	NA	NA	NA	NA
		Median	-3,58%	8,62%	28,7	48	12,9	18							
Innovation Network	302	Mean	-2,17%	1,58%	60,0	73	64,1	21	20%	40%	26%	13%	NA	NA	14%
		s.e.	2,76%	2,65%	11,2	5	13,8	1	2%	3%	3%	2%	NA	NA	2%
		Median	0,71%	1,38%	21,2	35	6,9	17							
Innovation Voucher	112	Mean	2,81%	-6,25%	17,2	32	13,4	18	8%	60%	18%	10%	NA	NA	21%
		s.e.	3,27%	5,02%	2,1	4	2,9	1	3%	5%	4%	3%	NA	NA	4%
		Median	-1,00%	2,12%	10,6	24	3,9	14							
Innovation Assistant	77	Mean	-0,78%	-9,37%	8,2	16	4,0	15	23%	38%	27%	9%	3%	6%	26%
		s.e.	4,42%	5,84%	1,0	2	0,8	1	5%	6%	5%	3%	2%	3%	5%
		Median	0,52%	-6,04%	4,5	9	0,9	11							
Other (Sample size too small)	27														
Total, all second time participators	622	Mean	-0,69%	-1,93%	46,9	60	62,5	19	18%	47%	21%	11%	2%	2%	17%
		s.e.	1,73%	2,12%	6,0	3	11,9	1	2%	2%	2%	1%	1%	1%	2%
		Median	-0,13%	1,17%	13,7	25	5,4	16							

Source: InnovationDenmark Database and Statistics Denmark.

Notes: In cells where the number of firms that can be identified is less than or equal to 5, the value NA is reported. All monetary figures are presented in millions of 2010 DK

APPENDIX 4: OTHER SPECIFICATIONS

Table A10

Fixed Effect difference in differences, effect on total factor productivity of first program participation, no covariates

(A) Average effect on annual TFP growth		**Innovation Network**	**Innovation Assistant**	**Innovation Voucher**	**Innovation Consortia**	**Industrial Ph.D.**	**DNATF**	**FP7**
	0	0.0085	0.0039	0.0323	0.0268	-0.0145	-0.0229	0.0409
		(0.0138)	(0.0197)	(0.0204)	(0.0442)	(0.0469)	(0.0801)	(0.0712)
	>=1	0.0432***	0.0217	0.0458***	0.0660***	0.0028	-0.0674	0.0044
		(0.0084)	(0.0133)	(0.0120)	(0.0245)	(0.0294)	(0.0492)	(0.0711)
Number of firms		164,180	163,290	163,295	162,716	162,698	162,641	162,635
Number of observations		883,111	873,686	874,503	868,703	868,429	867,967	867,932
Number or participants		1581	691	696	117	99	42	36

(B) Dynamic Effect on annual TFP growth	**Years after particpation**	**Innovation Network**	**Innovation Assistant**	**Innovation Voucher**	**Innovation Consortia**	**Industrial Ph.D.**	**DNATF**	**FP7**
	0	0.0086	0.0043	0.0322	0.0262	-0.0149	-0.0226	0.0408
		(0.0138)	(0.0198)	(0.0204)	(0.0444)	(0.0468)	(0.0802)	(0.0711)
	1	0.0435***	-0.0207	0.0133	0.0551	-0.0198	-0.0869	0.0551
		(0.0148)	(0.0232)	(0.0262)	(0.0426)	(0.0479)	(0.0840)	(0.1182)
	2	0.0307*	0.0551*	0.0806***	0.1317**	-0.0554	-0.0360	-0.1237
		(0.0164)	(0.0314)	(0.0244)	(0.0515)	(0.0862)	(0.1549)	(0.1331)
	>=3	0.0539***	0.0536***	0.0591***	0.0377	0.0513	-0.0440	0.0654
		(0.0153)	(0.0177)	(0.0153)	(0.0462)	(0.0388)	(0.0768)	(0.0531)
Number of firms		164,180	163,290	163,295	162,716	162,698	162,641	162,635
Number of observations		883,111	873,686	874,503	868,703	868,429	867,967	867,932
Number or participants		1581	691	696	117	99	42	36

Source: InnovationDenmark Database and Statistics Denmark

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Not shown, but included in all regressions are year indicators. Growth at time t is defined as tfpt – tfp_{t-1}

Table A11

Fixed Effect difference in differences, effect on total factor productivity of first program participation, no imputaion

(A) Average effect on annual TFP growth	Years after particpation	Innovation Network	Innovation Assistant	Innovation Voucher	Innovation Consortia	Industrial Ph.D.	DNATF	FP7
	0	-0.0052	-0.0212	0.0391**	0.0467	-0.0578	0.0483	0.0847
		(0.0144)	(0.0216)	(0.0179)	(0.0479)	(0.0508)	(0.0803)	(0.0721)
	>=1	0.0182**	-0.0228	0.0158	0.0367	-0.0400	-0.1163**	-0.0785
		(0.0089)	(0.0161)	(0.0123)	(0.0275)	(0.0263)	(0.0537)	(0.0846)
Number of firms		129,590	128,732	128,730	128,169	128,148	128,094	128,087
Number of observations		646,875	638,677	639,551	634,542	634,290	633,902	633,885
Number or participants		1334	585	580	99	88	33	30

(B) Dynamic Effect on annual TFP growth	Years after particpation	Innovation Network	Innovation Assistant	Innovation Voucher	Innovation Consortia	Industrial Ph.D.	DNATF	FP7
	0	-0.0051	-0.0209	0.0389**	0.0457	-0.0578	0.0479	0.0846
		(0.0143)	(0.0216)	(0.0179)	(0.0479)	(0.0508)	(0.0805)	(0.0722)
	1	0.0169	-0.0662***	-0.0267	0.0373	-0.0751	-0.1049	-0.0829
		(0.0141)	(0.0233)	(0.0250)	(0.0475)	(0.0515)	(0.0843)	(0.1078)
	2	0.0097	-0.0070	0.0556**	0.0979*	-0.0018	-0.0840	-0.0785
		(0.0173)	(0.0271)	(0.0264)	(0.0582)	(0.0643)	(0.1860)	(0.1046)
	>=3	0.0275*	0.0206	0.0353**	0.0014	-0.0331	-0.1605*	-0.0706
		(0.0160)	(0.0232)	(0.0178)	(0.0404)	(0.0451)	(0.0954)	(0.0930)
Number of firms		129,590	128,732	128,730	128,169	128,148	128,094	128,087
Number of observations		646,875	638,677	639,551	634,542	634,290	633,902	633,885
Number or participants		1334	585	580	99	88	33	30

Source: InnovationDenmark Database and Statistics Denmark

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Not shown, but included in all regressions are year indicators, lags of the following variables: 3 digit industry dummies, firm ownership indicators, firm age, log of labor, and log of capital as well as 2-digit industry indicators. Observations with a JKOD=R are dropped. Growth at time t is defined as $tfpt - tfp_{t-1}$