R&D CONTRIBUTIONS TO GROWTH

– AN EXERCISE BASED ON GROWTH ACCOUNTING

VI FREMMER VIDEN

Redaktion:
Martin Junge
Kasper Marc Rose Nielsen
Wen Shi Xuan

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INDHOLD

SAMMENFATNING

Flere undersøgelser peger på, at produktivitetsvæksten i Danmark har været sløj de sidste to årtier. Hvis den danske vækst havde fulgt den amerikanske siden midten af 90'erne, ville en gennemsnitlig LO-arbejder have tjent 3.000 kroner mere om måneden i dag (se Produktivitetskommissionen (2014)). Øget produktivitet er derfor en meget vigtig kilde til at forbedre levevilkår og velfærd.

Produktivitetsvækst opstår, når vi bliver bedre til at gøre tingene og kan producere mere uden at anvende flere ressourcer. Her spiller forskning og udvikling en central rolle. Pointen er, at forskningen skaber ny viden, som igen er med til at skabe grundlag for teknologiske forbedringer. Eksempler fra grundforskningen er Ørsteds og Faradays forskning i elektromagnetisme, der ligger til grund for de elkraftværker og vindmøller, som producerer strøm til vores hverdag. Eller kortlægningen af det menneskelige DNA, som ligger til grund for nye behandlingsformer af sygdomme. Forskningen kan også foregå tættere på produkter eller processer i virksomhederne, for eksempel i form af en ny teknologi eller en anden måde at organisere arbejdet på.

Danmark investerer hvert år cirka tre pct. af BNP i forskning og udvikling (FoU). Den private sektor står for knap to pct. og den offentlige sektor for ca. én pct. (UFM (2015)). I international sammenhæng placerer det Danmark på en sjetteplads blandt OECD-landene. Ét er niveauet for investeringerne, noget andet er spørgsmålet: Hvad bidrager forskning og udvikling med til den økonomiske vækst? Det er et vigtigt spørgsmål, og det er meget komplekst at besvare.

Virksomheder kan ved hjælp af forskning og udvikling blive mere innovative og dermed opnå konkurrencefordele, hvilket skaber forventning om positivt afkast og vækst. FoU-virksomhederne opnår en direkte effekt, når deres investeringer giver et positivt afkast. Andre virksomheder kan imidlertid også tilegne sig den nye viden og information, som FoU-virksomheder skaber, og til betydeligt lavere omkostninger. Selv om FoU-virksomhederne forsøger at inddæmme deres viden ved at patentere, hemmeligholde eller ved hjælp af en helt tredje strategi, vil det som regel være særdeles vanskeligt at gøre fuldkomment. Den nye viden blotlægges for eksempel ved en laboratorieundersøgelse af en pille eller ved at skille et nyt apparat ad, da viden er indlejret i produktet.[1] Det kan også være, at forskere skifter job og tager deres viden med. Det giver en spillover-effekt (eller et indirekte bidrag) fra FoU. Denne spredning af viden gør, at det samlede samfundsøkonomiske afkast af investeringer i FoU er større end det direkte privatøkonomiske afkast for den enkelte virksomhed.[2] Derfor er der fra politisk hold meget opmærksomhed på at fremme forskning og udvikling og spredning af viden. Stimulering af den private forskning og private udviklingsinvesteringer sker bl.a. igennem subsidier til, eller skattefordele for, investeringerne samt gennem offentlig forskning og fremme af samarbejde om forskning og udvikling.

Måling af bidraget fra FoU til økonomisk vækst har været genstand for faglig og politisk interesse i mange år. I denne analyse, som er udarbejdet af DEA på foranledning af Uddannelses- og Forskningsministeriet, analyserer DEA ud fra et vækstregnskab, hvilken rolle forskellige brancher spiller for private investeringer i FoU og deres bidrag til væksten i brancher og den aggregerede økonomi. To forhold gør dette muligt: Det ene er eksistensen af repræsentative statistiske undersøgelser af virksomhedernes udgifter til FoU over en længere årrække. Det andet er, at nationalregnskabet er ændret, så FoU fremover håndteres som investeringer i nationalregnskabet, hvilket blev gennemført ved hovedrevisionen i 2014 (Danmarks Statistik (2015)).

Analysen gennemføres for 59 brancher i perioden 1980-2012 med fokus på den markedsmæssige økonomi. Der konstrueres et kapitalapparat for FoU på brancheniveau, og ud fra et vækstregnskab beregnes dets direkte bidrag til økonomisk vækst, og efterfølgende estimeres det indirekte bidrag ud fra ændringer i produktiviteten. Det undersøges kun, om der er indirekte bidrag (spillover) mellem virksomheder inden for den samme branche. Hvis der er positiv spillover mellem virksomheder i forskellige brancher eller mellem lande, underestimeres det samlede bidrag fra spillover og dermed det samlede bidrag til væksten. Andre forbehold omkring den anvendte metode gennemgås nedenfor. I tillæg undersøges også inden for analyse-setuppet, om *offentlig* FoU påvirker produktiviteten i den markedsmæssige økonomi. Antallet af ansatte kandidater og ph.d.er fra universiteterne i brancherne anvendes til at approksimere forbindelsen mellem branchens produktivitet og de offentlige FoU.[3] Endelig testes også, om private investeringer i FoU fører til vækst af andre centrale makroøkonomiske variable. For det første; kan investeringer i FoU føre til mere eksport? Det fremføres ofte, at højtuddannet arbejdskraft er afgørende for eksporten. For det andet; hvis FoU fører til økonomisk vækst, kan det så også føre til øget beskæftigelse?

1. Spillover sker også mellem FoU-virksomheder, da FoU også kan anvendes til at lære af andres FoU og dermed opnå en teknologioverførsel.
2. FoU kan også give negative spillover-effekter. Den kan anvendes til at få konkurrenternes investeringer i for eksempel FoU til at være forældede. I den forbindelse skal den negative effekt modregnes i den positive.
3. Et problem omkring vækstbidraget fra offentlig FoU, som vi ikke adresserer, er crowding in/out af private investeringer. Det ligger imidlertid uden for denne rapports analyse.

RESULTATER

Rapportens hovedresultater

- Privat FoU har ud fra et vækstregnskab haft et direkte bidrag på 0,1 procentpoint om året til den økonomiske vækst i perioden 2000-2012. Bidraget svarer til fire til otte pct. af væksten i output fra den markedsmæssige økonomi. Den resterende del af væksten i den markedsmæssige økonomi stammer fra importerede varer, anden kapital, arbejdskraft og produktivitetsforbedringer.
- Det beregnede bidrag fra FoU er af samme størrelsesorden som bidraget fra materielle investeringer (bygninger, maskiner mv.), og estimatet er på linje med andre studier i Danmark, USA og nogle europæiske lande.
- Fra 1990'erne til 2000'erne er der sket en acceleration i det beregnede direkte bidrag fra FoU til den økonomiske vækst. Det er en indikation på, at Danmark i højere og højere grad er et videnssamfund.
- Privat FoU påvirker produktiviteten i brancherne. Mens analysen ikke finder et bidrag til den samlede markedsmæssige økonomi, hvilket kan skyldes måleproblemer, viser estimationerne i modellen, at en stigning på én pct. i FoU-kapitalapparatet giver 0,1 procentpoint stigning i produktivitetsvæksten i fremstillingssektoren, hvor data anses som værende mindre påvirket af målefejl.
- Det samlede estimerede bidrag fra privat FoU på væksten i fremstillingssektoren er 0,91 procentpoint i perioden 2000-2012. Det estimerede direkte bidrag er 0,27 procentpoint om året, og det estimerede indirekte bidrag er 0,64 procentpoint. Således står det indirekte bidrag for omkring 70 pct. og det direkte bidrag for omkring 30 pct.

Andre resultater

- Det estimerede direkte bidrag til væksten fordeler sig meget ujævnt på brancher. Medicinalindustri, maskinindustri, møbelindustri og anden industri står således for langt den største del af bidraget fra fremstillingssektoren. Uden for fremstillingssektoren er bank og forsikring de vigtigste brancher.
- Estimationerne i modellen viser, at bidraget fra offentlig FoU på produktiviteten i den markedsmæssige økonomi ikke er statistisk forskellig fra nul. Der er imidlertid mange usikkerheder forbundet med estimatet. En mulig forklaring er, at offentlige investeringer fremmer *(crowder-in)* private investeringer. Dermed er der en høj korrelation mellem offentlige og private investeringer, som gør det vanskeligt at måle bidraget fra dem begge samtidig.
- På trods af, at vi estimerer et bidrag på 0,91 procentpoint om året til væksten af forskning og udviklingskapitalapparatet i fremstillingssektoren, finder vi ikke en statistisk signifikant effekt på hverken eksporten eller beskæftigelsen i denne sektor.

SUPPLERENDE OVERVEJELSER

Resultaterne for fremstillingssektoren står stærkest i vores beregninger. Det skyldes ikke nødvendigvis, at der kun findes et positivt og signifikant bidrag fra FoU på produktivitet i den del af økonomien, men at fremstillingssektoren er velmålt. Er det muligt at sige noget om bidraget af FoU til den samlede markedsmæssige økonomi? Som resultaterne står nu, er der kun estimeret et direkte bidrag af FoU på 0,1 procentpoint. Det betyder, at det positive indirekte bidrag (spillover), som findes i fremstillingssektoren ikke genfindes statistisk i estimationerne for den øvrige markedsmæssige økonomi.

Alternativt kan det forsigtigt antages, at spillover er 0,64 procentpoint om året i fremstillingssektoren og nul i den øvrige markedsmæssige økonomi. Det samlede direkte bidrag er stadig 0,1 procentpoint. Men nu tillægges det indirekte bidrag fra spillover i fremstillingssektoren. Den vægtes med fremstillingssektorens størrelse af den markedsmæssige økonomi, som er 0,23 i 2012. Det samlede indirekte bidrag fra investeringer i privat FoU i den markedsmæssige økonomi bliver dermed 0,15 procentpoint og totalbidraget fra FoU på 0,25 procentpoint. Under de forudsætninger vil FoU samlet bidrage med 10-15 pct. af væksten i den markedsmæssige økonomi.

Et lidt mere optimistisk skøn er, at fordelingen mellem de direkte og indirekte bidrag, som findes for fremstillingssektoren, også gør sig gældende for resten af den markedsmæssige økonomi. Her er det direkte bidrag stadig 0,1 procentpoint som beregnet, og den udgør 30 pct. af det totale bidrag. Det totale bidrag kan derfor opgøres til 0,33 procentpoint om året i perioden 2000-2012, hvoraf det indirekte bidrag er 0,23 procentpoint. Bidraget til output-vækst fra privat FoU i den markedsmæssige økonomi vil med dette scenarium være på 13-19 pct. i perioden 2000-2012.

Resultatet for FoU-bidrag til outputvæksten spænder dermed fra 0,1 til 0,33 procentpoint i perioden 2000-2012 på den markedsmæssige økonomi. Det skal dog her understreges, at der er tale om stærkt forsimplede beregninger, som kun skal illustrere omfanget af resultatet inden for denne analysemetode.

Det er nødvendigt at tage et par forbehold for vores resultater.

- For det første måler vi ikke den kausale effekt af FoU på økonomisk vækst. Det kan være, at vækst skaber mere FoU-investering. Dertil kommer, at produktivitetsvækst er drevet af andre faktorer end FoU – fx globalisering og organisering af arbejdet, som kan være korreleret med FoU. Hvis FoU virksomheder også globaliserer mere end andre, vil det give et for højt estimat af FoU på vækst.

- For det andet koncentrerer vi os om spillover mellem virksomheder i samme branche, så evt. spillover mellem brancher udelades, hvilket vil give tendens til, at analysens estimat af FoU på vækst er for lavt. Mens spillover har lavere sandsynlighed for at forekomme mellem brancher, så kan spillover mellem brancher og på tværs af grænser føre til mere drastiske ændringer, fordi den kognitive afstand er større.

- For det tredje er der risiko for undervurdering af betydningen af langvarig FoU-aktivitet pga. økonomiske afskrivningsregler for FoU-kapitalapparatet, som gør, at konstante investeringer i FoU på langt sigt leder til et konstant vidensniveau og dermed nul bidrag fra investeringer i FoU.

- For det fjerde kan FoU-investeringer og teknologiske fremskridt føre til afledte bidrag, herunder komplementerende investeringer, som skygger for bidraget fra den nye viden.

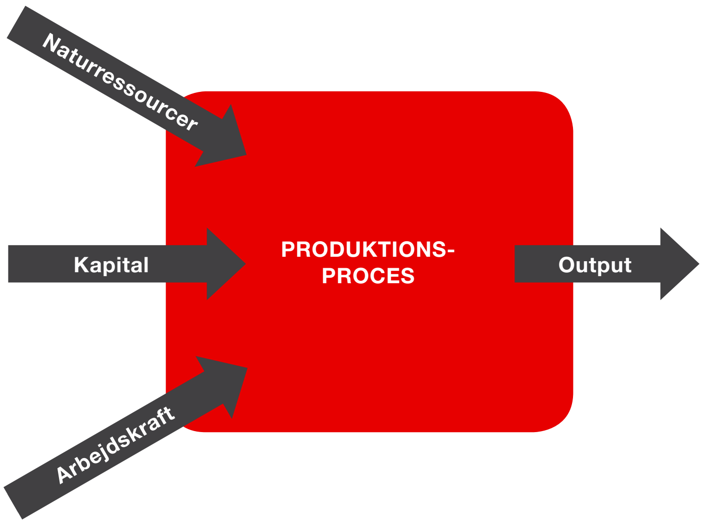
- For det femte bygger vækstregnskab på en traditionel makroøkonomisk tilgang, hvor der er fuldkommen konkurrence. Det betyder, at der ikke bliver taget højde for markedskontrol, hvor producenterne kan tage højere priser. Evalueret i et fuldkomment konkurrencesetup vil det komme til udtryk som produktivitet.

- Samlet set er det vores vurdering, at analyse baseret på vækstregnskab undervurderer bidraget fra investeringer i FoU.

METODE OG DATA

Metoden[4], som anvendes, er et vækstregnskab og kan i sin mest simple form skitseres vha. følgende figur:

Figur 1. *En simpel model for produktion*



For at producere varer og tjenester er der brug for input af forskellige produktionsfaktorer. I figuren er det kondenseret til kapital, arbejdskraft og naturressourcer.[5] På langt sigt producerer et land flere varer og tjenester på to måder:[6] Den første er ved at øge mængden af kapital. Men et stigende forhold mellem kapital og arbejdskraft vil betyde, at kapitalens vækstbidrag bliver mindre og mindre på grund af faldende marginalprodukt. Et vedvarende vækstbidrag fra kapital kræver derfor større og større investeringer, hvilket er urentabelt, da det vil kræve en forholdsmæssig stor stigning i opsparingskvoten for at have råd til at finansiere investeringerne. Den anden mulighed for vækst er at øge produktiviteten. Produktivitetsvækst er defineret som vækst i produktionen, der ikke kan henføres til inputtene i produktionsfunktionen, og dét er et mål for den langsigtede teknologiske udvikling. I Figur 1 svarer det til produktionsprocessen. Der er mange faktorer, der kan forbedre produktionsprocessen. Lovgivning og institutionelle faktorer vil være vigtige. Men også nye måder at organisere arbejdet på, nye teknologier og innovation, konkurrence og kreativ destruktion spiller en rolle. Langsigtet vækst sker gennem forbedringer af produktionsprocessen.

4. Denne er en kort sammenskrivning af metoden, der er mere udførligt behandlet i kapitlet Methodology and Data på side 23.
5. En virksomhed anvender også halvfabrikata fra andre virksomheder, og de er også produceret ved hjælp af arbejdskraft, kapital, naturressourcer og andre halvfabrikata. Ultimativt fører denne kæde til, at input i produktionen kondenseres til kun tre produktionsfaktorer.
6. Befolkning og ressourcer anses for at være knappe på langt sigt, og mængden af arbejdskraft og naturressourcer er vanskelige at forøge for et land. Ved befolkningstilvækst vil målet også være at øge mængden af varer og tjenester per person.

Forskning og udvikling er at betragte som investeringer og altså som kapital i denne sammenhæng. Årsagen er, at FoU har samme karakteristika som andre investeringer. For det første holder den viden og information, som skabes, ofte i mange år i fremtiden. For det andet kan virksomhederne have ejerskab over denne viden. For det tredje vil FoU give forventninger om fremtidig indtægt. For det fjerde kan den viden, som opstår, falde i værdi, fordi den forældes.[7]

FoU er også med til at forbedre produktionsprocessen. Det sker gennem den viden, som skabes. Selv om firmaer forsøger at holde viden for sig selv, vil det være vanskeligt at gøre fuldt ud. Dermed opstår muligheden for, at viden kan forbedre produktionsprocessen for andre virksomheder, uden at de afholder omkostningerne ved at kreere viden. Den videnskapital, som er investeret i én virksomhed, kan derfor delvist anvendes (næsten) gratis i en anden virksomhed.

Den anvendte metode er, som allerede nævnt, et vækstregnskab og er udviklet af Jorgenson et al. (1987) og forfinet af EUKLEMS (2007). Metoden baserer sig på, at modellen i Figur 1 anvendes på brancheniveau med nationalregnskabsdata. I ingen af de nævnte studier[8] er FoU betragtet som en investering og dermed behandlet som kapital, da nationalregnskabsdata på daværende tidspunkt ikke gav mulighed for dette. Det er imidlertid blevet muligt. Årsagen er, at nationalregnskabet er overgået til ESA2010 systemet i 2014.[9]

Ved opstillingen af vækstregnskabet er det vigtigt at få en meget detaljeret opsplitning af produktionsfaktorerne arbejdskraft, kapital og forbrug i produktionen.[10] I undersøgelsen er der otte forskellige typer af kapital, 234 typer af halvfabrikata og én type arbejdskraft, da nationalregnskabet ikke har opdelt arbejdskraften i forskellige typer. Umiddelbart virker det som en begrænsning, at arbejdskraften ikke er inddelt i for eksempel uddannelsestyper. Men analysen er foretaget på relativt detaljeret brancheniveau, dermed er variationen i arbejdskraften delvist indfanget. Derudover laver Danmarks Statistik et vækstregnskab, hvor arbejdskraften er inddelt i uddannelsestyper, og det ændrer kun marginalt på målingen af produktivitet. Uddannelse spiller altså en mindre rolle, når analysen gennemføres på detaljerede brancher. De syv typer af kapital består ud over FoU af bygninger, andre anlæg, transportmidler, ICT og maskiner, stambesætninger, olie, gas, mineraludvinding samt

7. I modsætning til almindelige kapitalinvesteringer bevarer viden en vis værdi og bør principielt ikke afskrives helt, da ny viden som regel bygger på eksisterende viden.
8. Dermed ikke sagt, at forskning og udvikling ikke spiller en væsentlig rolle i analyser, der anvender metoden. Mange af disse har imidlertid kun fokuseret på forskning og udviklingsbidrag til produktivitetsvæksten.
9. Tidligere har nationalregnskabet lavet et såkaldt satellitregnskab, hvor forskning og udvikling blev behandlet som investeringer, men det er altså kun fra 2014, at der har været officielle tal for dette i Danmark.
10. Forbrug i produktionen eller halvfabrikata indgår i vækstregnskabet (i modsætning til den simple model i Figur 1), da undersøgelsen er lavet på brancheniveau, og virksomhederne leverer varer og tjenester til hinanden.

en restgruppe, der består af software og originalværker inden for kunst, underholdning mv. Kapitalapparatet for FoU og restgruppen er konstrueret til denne analyse ved hjælp af en særlig dataleverance fra Danmark Statistik, hvor FoU-investeringer er opgjort på 69 brancher for perioden 1966-2014. Den detaljerede inddeling af halvfabrikata findes gennem input-output tabeller, hvor der er 117 produkter og tjenester på hjemlige erhverv samt 117 produkter og tjenester importeret fra udenlandske erhverv. Alle data kan downloades fra statistikbanken.dk, med undtagelse af investeringer i FoU fordelt på brancher.

Studiet her er ikke det første til at undersøge betydning af FoU på økonomisk vækst. En god oversigt findes i Hall et al. (2009b). Den metode, som anvendes her, fandt første gang anvendelse med et satellitregnskab konstrueret af Corrado et al. (2005). Fokus i den analyse var på det direkte bidrag til den økonomiske vækst af investeringer i immaterielle aktiver og altså ikke udelukkende FoU. Rapporten havde fokus på implementering og gav ingen resultater. I et opfølgende studie (Corrado et al. (2009)) finder forfatterne, at det direkte bidrag fra FoU til væksten i USA i perioden 1995-2005 var omkring 0,1 procentpoint om året. Et tilsvarende studie på europæiske lande i van Ark et al. (2009) finder, at bidraget fra ”innovativ ejendom”, hvoraf FoU er en del, i Danmark er på 0,27 procentpoint. Et nyere studie fra Danmarks Statistik (Danmarks Statistik (2015)) viser, at bidraget til dansk økonomi af FoU er på mellem 0,1 og 0,2 procentpoint i perioden 1966-2012. Ingen af disse studier undersøger effekten af FoU på produktiviteten (indirekte effekter).

Analysen fokuserer på den markedsmæssige økonomi eksklusiv boliger og private husholdninger. En del af resultaterne vil imidlertid udelukkende blive afrapporteret for fremstillingssektoren, da den i produktivitetssammenhæng formodes at være den mest velmålte.

Fortolkningen af resultaterne skal også tages varsomt jf. de forbehold, som er nævnt ovenfor.

UDDYBENDE RESULTATER

Væksten i den markedsmæssige økonomi for perioden 1980-2012 er vist i Tabel 1 for perioder af ti år. Produktionen steg med godt og vel fire pct. om året fra 1980-2000. Der bemærkes en nedgang i den økonomiske vækst i perioden fra 2000-2009, som skyldes finanskrisen. I et vækstregnskab ser man, at den vigtigste faktor i produktionen er forbrug, hvilket er naturligt, da en stigning i produktion øger forbruget af input. Bidraget fra arbejdskraft varierer over årene. Bidraget fra kapital har været faldende over alle årene: Fra 1 procentpoint i 1980-1989 er kapitalbidraget kun 0,1 procentpoint i perioden 2010-2012. Den sidste søjle i tabellen angiver produktivitetsudviklingen, der viser det velkendte problem i Danmark med faldende produktivitet.

Tabel 1. *Kilder til vækst i produktionen, markedsmæssig økonomi*

	Produktion	Arbejdskraft	Kapital	Forbrug i produktion	TFP
1980-1989	4,20%	-0,20%	1,00%	1,80%	1,70%
1990-1999	4,30%	0,30%	0,60%	1,90%	1,50%
2000-2009	1,70%	-0,10%	0,40%	1,20%	0,30%
2010-2012	2,60%	0,00%	0,10%	1,40%	1,00%

Kilde: Danmarks Statistik og egne beregninger.

Når bidraget til væksten for de forskellige typer af kapital opgøres i vækstregnskabet, ser billedet ud som i Tabel 2, hvor kapitalen inddeles i tre typer: materielle investeringer, software og FoU. Software er interessant, fordi det – som FoU – er en immateriel investeringstype. Bidraget fra FoU var på 0,07 procentpoint om året i perioden 1990-1999 og steg til 0,13 procentpoint om året i perioden 2000-2009. Af Tabel 2 fremgår det også, at bidraget fra de materielle investeringer har været faldende over alle årene. Faktisk udgør bidraget fra FoU lige så meget som fra de samlede materielle investeringer, og sammen med software bidrager de immaterielle investeringer med mere end de materielle investeringer i perioden efter 2000.

Tabel 2. *Bidraget til økonomisk vækst fra forskellige typer af kapital, markedsmæssig økonomi*

	FoU	Software	Materielle
1980-1989	0,01%	0,02%	0,96%
1990-1999	0,07%	0,10%	0,45%
2000-2009	0,13%	0,13%	0,17%
2010-2012	0,11%	0,11%	-0,07%

Kilde: Danmarks Statistik og egne beregninger.

Analysen ser også på, om der er en indirekte sammenhæng mellem vækst i FoU og produktivitetsudviklingen inden for brancherne. Her skal man være opmærksom på, at det ikke kun er inden for en branche, der kan opstå spillover. Det kan også forekomme mellem brancher samt mellem ind- og udland. Det må formodes, at teknologioverførslen har størst sandsynlighed for at foregå mellem virksomheder, som ligner hinanden. Dermed er der god grund til at fokusere på overførsler inden for samme branche. Til gengæld er det ikke nødvendigvis her, at det største indirekte bidrag kan forekomme, da en vis kognitiv afstand mellem idéer har potentialet til at give det største bidrag (se Hall et al. (2009b)). Ved ikke at medtage muligheden for bidrag uden for branchen underestimerer vi isoleret set bidraget fra spillover.

Bidraget fra vækst i kapitalapparatet for FoU til vækst i produktiviteten er estimeret med kontrol for konjunkturudviklingen.[11] Bidragene er estimeret for den markedsmæssige økonomi og fremstillingssektoren. Årsagen er, at produktiviteten er meget vanskelig at måle i servicesektoren, og bedre resultater kan opnås for fremstillingssektoren. Resultatet kan ses i Tabel 3.

Tabel 3. *Den indirekte effekt af private investeringer i FoU på produktivitetsvæksten*

	Markedsmæssig økonomi	Fremstillingssektoren
FoU	0,015	0,115
	(0,015)	(0,047)
Output gap	-	-0,017
	-	(-0,126)
N	890	368
R2	0,07	0,02

Kilde: Danmarks Statistik og egne beregninger.
Anm.: Standardfejl i parenteser

11. For industrien anvendes output gap som mål for konjunktur, og for den markedsmæssige økonomi anvendes årsdummyer.

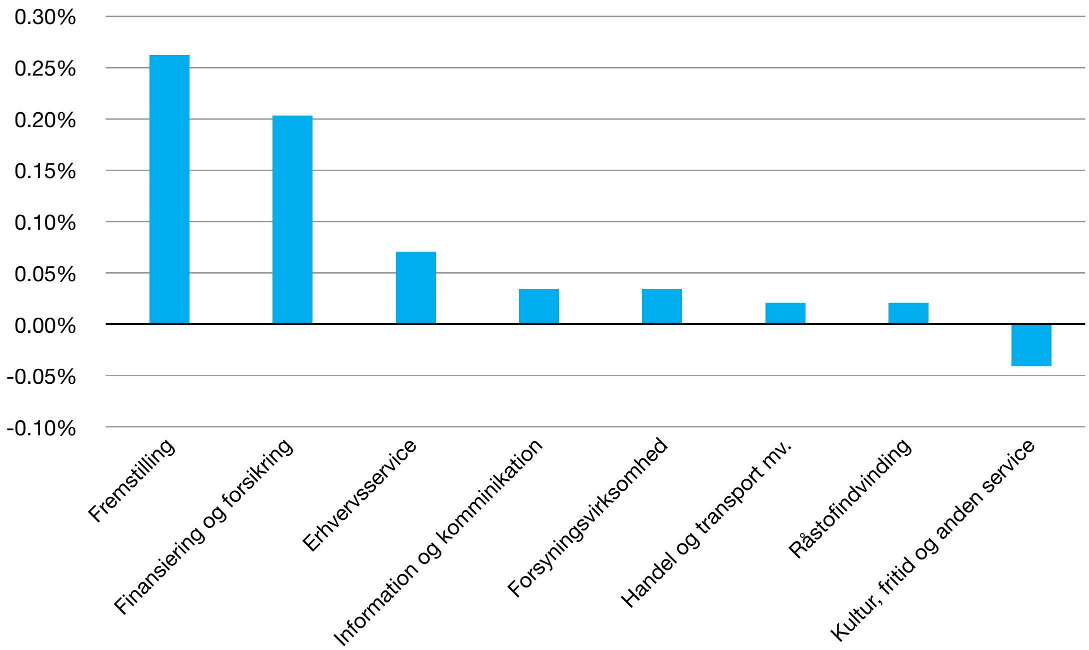
Det er muligt at sammenligne det indirekte og direkte bidrag i fremstillingssektoren. Det direkte bidrag i perioden 2000-2012 er 0,27 procentpoint på væksten (jf. Figur 2). I samme periode voksede FoU-kapitalapparatet med 5,6 pct., hvilket svarer til, at det indirekte bidrag var 0,64 pct. om året til produktionen i fremstillingssektoren. Det samlede bidrag af FoU var i alt 0,91 procentpoint til produktionen i fremstillingssektoren, og det direkte bidrag står for de 30 pct.

ANDRE RESULTATER

Bidraget fra FoU til den markedsmæssige økonomi beregnes ved at aggregere resultaterne fra et vækstregnskab gennemført på 59 brancher. Det gør det muligt at analysere, om nogle brancher er særligt vigtige med hensyn til FoU. I første omgang analyseres brede sektorer for at få et overblik. Bidraget fra sektorer, der enten har et positivt eller negativt bidrag, kan ses i Figur 2. Landbrug, skovbrug og fiskeri samt bygge og anlæg har ikke noget bidrag og er udeladt af figuren.

Det største bidrag til branchevækst i et vækstregnskab kommer fra fremstillingssektoren, og det næststørste kommer fra finansiering og forsikring. De øvrige sektorer har relativt små bidrag, under 0,1 procentpoint, til den markedsmæssige økonomi (jf. Figur 2). Kultur, fritid og anden service har endda et negativt bidrag, hvilket sker, når FoU forældes, uden at der reinvesteres i ny FoU, hvorved dem samlede videnskapital i modellen falder. En årsag kan være, at den økonomiske krise har haft en negativ effekt på investeringsniveauet.

Figur 2. *Bidraget fra FoU fra 2000 til 2012 fordelt på sektor, procentpoint*

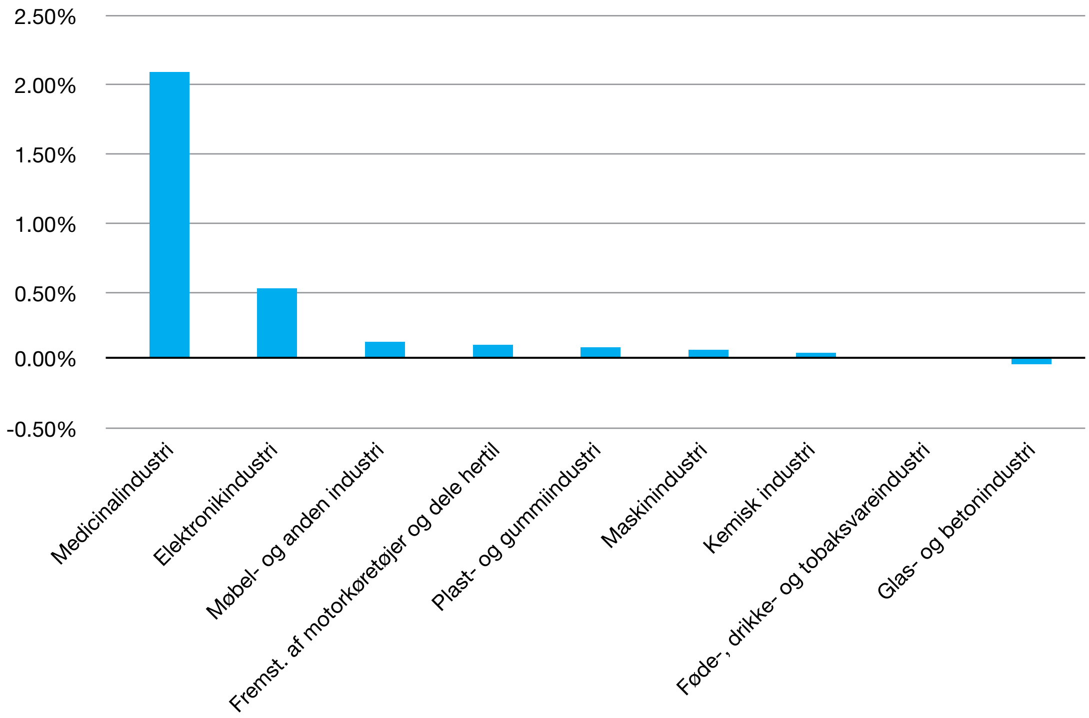


Kilde: Danmarks Statistik og egne beregninger.

Industrien er af særlig interesse, da det er den sektor med det største bidrag fra FoU til output. I Figur 3 er industribrancher med positivt eller negativt bidrag vist.[12] Især medicinalindustrien og elektronikindustrien har et højt bidrag. Opgørelsen viser, at FoU i sektorer og brancher er spredt meget ujævnt.

12. Følgende brancher under industrien er udeladt, da de ikke har noget bidrag: Tekstil- og læderindustri, træindustri, papirindustri, trykkerier mv., olieraffinaderier mv., fremstilling af metal, metalvareindustri, fremstilling af elektrisk udstyr, fremstilling af skibe og andre transportmidler samt reparation og installation af maskiner og udstyr.

Figur 3. *Bidraget fra FoU fra 2000 til 2012 fordelt på industrien, procentpoint*



Kilde: Danmarks Statistik og egne beregninger.

Analysen undersøger også, om væksten i FoU, der bidrager til væksten i industrien med 0,91 procentpoint, også kan forklare vækst i eksport og beskæftigelse i industrien. Det er gjort i en simpel regressionsmodel, der også tager højde for konjunkturerne. Der er ikke fundet nogen statistisk signifikant sammenhæng mellem FoU i disse vigtige makroøkonomiske variable.

Endelig er det i et simpelt modelsetup undersøgt, om offentlige investeringer i FoU har betydning for produktiviteten i den markedsmæssige økonomi. Det er et vanskeligt spørgsmål at besvare. Kanalerne mellem de offentlige og private sektorer kan variere fra uddannelse af forskere over samarbejde om forskningsprojekter til opstart af virksomheder baseret på idéer udviklet i regi af offentlig forskning. Valget er faldet på at bruge antallet af kandidater og ph.d.er ansat i brancherne til at fordele de offentlige FoU investeringer på brancher. For at omsætte forskning til viden, vil tilstedeværelse af højtuddannet personale ofte være en nødvendighed. Fordelingen er foretaget på seks forskellige forskningsområder, så når der bruges flere forskningskroner per kandidat inden for sundhedsvidenskab, får de brancher, som anvender mange af disse kandidater, en større andel af offentlige FoU-investeringer i modellen. Der kontrolleres samtidig i analysen for private investeringer i FoU og konjunkturerne. Resultatet er, at produktivitetsvæksten i den markedsmæssige økonomi ikke kan forklares med offentlige investeringer i FoU. Men analysen tager ikke højde for *crowding-in*. Dvs. hvis der er positiv samvariation mellem offentlige og private investeringer vil det skabe en kollinearitet mellem disse, som gør det vanskeligt at identificere (adskille) bidraget fra de to typer af investeringer.

INTRODUCTION

In 2013, private investments in R&D in Denmark were just below two percent of GDP, placing Denmark among the OECD countries with the highest private R&D investments. Public investments in R&D were above one percent in 2013.

Investments in R&D are important for innovation and for developing new competitive advantages. These will fuel expectations of higher returns and growth of business. This constitutes the private return on R&D investments for R&D active firms. Other firms may at a very low cost benefit from the knowledge and information created by other firms' R&D investments. This indirect contribution constitutes the spillover arising from the non-rival nature of knowledge and information. Many R&D firms protect their R&D by different means, but it is not possible to completely appropriate all knowledge and information. Other firms will acquire (some of) the new knowledge, and a spillover from R&D is thus created. This implies that the overall social return on R&D is greater than the direct return to the original private R&D investor.[13] The latter contribution from R&D operates through the productivity growth of firms, where productivity creates economic growth not caused by increased inputs, hence measuring the long-term technological change within an economy.

The main argument in support of R&D is that spillovers are positive, and that the overall social benefits are greater than the direct private benefits. This prompts a political argument for promoting policies that stimulate private investment in R&D via e.g. research collaboration, government subsidies or tax deductions for private investment in R&D.

The role of R&D in creating economic growth has been the focus of academic and political interest for many years now. Recent advances have made it possible to emphasize the relation between industry, R&D investment, and aggregate productivity. Two specific

13. R&D may also create a negative spillover. Because it gives a competitive advantage, other firms might have to scale down activities in order to survive.

developments have made this possible: The first is the representative surveys of investments in R&D made by firms over many years. The second is the capitalization of R&D investment in national accounts.

In this report, we try to answer the following questions: How much do R&D investments contribute to economic growth based on growth accounting? Which industries contribute the most? Does public R&D correlate with productivity growth? Does the growth in the private R&D capital stock correlate with other contributions on e.g. exports and employment growth?

We utilize the new data available, and we investigate the extent to which R&D investments in a growth account setting have contributed to economic growth at industry and aggregate macro level. We use growth accounting to estimate the contribution of R&D on economic growth as capital production input. Growth accounting also gives an estimate of productivity growth at industry level, which we use to estimate whether R&D capital growth correlates with productivity growth.

National Accounting data from Statistics Denmark has been used. The analysis covers 1980 to 2012, and its focus is on the market driven economy. We construct a R&D capital stock at industry level and estimate the contribution from growth in R&D capital stock to economic and productivity growth. We also investigate whether public R&D can explain productivity growth in the market driven economy. The latter is estimated based on the assumption that the number of graduates holding master's and PhD degrees employed in industry effectively distributes public R&D to various industries. We also examine whether there is a correlation between R&D and employment and exports. We expect investments in R&D to correlate positively with exports, because Denmark has a comparative advantage in highly educated labor, and attracting highly qualified staff makes up a large share of the country's R&D investments. It could also be that higher economic growth leads to high employment growth.

RESULTS

Our main findings

- Based on growth accounting the direct contribution of private R&D investments to economic growth in the market economy amounts to 0.1 percentage point during the period 2000-2012. The size of the gain amounts to four to eight percent of the total output growth. The rest of the growth comes from imported goods, other capital, labor, and productivity gains.
- The estimated contribution from R&D is of the same magnitude as investments of physical capital and in line with previously published results from Denmark, USA, and other countries.
- From the 1990's to the 2000's the estimated contribution from R&D to the economy has accelerated. This is an indication that the knowledge economy is increasingly significant.
- The analysis finds a correlation between R&D investments and productivity on the sector level (indirect contribution from spillover). However, no correlation is found on the macro level. This difference can probably be attributed to measurement errors. In manufacturing, which is more well measured, the econometric analysis suggests that a one percent increase in private R&D capital stock leads to 0.1 percent increase in productivity.
- The total contribution from private investments in R&D is the sum of the direct contribution from R&D investments and the indirect contribution (spillover) estimated on productivity growth. In manufacturing, the total contribution is estimated to 0.91 percentage points per year during the period 2000-2012. Of this, the estimated direct contribution is 0.27 percentage point per year (appx. 30 percent of total contribution), and estimated indirect contribution is 0.64 percentage points per year.

Other results

- The estimated direct contribution from private investments in R&D on economic growth varies considerably across sectors and industries. Manufacturing and financial and insurance sectors experience the highest contributions to economic growth from private investment in R&D. Within manufacturing, the concentration of R&D is high in: pharmaceuticals, machinery, furniture, and other types of manufacturing (incl. medical devices).
- Estimation in the model shows no significant contribution from public R&D on productivity growth in the market economy. There are uncertainties attributed to this estimation. One possible explanation could be that public and private R&D is complementary, and crowding-in creates collinearity between public and private investments, which makes it hard to establish statistical significance for both types of investments.
- Despite the estimated total contribution from private investment in R&D on growth being around one percentage point in manufacturing, there seems to be no statistically significant contribution to employment or export growth in manufacturing.

PERSPECTIVES

Can we say anything about the overall contribution from R&D on the market economy? As the results stand, we found an estimated direct contribution of 0.1 percentage point and no significant indirect contribution from R&D. The total effect is 0.1 percentage point. However, we have argued that in many of the non-manufacturing industries it is hard to measure productivity. Assume, as we found in the analysis, that in manufacturing the indirect contribution from R&D is 0.64 percentage point per year, and in non-manufacturing it is 0. The direct contribution is still 0.1 percentage points, and the indirect contribution is only the contribution from manufacturing weighted with the size of manufacturing in the market economy, 23 percent. The indirect contribution to the total market economy is in this case 0.15 percentage points on the market economy, and the total contribution from R&D is 0.25 percentage points. Suppose instead more optimistically that the result on manufacturing can be generalized to non-manufacturing, and the direct contribution is 30 percent of the total contribution. The direct contribution is still as estimated 0.1 percentage points in the market economy, and the indirect contribution is then 0.23 percentage points. In this case, the total contribution to growth is 0.33 percentage points per year. Depending on the assumptions, we end up with an R&D contribution between 0.1 to 0.33 percentage points per year to output growth, which is equivalent of approximately 5-15 percent of the growth in output in 2000-2012. We must stress that this calculation is highly simplistic and only intended to illustrate the scope of our results.

Measuring the contribution from R&D to economic growth is complex and will not be achieved by a single study. In this study, we provide a sensitivity analysis of the construction of R&D capital stock and a measurement of the cost of using R&D. However, our analysis contains a few caveats.

- Firstly, we do not measure the causal effect of R&D on economic growth. Growth accounting is non-stochastic. To measure a causal effect, we would need access to instrumental variables or a quasi-natural experiment, both of which are stochastic methods. One caveat which probably overestimates the effect of R&D is that economic growth creates R&D investment (endogenous growth). Another caveat is that we are leaving out other possible explanations for productivity growth, i.e. globalization and organizational changes. If R&D correlates positively with other growth drivers missing from the analysis, this will bias our estimate in an upward direction.

- Secondly, we concentrate on the spillovers within industry.[14] The reason for this is that spillover is

14. It is not possible to say whether the spillover will occur to the business investing in R&D or to other businesses within the industry.

most likely to occur when the receiver and sender are similar. However, spillover can also occur across industries as well as internationally, and these contributions may be larger, because the cognitive distance is larger implying a potential for more drastic changes. If these non-included indirect contributions from spillover are positive as expected, we are likely to have underestimated the total contribution from spillover and the contribution of spillover to economic growth.

- Thirdly, we might be underestimating the long term contribution from R&D due to depreciation of the knowledge stock. Depreciation is necessary in the model, but "obsolete" knowledge still forms the basis for most new knowledge. Hence, knowledge does not depreciate completely. Depreciation implies that constant investment in R&D over time will lead to a constant R&D stock, which again implies zero contribution from R&D, which is a too strict assumption.

- Fourthly, R&D investments and technological advances may lead to derived investments in physical capital to reap the benefit from the new knowledge. These complementary investments in physical capital may overshadow the actual contribution from the R&D, thus underestimating the contribution.

- Fifthly, growth accounting is based on traditional macroeconomic theory with full competition. This means that new knowledge leading to increased market power and improved earnings will show up as increased productivity.

- It is our judgment that the total impact of these caveats in growth accounting is an underestimation of the total contribution from R&D to economic growth.

The outline of the report is as follows: First, we outline the methodology and the data in Section 2. The emphasis will be on private investment in R&D. The results at aggregate and industry level of private investment in R&D on economic and productivity growth will be presented in Section 3. These include results for the market economy as well as for manufacturing. Section 4 covers public investment in R&D, and we examine whether this contributes to productivity growth. In Section 5 we examine, using a simple model, whether R&D growth correlates with exports and labor growth. Finally, before wrapping up, we present an analysis of the life cycle of R&D investment and the cost of financing R&D investment in Section 6.

METHODOLOGY AND DATA

In this report, a growth accounting framework developed by Jorgenson et al. (1987) and later refined in EUKLEMS (2007) was used. A brief description of the methodology with an emphasis on R&D investment will be given. The framework uses detailed industry data from the latest revised version of ESA2010 (Eurostat (2014)), which is the national accounting system in which R&D is treated as an investment in line with other types of capital.

The definition of R&D in ESA2010 stipulates that "Research and Development is creative work undertaken on a systematic basis to increase the stock of knowledge, and use of this stock of knowledge for the purpose of discovering or developing new products, including improved versions or qualities of existing products, or discovering or developing new or more efficient processes of production."

The private investment in R&D includes own-account R&D and bought-in R&D. To avoid double counting, bought-in R&D embedded in the final product has not been recorded as investment.[15]

The growth accounting framework now forms part of the official statistics.[16] However, official statistics are not of much use, because capital is divided into two types only, ICT (information and communications technologies) and none-ICT capital, which for our purpose, makes it impossible to analyze the role of R&D.

Data is mainly derived from the database www.statistikbanken.dk. Investments in R&D at a detailed industry level are not available from this database. For this project, Statistics Denmark has made available annual series for investment in R&D during the period 1966 to 2014 at the 69-industry level, which has enabled us to carry out the analysis based on these industries.

15. This is only relevant in public industries and in the scientific research and development industry, where bought-in R&D is treated as expenditure.
16. See www.statistikbanken.dk, table NP28.

GROWTH ACCOUNTING

Industry output growth is decomposed into contributions from primary inputs (labor and capital), secondary inputs (intermediates), and a residual, which is termed total factor productivity (TFP). TFP is the part of output growth not caused by inputs and is a measure of an economy's long-term technological change. The following identity suppressing time and industry indices shows growth accounting:

$$g_y = \Sigma_{l_i = 1,..,m_l} s_{l_i} g_{l_i} + \Sigma_{k_i = 1,...,m_k} s_{k_i} g_{k_i} + \Sigma_{m_i = 1,...,m_h} s_{m_i} g_{m_i} + tfp$$

Here g indicates growth rate and s a value share. On the left, y indicates output and, on the right, l indicates labor, k capital services, and m intermediates. The data consists of one type of labor $m_l = 1$, seven types of capital $m_k = 7$, and 234 types of intermediates $m_h = 234$. From data, we compute estimates of growth rates and value shares, and TFP is the residual. The following is a brief description of each input type.

Input of labor is the number of hours worked by employees and self-employed staff, while the value share of labor is the compensation of labor over output. We do not observe compensation of self-employed staff required to compute the value share of labor, but we assume that the hourly compensation of self-employed staff equals that of employees. The compensation of employees divided by the total number of working hours of employees in each industry gives an estimate of hourly wages for employees. The compensation of self-employed staff equals the number of hours worked multiplied by this hourly compensation. The total compensation of labor equals the sum of compensation of employee and of self-employed staff, respectively.[17]

It would have been helpful to divide labor into different types according to wages. However, such data only exist as micro data, which we do not have access to.

Capital services are not included. Instead, we assume – as is standard – that capital services are proportional to the net capital stock.[18] From the official database, we get seven types of capital. These are buildings, other structures, ICT and machines, transport, cultivated biological resources, intellectual property, and mineral exploitation and evaluation.[19] R&D is part of intellectual property, which also includes computer software and databases, entertainment, literary or artistic originals, and other

17. Compensation of employees and gross operating profit and other income add up to GDI and not GVA. The difference is net production taxes. These net production taxes are generally very small in Denmark. However, we have divided them between labor and capital according to the following simple rule: We add net production taxes to labor compensation in industries exempted from VAT and to capital in all other industries. The reason for this is that VAT-exempted industries usually pay a payroll tax on compensation of employees instead of VAT.
18. The reason for using the net capital stock instead of the gross capital stock is that the net capital stock also includes efficiency loss in capital.
19. Mineral exploitation and evaluation is usually part of intellectual property, but will be treated separately in this report. This is possible, since mining and quarrying are the only industries to use it.

intellectual property products, specified here as 'other intellectual property'. The net capital stock of R&D is not included in the data.[20] However, investment series of R&D enable us to calculate the net capital stock. We apply the perpetual inventory method (PIM). PIM is an economic model accumulating past investments over their estimated service lives to estimate capital stock. To do this, we need an estimate of the (expected) life cycle of R&D as well as the distribution of retirement and loss of efficiency. We assume that the distribution of retirement and loss of efficiency follows a geometric distribution with an expected life cycle of nine years. This is also the method applied by Statistics Denmark. Statistics Denmark divides R&D into three investment types: basic research, applied research, and development with expected life cycles of twelve, ten and eight years, respectively. We do not divide R&D into these three types, but we assume a service life of nine years, which is pretty close to the 'development' category. The reason for this is that 70 percent of R&D investment in the private sector is made up of development.[21]

The value share of capital equals gross operating surplus and other income minus compensation of self-employed staff over output. However, it is necessary to know the value share of the different types of capital. This requires knowledge about the price of capital services. Since this is not included either, we apply the concept of user cost instead. In neo-classical investment theory, user cost equals the marginal product of capital (price), which will be discussed later.

Finally, we divide intermediate inputs into 234 products and services, 117 imported and 117 domestic intermediates based on input-output tables.

R&D IN GROWTH ACCOUNTING

For many years, growth accounting at industry level has been based on tangible capital only.[22] However, it is increasingly common practice in national accounts to treat intangible capital as investments. One reason for this, of course, is that nowadays intangible capital is one of the more important growth drivers, and investment in education, training, and R&D has been rising. Another reason is the systematic collection of representative R&D investment data in many countries, which is a prerequisite for measuring investment at industry and aggregate level.

The first steps to incorporate intangibles including R&D investment in a growth accounting framework is Corrado et al. (2005). In their study, they construct satellite accounts consistent with treating intangibles as capital.

20. The net capital stock of 'other intellectual property' does not figure in the data, either.
21. For 'other intellectual property', we use the PIM calculation and an expected service life of five years.
22. However, the role of intangibles has played an important role. Due to lack of data, they have not formed part of capital but have been analyzed as part of the residual.

Besides R&D, other intangibles like economic competencies, organizational structure, and computerized information appear in the data as investments. A study of the US non-farming business sector estimates that R&D (scientific innovative property) contributed 0.05 percentage points to annual growth in labor productivity from 1973-1995, and 0.08 percentage points to annual growth in labor productivity from 1995-2003 (Corrado et al. (2009)). Their study shows that all intangibles included in the survey contributed 0.43 percentage points from 1973-1995, and 0.84 percentage points to annual growth in labor productivity from 1995-2003.

In a study using European data, including Danish figures, they find that during the period 1995-2006, intellectual property (including R&D) accounts for 0.27 percentage points of annual labor productivity growth in Denmark (van Ark et al., 2009). Statistics Denmark (2015) found that R&D contributed 0.1 percentage point to annual growth in labor productivity in the period 1967-2013. During the two economic recessions in 2001-2003 and 2008-2013, R&D contributed as much as 0.2 percentage points to annual labor productivity growth.

The study carried out by Statistics Denmark comes closest to this study. However, the former does not provide an analysis of sensitivity or compute the indirect contribution from R&D investment on economic growth through productivity.

USER COST OF R&D

The marginal product or price of each capital type is required in order to construct value shares for capital. Unlike labor and intermediates, we do not observe the price of capital services. However, we can estimate the cost of capital and use it as an approximation for the marginal product. In short, the cost of capital depends on four factors: depreciations, the financial structure of the firm, capital gains/losses, and the tax system. A brief discussion of each seems appropriate.

First, investments lose efficiency and do not last forever. In terms of R&D, it is more natural to think of obsolescence. It is costlier to own an asset that quickly becomes obsolete than one that does not. In our discussion on depreciations of R&D, we used an average service life of nine years for an R&D investment. We will assume that the depreciations are inversely proportional to expected life cycle. The longer the expected life, the lower the depreciations. Actually, this also follows from the assumptions we have used to construct the capital stock of R&D. In the sensitivity analysis, we experiment with different life cycles to see how sensitive the results are with respect to this assumption.

Second, investments are either financed by loans or own funding. Servicing the debt, therefore, is part of the cost of owing capital, exemplified by the market interest rate. In the analysis, we assume that R&D is financed in the same way as other types of capital. The cost of financing capital is not included for capital types, but we use an accounting identity stipulating that the cost of capital equals the income from capital. From this identity, we can calculate the internal rate of return and use this as the financing cost of capital. This assumption is quite restrictive. It is possible that R&D is more expensive to finance than other assets. Many R&D firms do not have huge investments in tangible capital to use as collateral for loans to invest in R&D, so they need to find alternative sources of funding. It also depends on the type of R&D that needs to be funded. The early stages of basic research are often very uncertain, and an investor might require a higher return at this, rather than at a later stage. Moreover, empirical work in this area shows that R&D-intensive firms use retained earnings (own funding) to finance R&D investment, which are generally more expensive to use than loans (Hall et al. (2009a)). In the sensitivity analysis, we experiment with this assumption to uncover how important it is.

Third, owning capital might induce a capital gain or loss. A common example is fluctuating prices of buildings, which occur due to changes in demand and supply. In many analyses, capital gains and losses are approximated by the actual price change of a new asset. However, user costs can be very 'noisy' due to large price changes over a single year. In our calculation, therefore, we have used an alternative, which is a weighted average of price changes over three years. This gives a much smoother measurement of expected capital gains/losses (see also Oulton (2007) for the importance of this assumption).

Fourth, return on capital is taxed by the government and introduces a wedge between the marginal product and cost of capital. Moreover, the tax system can influence the cost of capital in at least two other ways: investments that are not subject to immediate depreciations, but can be depreciated over a longer period; and tax credits provided for certain types of investment, which the government wants to favor. In our implementation, we simplify and assume that the tax system does not enter user cost of R&D. The reason for using the approximation is this: if investment in an asset can be written off immediately, and there are no tax credits, the tax system does not enter user costs. In Denmark, it is possible to write off R&D expenses immediately, and tax credits have only been introduced recently for firms with a deficit, so this approximation seems appropriate.

To summarize, we have implemented user cost of R&D as follows:

- Depreciation is defined by the inverse of the expected life cycle of an asset. The longer the life, the lower the depreciations.

- Taxes do not influence R&D user cost.
- Capital gains/losses are computed as a weighted average of price changes in new investments over the previous three years.
- R&D is financed like other assets.

DATA

The data used in our analysis derives from official statistics and have been downloaded from www.statistikbanken.dk. We use annual statistics on production, labor, and capital accounts at the 69-industry level. We also use input-output tables to disaggregate intermediates in production.

Since 2014, Danish national accounts comply with the recommendations of the ESA2010 system. In this system, R&D is treated as an investment. This means that internal R&D in private firms is estimated and added as output in the industry. It also means that bought-in R&D is no longer an intermediate in production, but is allocated to investments. Adding R&D as a capital type changes output and input in the economy. The implications are quite substantial as GDP was 1.2 percent higher in current prices than in the old 1990 system, and the growth of R&D investment over the years boosted GDP by 2.6 percent in 2008.

In the official statistics, R&D net capital stock is available for the overall economy only. For our analysis, we need a breakdown of 69 industries, and Statistics Denmark has given us access to annual R&D investments from the period 1966-2014 at industry level.

INDUSTRIES: LIMITATIONS AND CHOICE

We eliminated some industries from the analysis. First, the non-market sector is not included in the calculations. The non-market economy includes public administration, education, and health services. The non-market sector engages in untraded goods. Therefore output equals cost, and this sector's productivity is by definition zero. We exclude housing, both owner-occupied and rented. The former is an imputed industry and the latter is regulated. In addition, private households are excluded, since output in this industry is measured as labor input (au pairs etc.).

Despite eliminating these industries, care must be observed in respect of others: industries that use natural resources and land such as agriculture, fishing, forestry and mining. This is because natural resources and land are not part of the capital stock, and any changes in the supply of these factors are likely to influence the results. Moreover, the transport sector is heavily dependent on public infrastructure, exemplified by the building of the Great Belt Bridge implying major structural changes in the transport sector.

Finally, it should be noted that we report results on manufacturing only. Products are easier to adjust for quality changes compared to many services. The reason for this is that products are often more homogenous than services.[23] Further, historically this has received the most attention.

AGGREGATION OF PRODUCTIVITY, OUTPUT AND INPUT

Output is defined as sectoral output. Sectoral output is a measure of production corrected for deliveries within a given sector. This is preferred over value-added output, measuring productivity at firm or industry level (OECD (2001)). However, one drawback of this approach is the difficulty in measuring aggregate productivity growth. This is because aggregates cumulate productivity from inter-industry deliveries. A one percent increase in productivity across all industries adds up to more than a one percent increase at aggregate level. An increase in TFP may have two effects: a direct effect on industry output and an indirect effect via the output sold to other industries as intermediate goods. Hence intermediates augment the productivity gain in successive industries. The solution is to use Domar weights when aggregating to a higher level. A Domar weight is the sectoral output of an industry divided by the sectoral output at aggregate level. See Appendix A for a technical derivation of the aggregation scheme.

23. A caveat here is that R&D results in heterogeneous products, making quality adjustment harder, but very little can be done about this. Moreover, products are now commonly sold with services (servitization), which in turn will make it harder to measure prices correctly with the various service packages offered.

RESULTS

In this section, the results from growth accounting of the remaining 59[24] industries are shown at different levels of aggregation and for selected industries at the detailed level. The first level of aggregation is the whole market economy excl. housing and private households (called market economy), and the second level is the aggregation to twelve industries (called sectors). The section contains three parts: the results of growth accounting at market economy level, the direct contribution from private R&D at different industry levels, and the indirect contribution of private R&D on economic growth in market economy and in manufacturing.

AGGREGATE OUTPUT, INPUT, AND PRODUCTIVITY GROWTH

The growth in sectoral output, labor, capital, intermediates, and total factor productivity are shown for the market economy in Table 1. We have summarized the results in periods of ten years corresponding to the ’80s, ’90s, ’00s, and 2010-2012. We summarize all our results in decades because annual growth rates are very volatile, in particular at the detailed industry level. This also underlines our interest in the medium to long-term effect of R&D investment. The aggregation to market level is a bottom-up from individual industry level. As explained in the methodology and data section, and further discussed in Appendix A, Domar weights have been applied.

The first column shows the average annual output growth in the market economy. Annual growth rates showed similar levels in the ’80s and ’90s. The growth was much lower in the ’00s and in 2010-2012. The main reason for the very low growth rates in the two latter periods is the financial crisis. The growth accounting framework allows us to decompose output growth into contributions from primary and secondary inputs and productivity.

24. We eliminated ten industries from the analysis: non-market industries and housing.

The most important input is (imported) intermediates, which is hardly surprising. The more intermediates used by an industry, the more output is created. At this level of aggregation, the intermediate inputs are mainly imported goods, which, in a small open economy like the Danish, is quite high. Labor (cf. column 2) contributed negatively in the ’80s and positively in the ’90s. This is in line with the fact that, contrary to the ’90s, unemployment was a problem in the ’80s. The contribution of labor was either negative or zero in the ’00s and in 2010-2012. Again, the development masks huge changes within the period, because the unemployment rate dropped to a historical low around 2008, before rising once again.

Table 1. *Growth in output and the sources of growth, market economy*

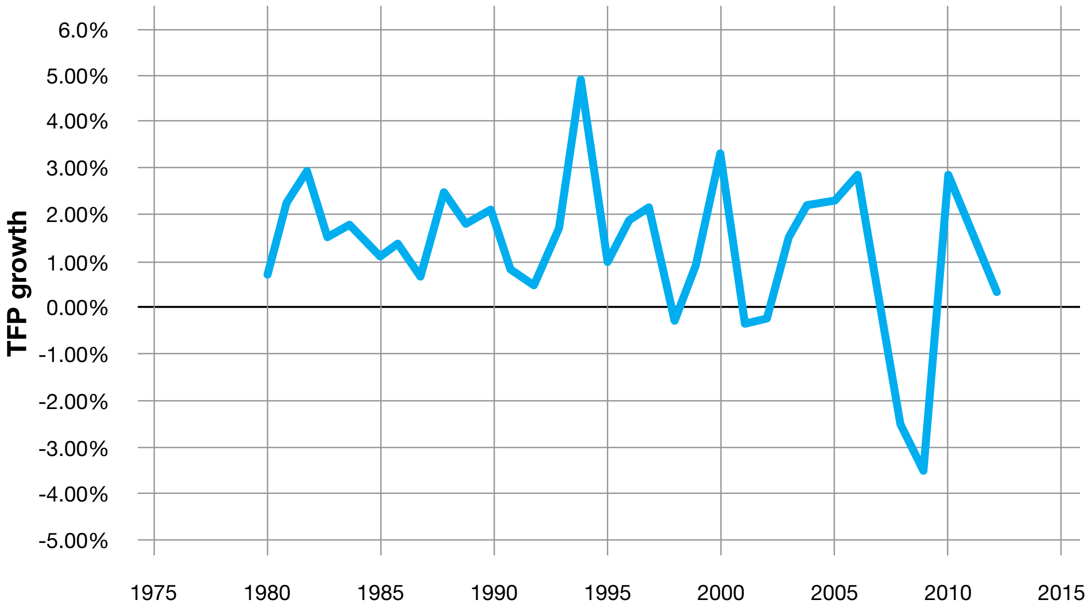
	Output*	Labor	Capital	Intermediates	TFP
1980-1989	4.2%	-0.2%	1.0%	1.8%	1.7%
1990-1999	4.3%	0.3%	0.6%	1.9%	1.5%
2000-2009	1.7%	-0.1%	0.4%	1.2%	0.3%
2010-2012	2.6%	0.0%	0.1%	1.4%	1.0%

Note: * This is sectoral output in the market economy.
Source: Statistics Denmark and our own calculations.

Looking at the contribution from capital in column three, it is evident that it has been declining continuously from the ’80s to 2010-2012. The development, however, differs across capital types, which will be discussed later. Finally, the last column gives the contribution of annual growth in total factor productivity. It has shown a decrease, giving cause for major concern in Denmark for some years, as Denmark ranks at the bottom among the EU countries on productivity growth.

Productivity is sensitive to the business cycle, which is hard to see in Table 1. First, capital utilization is high during a period of boom – and low in a recession. This means that TFP is higher in a boom period and lower in a recession, because we are measuring capital services as proportional to net capital stock, which is less sensitive to utilization. Second, low productivity firms are less likely to survive in a recession than in boom periods, which means that productivity increases in recessions and decreases in periods of boom. Third, the labor market is tight in a boom period, and the marginal worker tends to be less skilled, which might influence productivity negatively. If wages are sticky, and unskilled workers are employed in boom periods, they might be better paid than the cost of their marginal product, and this has a tendency to decrease productivity. The movements described introduce reverse moves in TFP, whereas experience suggests that TFP is most likely to be pro-cyclical.

Figure 1. *Market economy productivity growth 1980-2012*



Source: Statistics Denmark and our own calculations.

In Figure 1, we show the growth in productivity for the market economy from 1980 to 2012. The declining productivity trend that we saw in Table 1 is not evident, because the variation in productivity growth is very high. The volatility of productivity growth is one reason for focusing on averaged annual growth rates over ten year periods. The evidence in Figure 1 suggests that productivity growth is pro-cyclical. In 1994, the economy turned from a long recession to a boom period, and productivity rose sharply when the Danish economy was kick-started by major labor market reforms. The financial crisis is also very evident in 2008 and 2009. Productivity seems very sensitive to the turnaround in the business cycle before slowly recovering. A later analysis of the spillover of growth in R&D capital to productivity growth in a regression analysis will include the output gap[25] to check for business cycle effects.

Looking at Figure 1, we argue that the choice of sub-periods for analysis is more or less arbitrary. It should be noted that the period from 2000-2012 was heavily influenced by the economic crisis occurring in 2008 and continuing in the following years.

We can summarize that the growth accounting exercise shows familiar results. Productivity growth has declined in Denmark from the '90s through the '00s. Moreover, (market economy) productivity growth is very volatile, because it is a residual, and because of business cycles and measurement errors. Reporting averages over long periods will result in measuring trending productivity growth detached from business cycle fluctuations.

DIRECT CONTRIBUTION FROM PRIVATE R&D

Table 1 and Figure 1 display evidence we are already familiar with. The focus of this paper is on R&D, which is treated as a component of capital like other types of tangible capital. In the analysis, we include software as the only other type of intangible capital. In the debate on intangibles versus tangibles, it is of interest to report on software as well as R&D. For this reason, we divide capital into three types: tangibles, software, and R&D.

The direct contribution from R&D added 0.07 percentage points to annual economic growth in the period 1990-1999, doubling to 0.13 percentage points in the period 2000-2009. These estimates are in line with literature and results from the US.[26] The role of tangible capital is declining monotonically over the decades (cf. Table 2, column 3). Hence, the much lower contribution of tangible capital drives the permanent decrease in the contribution of capital to economic growth that we

25. The output gap is current output minus potential output. In a recession, potential output will be higher than current output, because production factors are idle and vice versa.
26. From 2000 to 2005, R&D contributed 0.1 percentage point to labor productivity growth in the US. In the period 2000-2012, the number of hours worked decreased by 0.6 percent per year in Denmark. This is negligible compared with the substantial increase in R&D capital stock (4.1 percent per year). The contribution of R&D to labor productivity is slightly higher than 0.13 percentage points in the period 2000-2012.

saw in Table 1. Contribution of software shows a similar pattern to R&D. However, software accelerated from the ’80s to the ’90s, whereas R&D accelerated from the ’90s to the ’00s.[27] Compared with the previous contributions from tangible capital, these are still modest contributions to the overall annual market economy growth. However, intangible capital seems to have outperformed tangible capital in the ’00s. Note that other types of intangible – economic competencies and organizational structures – are not included in the measurements. These were highlighted by Corrado et al. (2009) as the most important drivers of growth in the beginning of the ’00s in the US and (Western) Europe. However, extremely rough estimates of intangible capital are the basis of their calculations, and further investigation is needed to obtain evidence is more reliable with regard to the contribution of these other types of intangibles.

Table 2. *Decomposition of contribution of capital to output growth, market economy*

	R&D	Software	Tangibles
1980-1989	0.01%	0.02%	0.96%
1990-1999	0.07%	0.10%	0.45%
2000-2009	0.13%	0.13%	0.17%
2010-2012	0.11%	0.11%	-0.07%

Source: Statistics Denmark and our own calculations.

27. Increases occur from very low levels. We should treat the early estimates of software and R&D with care. First, the primary sources tend to be uncertain in the early period compared to recent periods. Second, contributions from R&D in the ’80s are lower than calculated by Statistics Denmark (2015). This could be due to different approaches applied when calculating the initial stock of R&D. Our estimates of the contribution made by R&D are similar to those of Statistics Denmark (2015) in the ’90s, ’00s and 2010-2012.

Table 2 also shows some evidence that R&D is less sensitive to business cycles. In case of R&D, it makes good sense that investments are not very sensitive to the business cycle. A main component in R&D is the earnings of researchers, which is tacit knowledge. Lay off researchers, and a share of the knowledge will diminish. Consequently, many R&D firms might smooth out investment in R&D to avoid adjustment costs.[28]

The period 2000-2009 might be sensitive to the recession that began in 2008. However, our results remain true when we compute the contributions of the three types of capital from 2000 to 2007. The contributions are 0.14, 0.12, and 0.22 percentage points on annual economic growth from R&D, software, and tangibles, respectively. The small contribution of tangibles to economic growth in the '00s is driven partly by the financial crisis, but this is not enough to offset the fact that intangibles are at least as important for economic growth as tangible capital.

Sector differences

In Table 1 and Table 2 we focused on the market economy. A huge advantage of making the KLEMS-based growth accounts stems from the ability to investigate the contribution of individual sectors and industries to aggregate growth. We do this in two steps: First, we look at growth across broad sectors. Second, we look in more detail at the sectors 'manufacturing' and 'other business services'. We focus on the '90s, the '00s, and the change (acceleration) from the '90s to the '00s, including the financial crisis. The purpose is to see whether the results are driven by a few sectors/industries, and to investigate whether the acceleration is universal or limited to a few sectors/industries.

28. Some researchers include adjustment cost to investment in user costs and highlight the importance for R&D (Hall et al. (2009a)). Later, we change user cost for R&D, which we can interpret as including adjustment cost to R&D.

Table 3. *Output growth and R&D contribution to output growth by sector*

	1990-1999		2000-2012	
	Output	R&D	Output	R&D
Agriculture, forestry, and fishing	1.11%	0.00%	0.52%	0.00%
Arts, entertainment, and other services	1.80%	0.04%	0.27%	-0.04%
Construction	1.66%	0.00%	-0.90%	0.00%
Financial and insurance	1.97%	0.02%	3.88%	0.21%
Information and communication	10.60%	0.05%	5.54%	0.04%
Manufacturing	2.57%	0.09%	0.19%	0.27%
Mining and quarrying	7.59%	0.00%	-4.10%	0.02%
Other business services	3.34%	0.12%	3.18%	0.07%
Rescue services and adult education	5.74%	0.00%	-0.38%	0.00%
Real estate agencies	-2.94%	0.00%	-3.49%	0.00%
Trade and transport	3.83%	0.02%	1.90%	0.02%
Utility services	3.02%	0.01%	0.16%	0.03%

Source: Statistics Denmark and our own calculations.

The highest output growth rates in the ’90s occurred in information and communication, and in mining and quarrying (cf.Table 3). Given the technological development, it is hardly surprising that information and communication show very large growth rates. However, the sector is generally very small compared to e.g. ‘trade and transport’, ‘manufacturing’, ‘other business services’, and ‘construction’. These all showed medium growth rates in output in the ’90s. ‘Trade and transport’ rose by 3.8 percent and ‘other business services’ by 3.3 percent. ‘Manufacturing’ and ‘construction’ showed growth rates of 2.6 and 1.7 percent, respectively.

Table 3 shows that the contribution from R&D is positive in many of the industries in the ’90s. The highest R&D contribution occurs in ‘other business services’ and ‘manufacturing’ with contributions of 0.12 and 0.09 percentage points, respectively. Below, we take a detailed look at the individual industries within these sectors. During the ’90s, there are no R&D contributions from ‘agriculture, forestry and fishing’, ‘construction’, ‘mining and quarrying’, ‘rescue services and adult education’, and ‘real estate agencies’.

Table 3 shows the annual growth rates in output in the period 2000-2012 to be much smaller than in the period 1990-1999 except for the ‘financial and insurance’ sector. The main reason for this development is the financial crisis. During 2000-2012, the ‘information and communication’ sector secured the highest growth rate, but this time followed by the ‘financial and insurance’ sector. It is surprising to see that the ‘financial and insurance’ sector is one of the best performers during the ’00s, given that the financial crisis hit this sector severely. The main explanation is that, despite severe cut backs in banking during the crisis, this sector had extremely high growth rates in the pre-financial crisis period to make up for this. Table 3 shows the major sectors to have a much smaller output growth. ‘Trade and transport’ grew only by 1.9 percent, ‘manufacturing’ by 0.2 percent, and ‘construction’ had an average annual growth rate of -0.9 percent. The only major sector that sustained a high growth in output was the ‘other business services’ sector.

In the ’00s, R&D sustained the highest contribution to economic growth in manufacturing followed by ‘financial and insurance’ – with contributions of 0.27 and 0.21 percentage points, respectively.[29] In ‘other business services’, R&D contributed 0.08 percentage points. ‘Arts, entertainment and other services’ show a negative contribution from R&D to economic growth. Investment in R&D in this sector also dropped during the ’00s. Finally, ‘agriculture, forestry and fishing’, ‘construction’, ‘rescue services and adult education’, and ‘real estate agencies’ did

29. The financial and insurance industry also invests heavily in software. Investment in R&D can be closely related to software in this sector. It is beyond the scope of this study to investigate whether software and R&D are closely related or not.

not experience any contribution from R&D in the period 2000-2012. Later, when we analyze the indirect contribution from R&D to productivity, we exclude industries with no contribution from R&D, since it might not be relevant for these industries to invest in R&D, nor may the association between R&D and productivity be relevant.

The acceleration in R&D contribution that we saw in Table 2 is unevenly distributed across sectors. On the one hand, the ‘manufacturing’ and ‘financial and insurance’ sectors have accelerated to much higher levels of R&D contribution while ‘trade and transport’, ‘utility services’, and ‘mining and quarrying’ have experienced small accelerations. On the other hand, ‘arts, entertainment and other services’, ‘information and communication’, and ‘other business services’ experienced a drop in R&D contribution.

From Table 3, it is clear that sectors sustain different contributions of R&D to economic growth, and the change over time is uneven across sectors. We will gain more insight into this in the next two sections, where we focus on the details in ‘manufacturing’ and ‘other business services’.

Manufacturing

For several reasons, manufacturing is an important industry. First, R&D sustained the largest contribution to economic growth of all sectors in the period 2000-2012. Second, we usually consider it to be the most accurately measured, and third: The sector is the most important one for exports. In Table 4, output growth and R&D contributions has been divided into 19 industries within manufacturing. In Table 4, we also provide the Domar weight for year 2012, which is used for computing output growth in the market economy in Table 1.

The industry distribution of output growth is very uneven during the ’90s. The pharmaceutical industry sustained a very high output growth rate of 13 percent. The runner-up is ‘manufacture of electronic components’. Both industries are what we might call knowledge-based industries. It is also clear from Table 4 that these two industries sustain the largest contributions from R&D in the ’90s. Other industries with large R&D contributions are ‘manufacture of chemicals’, ‘electrical equipment’, ‘manufacture of machinery’, and ‘manufacture of rubber and plastic products’. These industries showed a medium growth rate in output in the period 1990-1999. A few industries sustained no contributions from R&D. These are ‘textiles and leather products’, ‘manufacture of wood and wood products’, ‘printing etc.’, ‘oil refinery etc.’, ‘manufacture of ships and other transport equipment’, and ‘repair and installation of machinery and equipment’.[30]

30. ‘Repair and installation of machinery and equipment’ is a service provided by industries. However, it does probably not account for the complete servitization of manufacturing firms.

For the period 2000-2012, Table 4 shows that many industries have experienced negative output growth rates, which is mainly due to the financial crisis. 'Textiles and leather products', 'manufacture of basic metals', 'manufacture of ship and other transport equipment', 'manufacture of wood and wood products', 'printing etc.', 'manufacture of motor vehicles and related parts' all showed negative average annual growth rates. 'Pharmaceuticals', 'repair and installation of machinery and equipment', 'manufacture of machinery', 'oil refinery etc.', 'manufacture of chemicals', and 'manufacture of electronic components' all showed positive growth rates despite the financial crisis. Interestingly, these are also the ones sustaining the highest R&D contributions.
All industries except two experienced a slowdown from the '90s through the '00s. The first exception is 'oil refinery', an exceptional industry as the dominant input is crude oil, and since the development in the oil market drives most of the results in this sector. The second exception is 'repair and installation of machinery and equipment' where maintenance might have become an important business during the financial crisis. Instead of purchasing new durable equipment, servicing existing equipment is a means to smooth out costs during a recession.

Table 4. *Output and R&D in manufacturing*

	1990-1999		2000-2012		
	Output	**R&D**	**Output**	**R&D**	**Domar weights***
Manufacture of food products, beverages and tobacco	1.52%	0.01%	0.11%	0.02%	0.08
Textiles and leather products	-2.20%	0.00%	-7.80%	0.00%	0.00
Manufacture of wood and wood products	3.28%	0.00%	-3.66%	0.00%	0.01
Manufacture of paper and paper products	0.85%	0.00%	-2.91%	0.00%	0.01
Printing etc.	0.17%	0.00%	-3.58%	0.00%	0.01
Oil refinery etc.	1.33%	0.00%	1.43%	0.00%	0.02
Manufacture of chemicals	2.61%	0.21%	0.33%	0.05%	0.02
Pharmaceuticals	12.96%	0.77%	6.40%	2.09%	0.04
Manufacture of rubber and plastic products	0.84%	0.06%	-2.66%	0.09%	0.01
Manufacture of other non-metallic mineral products	1.15%	0.00%	-2.65%	-0.01%	0.01
Manufacture of basic metals	2.65%	0.01%	-6.95%	0.00%	0.01
Manufacture of fabricated metals	1.14%	0.01%	-1.06%	0.00%	0.02
Manufacture of electronic components	6.65%	0.24%	0.20%	0.51%	0.02
Electrical equipment	1.66%	0.09%	-0.52%	0.00%	0.01
Manufacture of machinery	2.85%	0.09%	1.60%	0.08%	0.07
Manufacture of motor vehicles and related parts	2.03%	0.03%	-3.14%	0.11%	0.00
Manufacture of ships and other transport equipment	-4.18%	0.00%	-6.19%	0.00%	0.00
Manufacture of furniture and other manufacturing	1.30%	0.04%	-2.41%	0.13%	0.02
Repair and installation of machinery and equipment	-0.07%	0.00%	1.75%	0.00%	0.01

Note: * Domar weights calculated from 2012.
Source: Statistics Denmark and our own calculations.

Despite the lower output growth rates, the contribution from R&D has increased over time. 'Pharmaceuticals' and 'manufacture of electronic components' stand out with the highest contributions. It is also interesting to note that 'manufacturing of furniture and other manufacturing'[31] has an increased contribution from R&D, and the same is true of 'manufacture of motor vehicles and related parts'. Overall, many industries sustain increases in R&D contributions. However, it is interesting to note that some industries have experienced a drop in R&D contribution or have negative contributions in the period 2000-2012. The most significant drop is in 'manufacture of chemicals', which decreased from 0.21 percent to 0.05 percent from the '90s through the '00s. While the economic crisis can explain these decreases, we cannot be sure that the industries will recover. This could be due to R&D having moved elsewhere, either abroad or to another industry.[32] It could also be that R&D might no longer be sufficiently beneficial in some industries. Let us suppose that someday prevention of disease is a reality and that treatment by pharmaceutical products, therefore, will be less important; the expected return of investing in R&D in pharma might be lowered, and R&D investment will go down as a result.

It is also evident from Table 4 that some industries do not receive a contribution from R&D in the '90s or in the '00s, namely 'textiles and leather products', 'manufacture of wood and wood products', 'printing etc.', and 'oil refinery, etc.' Domar weights are shown in the table and used to aggregate to the market economy to indicate the importance of the individual industries. The weights are for 2012, but we can see that 'manufacture of food products, beverages and tobacco', 'manufacture of machinery' and 'pharmaceuticals' carry the largest weights.

The acceleration in R&D at the market economy level is driven in order of importance by 'pharmaceuticals', 'manufacturing of machinery', and 'manufacture of furniture and other manufacturing'. This is because these industries have a huge increase in R&D contributions and a relatively large Domar weight.

Other business services

'Other business services' is also a very interesting sector. First, this is the sector with the most important R&D-producing industry, scientific research and development. Second, after manufacturing, this sector sustained the highest contribution from R&D growth in the '90s, but experienced a slowdown in the '00s.

'Other business services' is split into nine industries in Table 5. In the '90s, 'rental and leasing' had the largest output growth rate followed by 'security and

31. Other manufacturing includes medical equipment and toys.
32. Note that this would require the industry not to buy in R&D again, because bought-in R&D is included as investment.

investigation', and 'advertising and market research'. 'Scientific research and development' had a negative output growth, and 'legal and accounting activities' was close to zero. The contribution from R&D to growth was largest in 'architectural and engineering activities' and in 'legal and accounting activities'. These are also the two industries carrying the largest Domar weights, and this could explain the high contribution to market economy growth of R&D in the '90s in 'other business services'.

In the '00s, the slowdown of 'other business services' is not as clear as it was for manufacturing. One reason could be that the service sector is the quickest to recover after a recession. The growth rates have dropped compared with the '90s, but not to negative levels as in manufacturing. Actually, they have risen in 'scientific research and development', 'legal and accounting activities', and 'employment activities'. The contribution from R&D to economic growth has decreased for all industries since the '90s except for 'scientific research and development', where contributions from R&D increased from 0.02 percent to 0.71 percent. This industry sells R&D products used as investment in other industries.

Table 5. *Output and R&D in other business services*

	1990-1999		2000-2012		
	Output	R&D	Output	R&D	Domar Weights*
Legal and accounting activities	0.18%	0.11%	2.71%	0.02%	0.03
Architectural and engineering activities	1.90%	0.31%	0.43%	0.01%	0.03
Scientific research and development	-5.41%	0.02%	10.72%	0.71%	0.01
Advertising and market research	4.14%	0.04%	-0.18%	0.00%	0.01
Other professional activities	3.31%	0.06%	1.38%	0.02%	0.01
Rental and leasing activities	7.64%	0.00%	5.16%	0.00%	0.01
Employment activities	3.85%	0.00%	8.71%	0.00%	0.01
Travel agency activities	2.07%	0.00%	1.55%	0.00%	0.01
Security and investigation	4.27%	0.02%	2.68%	0.01%	0.02

Note: * Domar weights calculated from 2012 figures.
Source: Statistics Denmark and our own calculations.

The rise in R&D contributions in ‘scientific research and development’ is not enough to offset the decrease in ‘architectural and engineering activities’ and ‘legal and accounting activities’, and the total contribution from ‘other business services’ is comparatively less in the ’00s than in the ’90s. From the Domar weights, it is evident that ‘architectural and engineering activities’ and ‘legal and accounting activities’ are more significant than ‘scientific research and development’.

The drop in R&D contributions in some industries could be due to the economic crisis, but another explanation could be that R&D has been relocated to other industries or abroad (see footnote 32). It might also be that R&D is less beneficial in these industries and that firms have downscaled activities as a consequence. Some industries have no or very small R&D contributions in both periods. These are ‘rental and leasing activities’, ‘employment activities’, and ‘travel agency activities’.

To sum up, the direct contribution from R&D to the total market economy has remained at a level of around 0.1 percent in annual growth. It has accelerated from the ’90s to the ’00s and now, at least, remaining at the level of tangible capital. The ‘pharmaceuticals’ and ‘manufacture of machinery’ industries are the two industries driving this development. Smaller contributions come from ‘manufacture of furniture and other manufacturing’, and the ‘financial and insurance’ sector. Some sectors/industries have gone the other way, and their contributions from R&D have either been reduced or stagnated: ‘arts, entertainment and other services’, and ‘other business services’ are some of the most prominent examples. The development, therefore, is not uniform across industries.

INDIRECT CONTRIBUTION FROM PRIVATE R&D

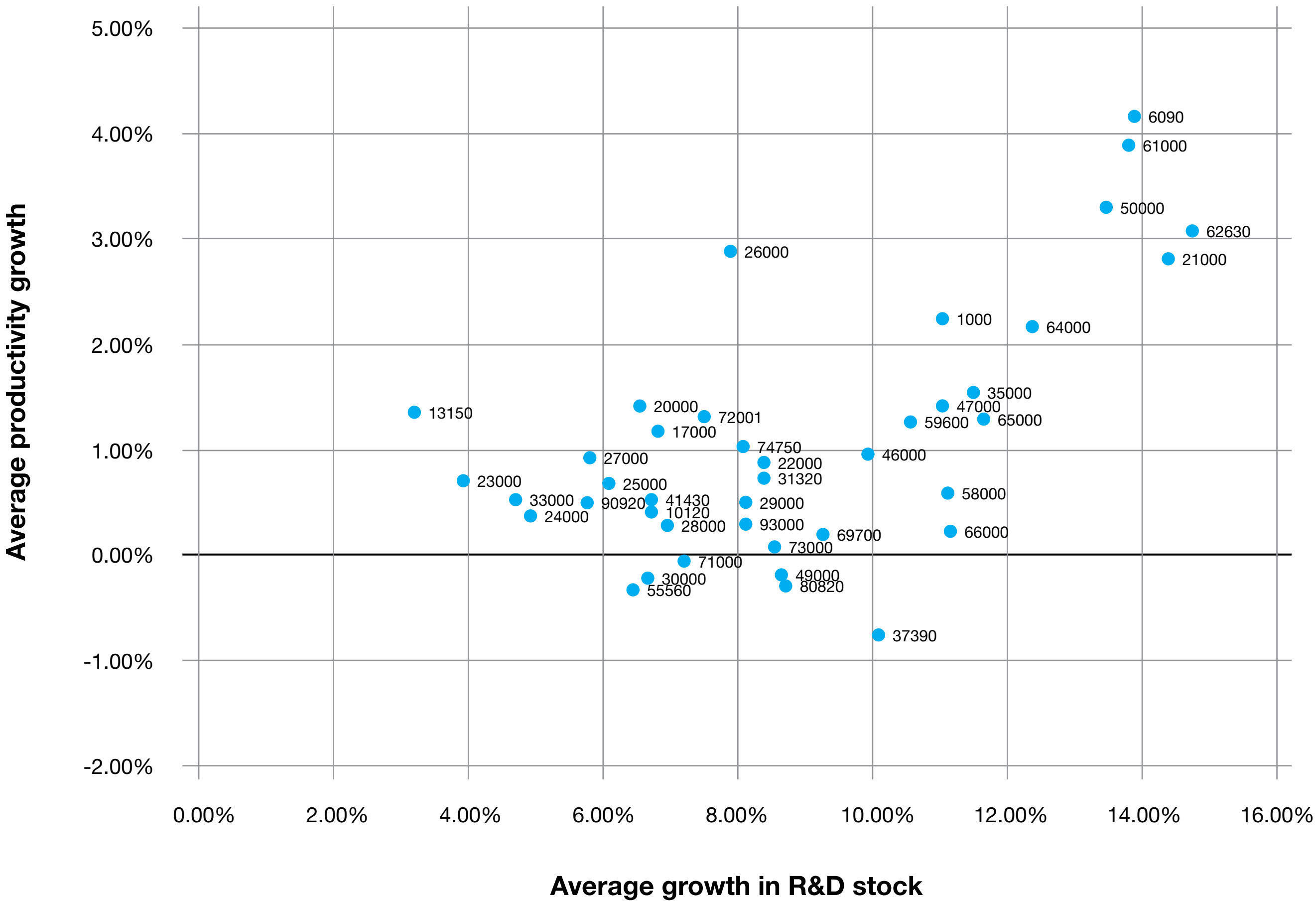
We now turn to the indirect contribution from R&D investment to productivity within industries. We do this by regressing growth in productivity onto growth in the R&D capital stock. In some industries, R&D is zero – either true zeros or so small that we cannot measure them. These industries have been mentioned several times already. There are several reasons for the zeros. For example, they could be structural zeros, which means that no firms find it beneficial to invest in R&D; or there could be issues of confidentiality. We exclude these industries from the computation of the indirect contributions from R&D in our preferred specification.

As above, we concentrate on the period from 1990 to 2012. The total number of industries with positive R&D capital stock for the whole market economy is 39, and the sample size is 890 industry-year observations. We also analyze the subsample of industries in manufacturing. This is particularly important when we analyze productivity (the residual), where all measurement errors appear. 16 industries within manufacturing have positive R&D capital stock, which means that 368 industry-year observations have been applied to this subsample.

Before we discuss this regression, we note in Figure 2 a (weak) positive relationship between industry productivity growth and growth in R&D capital stock. Industries such as the pharmaceutical industry (21000), IT and information services (62630), water transport (50000), telecommunications (61000), and mining and quarrying (06090) have high output growth and high R&D growth. Sewerage, waste collection, treatment and disposal activities, etc. (37390) have a high R&D growth rate but low productivity. See the codes for the remaining industries in Appendix B.

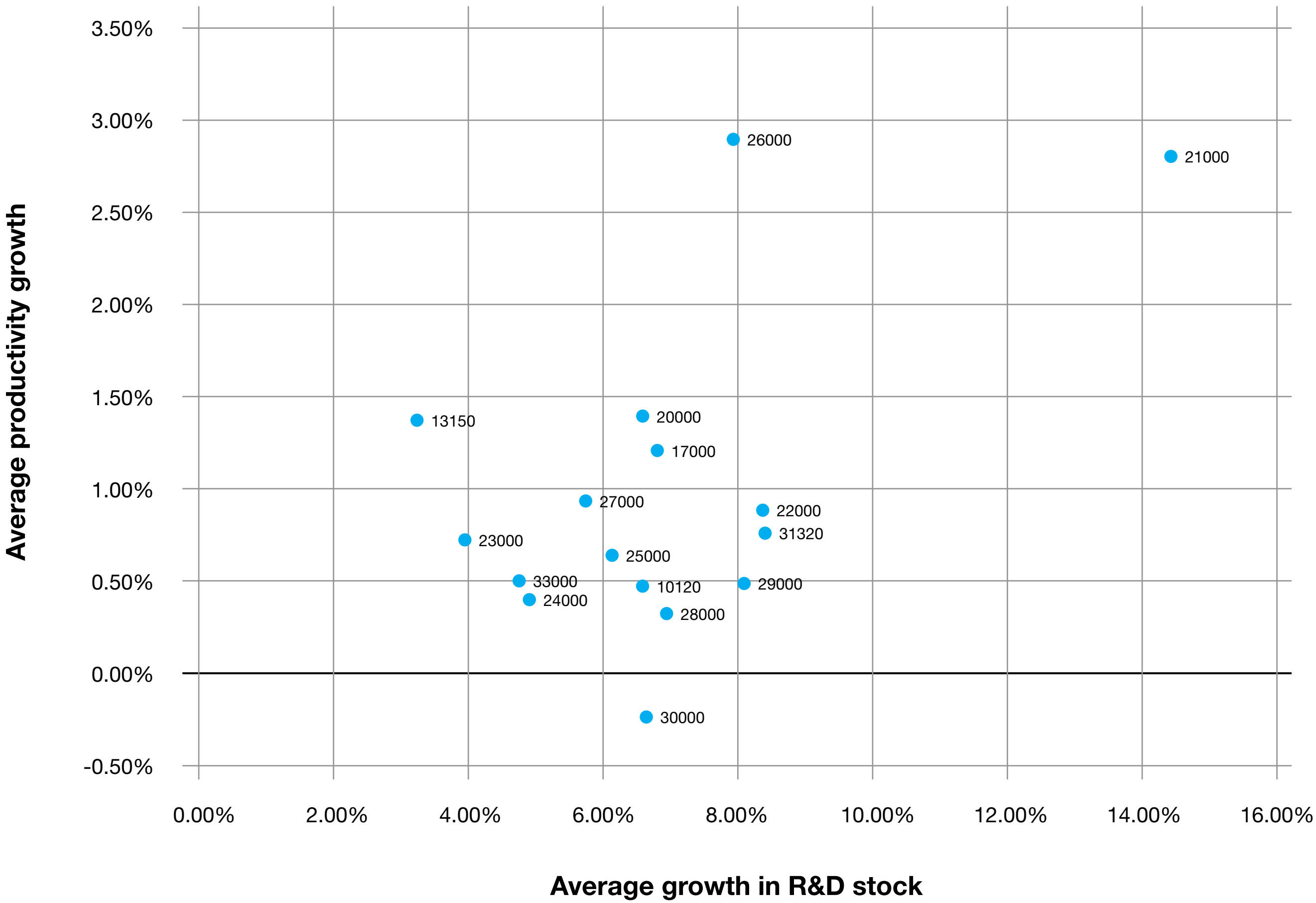
In Figure 3, we concentrate on manufacturing industries. Here, too, there seems to be a positive connection between R&D and productivity growth. In particular, we find that pharmaceuticals (21000) have a much higher productivity and growth in R&D stock compared to the other industries. Manufacture of electronic components (26000) experiences a very high growth rate in productivity and just over a medium growth rate in R&D capital stock.

Figure 2. *TFP growth and growth in R&D capital stock, market economy*



Note: Labels are industry codes (see Appendix B).
Source: Statistics Denmark and our own calculations.

Figure 3. *TFP growth and growth in R&D capital stock, manufacturing*



Note: Labels are industry codes (see Appendix B).
Source: Statistics Denmark and our own calculations.

The correlation between growth in productivity and R&D capital is investigated in a regression model. The first step is to set up the regression model. First, our dependent variable is a growth rate in productivity and we prefer to measure the R&D capital stock in growth rates as well. Second, we look at the contemporary contribution from R&D growth and productivity growth. We have experimented with different lags of growth in R&D, and no major differences are evident. The cross-sectional variation in the data is the most important. Third, we include output gaps[33] to check for business cycle effects. The model is overly simplified, and may serve as a benchmark, but, in the future, the inclusion of other growth drivers will improve the model.[34]

Note, we focus on indirect contribution from local intra-industry spillover. This is because spillover is more likely to occur, if the sender and receiver are similar, and where firms within the same industry and country are more likely to share production processes and products. However, the gain from spillover might increase with a larger cognitive distance between senders and receivers. Hence, we might look at the spillover which is most likely to occur, but with the smallest potential. The problem with inter-industry and inter-country spillovers is the difficulty in finding a channel, through which the contributions from these spillovers operate, and which can be used to gauge the impact. There are no representative sets of data describing the relation between R&D in one industry (country) with another industry (country). Instead, indirect evidence, i.e. input-output tables or trade patterns, is used to describe company interaction. To the extent that these spillovers are positive, we have underestimated the contribution from R&D to productivity.

The results from regressions in the market economy and manufacturing are listed in Table 6. The parameter estimated is an elasticity and measure the percentage increase in productivity for a one percent increase in R&D capital stock. At the market economy level, the estimate is not significantly different from zero, and no contribution from spillover is detected. The next column in Table 6 shows the same model estimated on the subsample of industries in manufacturing. Here we find that an increase in R&D capital stock of one percent increases productivity by 0.115 percent. We find the result to be statistically significant. We also note that the output gap is uncorrelated with productivity growth.

33. Output gap is measured by OECD and is taken from OECD (2015).
34. Other growth drivers are e.g. creative destruction, globalization, organization of work. Measuring these at industry level over many years is hard work. A simple way to check for missing variables is to include industry fixed effects. But these fixed effects might actually pick up the effect of R&D on productivity and could be devastating to our analysis. When we include industry dummies, the correlation between R&D growth and productivity growth disappears.

Table 6. *The indirect effect of R&D on growth in productivity*

	Market economy	Manufacturing		
	Growth in R&D stock	Growth in R&D stock	R&D Investment over GDP	Log R&D stock
R&D	0.015	**0.115**	-0.004	0.002
	(0.015)	(0.047)	(0.002)	(0.002)
Output gap	-	-0.017	-0.011	0.017
	-	(0.126)	(0.141)	(0.128)
N	890	368	368	368
R^2	0.07	0.02	0.00	0.00

Note: In the model for all industries, we check for business cycles with year dummies instead of the output gap. Bold is significant at the five percent significance level. Clustered standard errors in brackets.
Source: Statistics Denmark and our own calculations.

In Table 6, we have also added a few extra measures of R&D capital stock occasionally used in the literature or because we considered them important to check the robustness of results. First, we include a measure, which does not need an estimate of the capital stock. The measure is R&D investment over GVA, which is used in Griffith et al. (2004). Since the capital stock is unobserved, it can be helpful to use this alternative measure. When depreciations are low, this measure is closely related to the R&D capital stock. In column 3 of Table 6 we can see that this alternative measure is insignificant. Given its success in other studies, we also tried to run the regression on the period 1993-2012, not reported in the table, and we found that it was positive and statistically significant.[35] Second, we also added the result from a regression of growth in productivity onto R&D capital stock in levels, and the result is not statistically different from zero. Please note that we did all regressions on the total sample, i.e. we included industries with no R&D capital stock. We do not report this, but we found that the results were qualitatively similar.

35. We chose this period because investment series at industry level is available in the official statistics from 1993, which is a mark of quality, and this measurement requires much better annual investment data.

In Table 6, we also report a very low R-square for all regressions. The R-square is expected to be low, because we are running a regression on a residual, which contains all measurement errors. Focus and attention must be on the parameter estimates of R&D.

We have now estimated the indirect and direct contributions from R&D at the market level and in manufacturing. We can say something about their relative importance in manufacturing, because at the market economy level there does not seem to be an indirect contribution of R&D. The growth rate in the R&D capital stock was 5.6 percent per year from 2000 to 2012 in manufacturing. The total indirect contribution from manufacturing to productivity growth is 0.64 percent (0.115 times 5.6). The sum of the direct contribution (0.27 in manufacturing, cf. Table 3), and the indirect contribution is therefore 0.91 percentage points from 2000 to 2012. The indirect contribution is 70 percent of the total contribution, and the direct contribution is only 30 percent. This means that the contribution from spillover to R&D contributes more to economic growth than the direct contribution from the investment.

A few caveats should be mentioned. First, the model is simple and thus likely to be misspecified, since we are missing out on some variables, which will leave us with biased parameters. Second, from endogenous growth theory, we know that causality can go the other way, i.e. productivity might induce the firm to implement R&D. In the latter case, the bias is expected to take an upward turn, meaning that we are overestimating the contribution. Third, the indirect contribution is the intra-industry spillover. If (positive) inter-industry or international spillover occurs, the contribution can be even larger than our estimations suggest.

PUBLIC R&D

In the previous section, we have looked at private investment in R&D, and the direct and indirect contribution to intra-industry growth rates. We have established that the total contribution from R&D was close to 0.9 percent growth in output in manufacturing. The direct and indirect contributions were approximately 30 percent and 70 percent, respectively. The question we ask in this section is whether public R&D increases productivity in the private sector.

Public R&D can influence economic growth through various channels. Salter et al. (2001) classify six different categories, though not mutually exclusive:

- Increasing the stock of useful knowledge
- Training skilled graduates
- Creating new scientific instrumentation and methodologies
- Forming networks and stimulating new interactions.
- Increasing the capacity for scientific and technological problem-solving
- Creating new firms

Teaching at the universities is research-based, which means that graduates with master's and PhD degrees should be at the frontier of current knowledge. Hence we consider education of skilled graduates an important channel for public research spillover into industry. During their studies, they will have acquired knowledge about instrumentation and methodologies, and knowledge of recent scientific research. They could also be vital for forming networks and stimulating new interactions, as well as training industry in specific skills either as students or after graduation. Salter et al. (2001) write, "… graduates provide a key mechanism for the benefits of public funding to be transferred to industry ..."

So, we approach the role of public R&D in two very simplified ways. First, we ask whether total public R&D stock is correlated with aggregate productivity in the market economy. A major problem with this, however, is that we do not know the time lag between public R&D and the potential contribution to economic growth. This might be particularly important for public R&D as it is more focused on basic research. In some scientific areas, the time lag might be very short, and in other areas it could be extremely long. A possible source to identify the role of public R&D at this level of aggregation would be international data., which is outside the scope of the analysis.

Second, we distribute the public R&D capital to industries to get some cross-sectional variation in the data. In this setting, the time lag is probably less important as long as it is consistent. The problem with this approach is finding a weighting scheme to help distribute public R&D. We assume that graduates are important for diffusion of public R&D in the private sector. From micro data and public finances, we can distribute public R&D to private industries in different fields, namely the following: humanities, social sciences, engineering, natural sciences, health, and agricultural and veterinary science. The weights we apply to distribute the public R&D capital stock to industry is a combination of two weights. The first is the share of candidates with master's and PhD degrees in industry i by field j, we call it ω_{ij}. The second is the share of general advancement of knowledge[36] across field j, we call it $\hat{\omega}_j$. The weight we apply is the product of these two weights. It is important to note that the expenditure in private investment in R&D includes salaries to scientific personnel thus already accounting for the value of education in R&D. It would probably be impossible for private firms to engage in R&D to the same extent without public investment in R&D. Hence the weakness of this approach is that candidates with master's and PhD degrees are already an important component of private R&D.

In Table 7, we report the results from the two samples, total market economy and manufacturing. The first column in Table 7 shows that neither private nor public R&D is correlated with productivity at market economy level. As emphasized above, there are potential problems with measuring the timing of this correlation. We have tried by using different lag rates in private and public R&D without success. However, we only have twenty observations in Denmark, and for this to be a viable approach, we require data for several countries, which would increase the number of observations and the chances of identifying statistical results.

In the second column in Table 7, we have reported results for manufacturing only. The contribution from private R&D is still positive and significant, but the parameter is slightly smaller than before. Public investment in R&D is insignificant. We have tried to exclude private R&D, in which case the public R&D becomes positive and significant in manufacturing. This result is consistent with a positive correlation between private and public R&D within industry, which can occur if investments are complementary and create crowding-in.

36. Most of public investment in R&D comprises general advancement of knowledge.

Table 7. *The indirect effect of private and public R&D on productivity growth*

	Market economy	Manufacturing
R&D private	-0.002	**0.085**
	(0.035)	(0.042)
R&D public	-0.064	0.039
	(0.065)	(0.025)
Output gap	-	0.012
	-	(0.106)
N	20	437
R2	0.05	0.02

Note: Bold is significant at the five percent significance level. Clustered standard errors in brackets.
Source: Statistics Denmark and our own calculations.

The conclusion from this analysis is that public R&D, in particular the education of highly qualified scientific personnel, is important. First, this is because a large part of private investment in R&D constitutes earnings for scientific personnel with a university degree. Second, we measure investment in public R&D by the share of graduates in different industries, and when we exclude private investment in R&D, growth in the investment in public R&D is positively correlated with productivity growth.

However, we must also acknowledge that the channels through which public R&D influences private R&D cannot be identified through graduates alone. Other channels like spin-outs, collaborative schemes, etc. can be used to locate spillover between public research and economic growth.

EXPORTS AND LABOR

In a policy context, it is also of interest to investigate the role of private R&D in variables such as exports and labor. Exports are important as a generator of income, which can then be spent on imports, investment, etc. Labor is also important, because higher employment levels increase income and reduces the burden of the public sector by reducing income transfers and increasing the tax base.

Table 8. *Growth in export and labor*

	Market economy			Manufacturing		
	Labor quantity	Labor quality	Exports	Labor quantity	Labor quality	Exports
Private R&D	0.010	-0.017	-0.104	0.171	0.110	0.335
	(0.008)	(0.014)	(0.086)	(0.110)	(0.069)	(0.272)
Output gap	-	-	-	**0.624**	-0.248	**0.749**
				(0.187)	(0.183)	(0.228)
N	890	1003	868	368	368	368
R2	0.11	0.00	0.03	0.06	0.01	0.04

Note: Bold is significant at the five percent significance level. Clustered standard errors in brackets.
Source: Statistics Denmark and our own calculations.

First, we analyze the correlation of growth in R&D capital stock on the one hand, and growth in labor quantity and quality on the other. We have previously established that R&D and economic growth is correlated, and that growth in firms might lead to an increase in employment and in the number of hours worked in industry – with more R&D. Second, we analyze whether an increase in R&D capital stock might also shift the demand for labor from low-skilled to highly skilled workers or vice versa. For example, R&D-intensive industries might have to use highly skilled sales personnel, because knowledge is required to sell the products.

In Table 8, we have regressed growth in labor quantity and quality[37] onto growth in private R&D.[38] We do the regression for the two samples previously reported. We find that in the market economy, there is no connection between R&D and growth in quantity or quality of the labor force. In manufacturing, we find a positive correlation between growth in R&D investment and the labor quality used in manufacturing industries. This is an interesting result indicating that R&D might require other types of highly educated personnel in the industry.

In Denmark, our most important (natural) resource is highly educated labor. We know from international economics that a country's comparative advantage might be reflected in export of goods and services. In Table 8, the contribution from R&D measured as growth in R&D capital stock on export growth can be seen for all industries and in manufacturing. In both cases, the contribution from R&D is insignificant for exports.

The same caveats apply to this section as to the previous regression analysis. The model is overly simplified and serves as a first benchmark towards understanding the role of R&D in employment and exports from an industry perspective.

37. We measure labor quantity by growth in the number of hours worked by employees and self-employed staff. The quality of labor is taken from industry growth accounts in Statistics Denmark, where we find an index of labor quality contributions to economic growth. Quality of labor is measured by length of education and aggregated to an index by relative wages.
38. We also included measures of business cycles as a regressor, because especially labor quantity (and exports) depends heavily on this.

SENSITIVITY ANALYSIS

In this section, we confront our model with alternative assumptions about the financing of R&D investment and the life cycle of R&D investment. It is important to realize how sensitive our results are to the chosen values, because we lack good evidence necessary for growth accounting. We will focus on two different analyses from our results section to summarize sensitivity. The first result whose sensitivity to assumptions we will look at is the direct contribution from R&D to the market economy, and the second is the indirect contribution in manufacturing.

LIFE CYCLE OF R&D

Evidence on the life cycle of private R&D is very difficult to find. In Hall et al. (2009b), which surveys some of the studies, the depreciations range from ten to 36 percent depending on the industry studied. In Statistics Denmark, three different life cycles for the three different types of R&D are assumed. Basic research is assumed to have a life cycle of 12 years, applied research ten years, and development eight years.

The implementation of Statistics Denmark follows the recommendation by ESA2010 (Eurostat (2014)), which says that an average life cycle of ten years is acceptable until further reliable evidence becomes available.

In our preferred model in the previous section, we assumed a nine-year lifespan (depreciation around 11 percent), since we cannot distinguish between the three types of R&D. As most R&D in the private sector is spent on development, namely 70 percent, the life cycle we have chosen is close to that of development.

Instead of relying on only one measure of life cycle, we have analyzed different alternative life cycles here. We assume a life cycle to be shorter or longer, i.e. six or 12 years (depreciations at 17 and eight percent, respectively). Compared to Hall et al. (2009b), these depreciations might be very small, but we come close to Statistics Denmark's findings, which we consider more important.

In Table 9, we note the results in the first two columns. A shorter life cycle decreases the direct contribution at the market level and the indirect contributions in manufacturing.[39] The reasoning for this is complicated for various reasons. First, a higher depreciation increases the cost of using R&D relative to other types of capital. This has a tendency to increase the marginal product of R&D and increase the direct contribution. However, at the same time, the growth in the R&D stock is smaller, and this reduces the direct contribution. Vice versa for a longer life cycle of R&D in column 2.

This result has implications for our analysis. First, it seems that a shorter (longer) life decreases (increases) the return to R&D – directly as well as indirectly. The direct contribution from R&D to the market economy is still around 0.1 percentage point dropping to below 0.1 in 2010-2012 if the life cycle is only six years. Similarly, the indirect contribution from R&D in manufacturing dropped from 0.115 to 0.083 for a six-year life cycle.

Another important result noted previously is the fact that the contribution from R&D to economic growth has accelerated over time. This still seems to be the case no matter what life cycle we assume. How about the distribution of the direct contribution across industries? Since the effect of changing the life cycle of R&D investment has two effects with opposite signs, the relative industry results might change. However, we expect these changes to be small compared with the actual difference across industries.

FINANCING R&D

We experienced considerable concern in applying growth accounting to R&D, since the typical growth accounting exercise used in the previous section assumes that all investments are financed in the same way. However, firms or investors in R&D might be different and want to secure a higher return mainly due to the high risk – particularly at the early stage – inherent in R&D. There is ample evidence that R&D is more expensive to finance (see Hall et al. (2009a)). Small and new innovative firms experience high cost of capital, and large firms prefer internal funding, which is generally more expensive to use than external funding.

In the last two columns of Table 9, we have used alternative measurements of user cost for R&D. If user cost is 33 percent higher, then the direct contribution from R&D will increase at the aggregate level. The marginal product of R&D has increased because of the higher required rate of return to investment. Contrary to the results for life cycle, this assumption has a monotonic (positive) effect on the direct contribution. The indirect contribution moves in the opposite direction, which is a

39. We also computed the direct contribution in manufacturing, which also dropped due to the shorter life cycle of private R&D investment.

consequence of the increase in the direct contribution reducing the total factor productivity in each industry. We find that the distribution between direct and indirect contribution is highly influenced by the assumption made on the financing of R&D.[40]

The acceleration in the direct contribution from the ’90s to the ’00s persists. It is also highly likely that the relative importance of industries is unaffected by the changes in user cost, mainly because we assume that user cost changes monotonically across industries.

Table 9. *Sensitivity analysis*

	Life cycle of R&D		Finance R&D	
	6 years	12 years	-33%	33%
Direct (market economy)				
1980-1989	0.01	0.00	0.00	0.01
1990-1999	0.07	0.06	0.04	0.09
2000-2009	0.12	0.13	0.09	0.17
2010-2012	0.08	0.13	0.07	0.15
Indirect (manufacturing)	**0.083**	**0.138**	**0.127**	**0.104**

Source: Statistics Denmark and our own calculations.

40. When we compute the direct effect of private investment in R&D in manufacturing, there will be a 0.35 increase if user cost is 33 percent higher. In this case, the distribution of indirect versus direct effect is 63 and 37 percent, respectively.

CONCLUSION

In this report, we have tried to answer the following questions: What is the contribution from R&D to economic growth in the market economy? Which industries contribute? Does public R&D correlate with productivity growth? Does growth in private R&D capital stock correlate with e.g. exports and employment growth?

We decomposed economic growth in production in contributions from primary input, intermediates, and total factor productivity, the latter is the part of growth not caused by inputs and measures long-term technological change. The contribution from private R&D capital stock as an input to economic growth is estimated at 0.1 percentage point in the period 2000-2012. The contribution is mainly driven by a few sectors, ‘manufacturing’ and ‘finance and insurance’, and within ‘manufacturing’, ‘pharmaceuticals,’ ‘manufacture of machinery’, ‘manufacture of furniture and other manufacture’. We also found an acceleration of contributions from R&D on growth.

The contribution from private R&D capital stock to total factor productivity was estimated at zero for the market economy, which might be due to the great uncertainty in total factor productivity measurements for some industries. Instead, we also computed the contribution from private R&D capital stock to total factor productivity in manufacturing only. Here we found that a one percent increase in private R&D capital stock increases total factor productivity (and economic growth not directly caused by inputs) by 0.115 percentage points.

We found that public R&D capital stock had no contribution to total factor productivity in the market economy nor in manufacturing. However, one possible explanation could be that we did not account for complementarities in public and private investment in R&D and possible crowding-in of investments.

Neither was the contribution from R&D to other macroeconomic variables like exports and employment significantly different from zero.

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APPENDIX A: HOW TO AGGREGATE ACROSS INDUSTRIES

We use a bottom-up approach to aggregate across industries. When we aggregate, we integrate industries by removing intra-industry deliveries. The question is what the relationship is between aggregate productivity, aggregate inputs, and aggregate output. Here we show derivation of the famous Domar-weights.

First, we rewrite the industry equation with a slight change in notation. We divide intermediates into two types, x and z. The first, x, denotes intermediates from industries, which we aggregate over. The second, z, denotes intermediates either produced in domestic firms, which we do not aggregate over, or imported intermediates.

$$(1) g_y^{\,i} = s_l^i\, g_l^i + s_k^i\, g_k^i + s_x^{\,i}\, g_x^{\,i} + s_z^i\, g_z^{\,i} + tfp^i$$

As before, y denotes output, l labor, k capital, and x and z intermediates. Share in output is s. Here we ignore that labor, capital, and intermediates can be further disaggregated.

Second, when we aggregate across industries, we leave out x, so we define aggregate output as $\hat{y}$. We write output from industry i as:

$$(2) g_y^{\,i} = s_{\hat{y}}^i\, g_{\hat{y}}^i + s_x^{\,i}\, g_x^{\,i}$$

Combining equation (1) and (2), we can write the aggregate output:

$$(3) g_{\hat{y}}^{\,i} = \frac{s_l^i}{s_{\hat{y}}^i}\, g_l^i + \frac{s_k^i}{s_{\hat{y}}^i}\, g_k^i + \frac{s_z^i}{s_{\hat{y}}^i}\, g_z^{\,i} + \frac{1}{s_{\hat{y}}^i}\, tfp^i$$

Aggregation across industries gives the following equation for growth in aggregate output:

$$(4) g_{\hat{y}} = \Sigma_{i=1}^{n}\, \hat{s}_{\hat{y}}^i\, g_{\hat{y}}^i$$

The value share $\hat{s}$ is the share in aggregate output.

Equation (3) and (4) can be combined to get:

$$(5) g_{\hat{y}} = \Sigma_{i=1}^{n} \left(\frac{\hat{s}_{\hat{y}}^{i}}{s_{\hat{y}}^{i}} s_l^i g_l^i + \frac{\hat{s}_{\hat{y}}^{i}}{s_{\hat{y}}^{i}} s_k^i g_k^i + \frac{\hat{s}_{\hat{y}}^{i}}{s_{\hat{y}}^{i}} s_z^i g_z^i + \frac{\hat{s}_{\hat{y}}^{i}}{s_{\hat{y}}^{i}} tfp^i \right)$$

Here $\frac{\hat{s}_{\hat{y}}^{i}}{s_{\hat{y}}^{i}}$ is the Domar weight.

This equation makes it clear that we can use Domar weights to aggregate across industries.

If Denmark were a closed economy and we aggregated across all industries, then z would be 0. In other words: $\hat{y}$ would be value-added in this case – and only in this case. But Denmark is a small open economy, and imported intermediates are important inputs to the production function.

APPENDIX B: INDUSTRY CODING

01000	Agriculture and horticulture
02000	Forestry
03000	Fishing
06090	Mining and quarrying
10120	Manufacture of food products, beverages, and tobacco
13150	Textiles and leather products
16000	Manufacture of wood and wood products
17000	Manufacture of paper and paper products
18000	Printing etc.
19000	Oil refinery etc.
20000	Manufacture of chemicals
21000	Pharmaceuticals
22000	Manufacture of rubber and plastic products
23000	Manufacture of other non-metallic mineral products
24000	Manufacture of basic metals
25000	Manufacture of fabricated metal products
26000	Manufacture of electronic components
27000	Electrical equipment
28000	Manufacture of machinery
29000	Manufacture of motor vehicles and related parts
30000	Manufacture of ships and other transport equipment
31320	Manufacture of furniture and other manufacturing
33000	Repair and installation of machinery and equipment
35000	Electricity, gas, steam and air conditioning supply
36000	Water collection, purification and supply
37390	Sewerage; waste collection, treatment and disposal activities, etc.
41430	Construction
45000	Wholesale and retail trade and repair of motor vehicles and motorcycles
46000	Wholesale
47000	Retail sale
49000	Land transport and transport via pipelines
50000	Water transport
51000	Air transport
52000	Support activities for transportation
53000	Postal and courier activities
55560	Accommodation and food service activities
58000	Publishing activities

59600	Motion picture and television program prod., sound recording; radio and television
61000	Telecommunications
62630	IT and information service activities
64000	Financial service activities, except insurance and pension funding
65000	Insurance and pension funding
66000	Other financial activities
68100	Buying and selling of real estate
68300	Renting of non-residential buildings
68203	Renting of residential buildings
68204	Owner-occupied dwellings
69700	Legal and accounting activities; activities of head offices; management consultancy
71000	Architectural and engineering activities
72001	Scientific research and development (market)
72002	Scientific research and development (non-market)
73000	Advertising and market research
74750	Other professional, scientific and technical activities; veterinary activities
77000	Rental and leasing activities
78000	Employment activities
79000	Travel agent activities
80820	Security and investigation; services to buildings and landscape; other business services
84202	Public administration, etc.
84101	Rescue services, etc. (market)
85202	Education (non-market)
85101	Education (market)
86000	Human health activities
87880	Residential care
90920	Arts and entertainment; libraries, museums and other cultural activities; gambling
93000	Sports activities and amusement and recreation activities
94000	Activities of membership organisations
95000	Repair of personal goods
96000	Other personal service activities
97000	Activities of households as employers of domestic personnel

VÆKST GENNEM VIDEN

DEA er en ideologisk uafhængig tænketank, der arbejder for, at Danmark øger sin værdiskabelse og vækst samt tiltrækker internationale virksomheder gennem viden om uddannelse, forskning og innovation.

Tænketanken DEA kæmper grundlæggende for, at flere unge får en uddannelse, der efterspørges, at forskning bliver omsat til innovation i private og offentlige virksomheder, og at Danmark er et attraktivt land for videnbaserede virksomheder.

DEA vil nå sine mål gennem:

- Analyser og undersøgelser, der styrker DEAs dagsorden
- Involvering af virksomheder, uddannelsesinstitutioner og organisationer via partnerskaber og projekter
- Udfordring af vanetænkning og bidrag til løsning af samfundsudfordringer

DEA
VI FREMMER VIDEN

Fiolstræde 44 / DK-1171 København K / Tel +45 3342 6600 / dea@dea.nu / www.dea.nu