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International battle of giants
The role of investment in research and fixed assets

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Dankwoord

Deze studie maakt deel uit van het project `Marktwerking in Nederland' en is deels gefinancieerd door OCfEB en het Ministerie van Economische Zaken. Het commentaar op eerdere versies van dit rapport door de begeleidingsgroep bestaande uit Jarig van Sinderen (voorzitter), Peter Gerbrands, Joost Kuijper, Coen van Riel, Rudy van Zijp and Arie van der Zwan, is erg nuttig geweest. Hetzelfde geldt voor de suggesties van de CPB-ers Eric Bartelsman, Peter v.d. Berg, Kees Burk, Henk Don, Frank van Erp, Theon van Dijk and Herman Noordman. Bovendien zijn opmerkingen van Th. v.d. Klundert verwerkt. Het statistische werk is grotendeels utgevoerd door Jeannette Verbruggen. Dit rapport is ook uitgebracht in de Onderzoeksreeks directie Marktwerking van het Ministerie van Economische Zaken.

Executive summary in Dutch

Internationaal gevecht tussen giganten: De rol van investeringen in onderzoek en vaste activa

Probleemstelling

De probleemstelling van dit project luidt: empirisch onderzoek naar marktwerking, innovatie en internationalisatie van grote R&D-intensieve ondernemingen met een vestiging in Nederland. Internationalisatie omvat het keuzeprobleem tussen exporteren naar en investeren in het buitenland. Deze drie elementen worden in kaart gebracht op basis van de endogene groei- en handelstheorieën. In die theorieën zijn de actoren concurrerende ondernemingen, en niet zozeer concurrerende landen. De theorie legt de nadruk op R&D-investeringen als middel tot innovatie. Dit rapport voegt daar investeringen in vaste activa aan toe. Het onderzoek heeft tot doel vanuit het micro-economische niveau het inzicht te vergroten in de marktwerking voor grote export-georiënteerde ondernemingen om daaruit conclusies te kunnen trekken m.b.t. de mogelijkheden voor een nationaal mededingings- en technologiebeleid voor deze doelgroep.

Uitwerking

Vaak beziet het beleid marktwerking vanuit een nationaal perspectief. Met mededingingspolitiek gaat het beleid macht op de nationale markt tegen, waarbij meestal impliciet een groot gewicht wordt toegekend aan de concurrentie in bestaande producten. Het nationale perspectief blijkt ook bij de visie op internationale economische relaties. Beleidsmakers veronderstellen wedijverende landen met een accent op de internationale handel. Bij dat uitgangspunt wordt uitgegaan van gegevens per land en worden daarmee causale verbanden geanalyseerd.

Voor grote multinationals die veel investeren in onderzoek en ontwikkeling (**R**esearch & **D**evelopment) is de nadruk op bestaande producten en het nationale perspectief van beperkt belang.

Ondernemingen investeren juist in R&D om nieuwe producten en betere procestechnologie te ontwikkelen. Die creatie eist onvolledige concurrentie, dus marktmacht. Praktisch blijkt die macht uit de concentratie van R&D bij grote multinationals. Dit rapport toont aan dat de twintig grootste ondernemingen op het gebied van elektronica en computers ongeveer de helft van alle R&D-uitgaven op die velden van onderzoek in de wereld doen. Bij farmacie is dat aandeel nog hoger. Bij chemie is de concentratie ook groot, maar minder: de top 17 concerns hebben een aandeel van een derde in de R&D-uitgaven.

Concentratie speelt ook op nationaal niveau. In de Verenigde Staten verrichten de top-10 ondernemingen bijna een kwart van het onderzoek, in Duitsland heeft de top-8 een aandeel van ongeveer zestig procent, in Nederland heeft de top-5 een aandeel van bijna de helft. Theoretisch is ook afgeleid dat ondernemingen een zekere marktmacht nodig hebben om de winst te maken die nodig is om de R&D-uitgaven te financieren.

Het belang van het nationale perspectief is beperkt, want voor grote R&D-intensieve ondernemingen zijn in de eerste plaats de internationale markt en het gedrag van rivalen van belang. Internationaal investeren en internationale handel zijn keuzeproblemen voor het concernmanagement, dat kiest tussen exporteren vanuit het moederland of investeren in productiefaciliteiten dichtbij de buitenlandse klanten. Landen, en daarmee nationaal beleid, zijn pas in de tweede plaats belangrijk voor R&D-intensieve giganten.

Als gevolg van concentratie zijn grote R&D-intensieve ondernemingen belangrijke spelers in het proces van technische ontwikkeling, zodat in de driehoek de hoekstenen onvolledige mededinging, nieuwe technologie en internationalisatie aan elkaar zijn gerelateerd. Het belang van deze driehoek voor de hele economie is dat deze fungeert als motor van economische groei.

Dit rapport is voor beleidsmakers vooral van belang, omdat het start vanuit het gezichtspunt van *grote R&D-intensieve multinationals* op die driehoek en niet vanuit een nationale optiek.

Meer specifiek is het doel van dit rapport om de investeringen in R&D en vaste activa van grote R&D-intensieve multinationals uit de Fortune Global 500 lijst te onderzoeken. Deze ondernemingen verrichten samen een aanzienlijk deel van de mondiale R&D-inspanning. Daarbij wordt ook geanalyseerd of die ondernemingen op elkaars investeringsgedrag reageren, zodat de oligopolistische marktvorm wordt verkend. Deze analyse is origineel en gebaseerd op een databank die ten behoeve van dit doel is gemaakt.

Vervolgens wordt geanalyseerd hoe het R&D-budget zo goed mogelijk kan worden gebruikt. Leidraad is de kennisproductiefunctie: het belangrijkste theoretische concept van de endogene groeitheorie. Dit rapport demonstreert verschillende concrete manieren uit de praktijk, hoe kennisproductie kan worden opgevoerd in de relatie met die kennisproductiefunctie.

Daarna komt de vraag aan bod hoe de investeringsbudgetten door het concernbestuur internationaal worden verdeeld en waarom. Dit rapport legt de nadruk op Nederland als vestigingsplaats, waarbij vele giganten bij naam worden genoemd ter concretisering van de beschouwing. Leidraad voor de beschouwing is de vestigingsplaatstheorie die voor R&D-giganten twee dimensies onderscheidt. De eerste is landen-gebonden, namelijk de verzameling van comparatieve factoren tussen landen, zoals productiefactoren en instituties. De tweede dimensie is product gebonden, namelijk de verhouding tussen transportkosten naar de afzetmarkt en schaalbenutting van een buitenlandse vestiging.

Ook wordt ingegaan op de invloed van die beslissingen op macro-economisch niveau. Daarbij wordt de motor van de economische groei uit de endogene groeitheorie gepresenteerd. Deze omvat een component die het onderscheidend vermogen tussen de producten beschrijft (oftewel de substitutie-elasticiteit tussen de producten) en een component die direct samenhangt met de kennisproductiefunctie en het R&D-budget. Het gevaar voor de economische groei van de verschuiving van Research naar Development bij vele R&D-giganten wordt toegelicht. Bovendien illustreert het rapport dat een onderschatting van het onderscheidend vermogen tussen productvariëteiten door statistici leidt tot een overschatting van de inflatie en onderschatting van de groei.

Afgesloten wordt met conclusies voor beleidsmakers. Het rapport benadrukt de uitdagingen voor mededingingspolitiek die voortvloeien uit de creativiteit die verbonden is aan R&D. Bovendien blijken voor R&D-intensive grote concerns, naast technologie-politiek, nog vele andere beleidsinstrumenten belangrijk, zoals wettelijke aansprakelijkheid, intellectuele eigendomsrechten en vestigingsplaatspolitiek.
Om de presentatie aansprekend te maken, geeft de Engelse tekst bij alle onderwerpen, illustraties uit de praktijk. Hieronder worden de belangrijkste uitkomsten van dit rapport op een niet-technische manier samengevat.

Hoeveel investeren in R&D en vaste activa ?

Belangrijke wapens van ondernemingen zijn de omvang van de investeringen in R&D en in die van vaste activa; onder andere hiermee creëren zij de toekomstige markt-posities ten opzichte van concurrenten. Voor R&D-intensieve ondernemingen zijn de R&D- en vaste activa-budgetten beide belangrijk, want ze zijn beide omvangrijk en hebben een ander doel. R&D is het strategische strijdmiddel in de lange termijn positionering en is meestal gericht op nieuwe producten, wat in de informatie technologie vaak nieuwe experimentele software is. Ondernemingen in basisindustrieën investeren hun R&D vooral in goedkopere en schonere eigen procestechnologie.

Investeringen in vaste activa werken vooral op de middellange termijn. Zij creëren productiecapaciteit en maken de productie goedkoper en milieuvriendelijker, want de nieuwste machines zijn het efficiëntst en het schoonst.

R&D-klassementen in Nederland

Het rapport noemt ook de belangrijkste R&D-investeerders in Nederland uit binnen- en buitenland bij naam. Hieronder staan twee klassementen van "Nederlandse" concerns samengevat.

Het bestedings-klassement
In 1995 besteedden ondernemingen in Nederland 6855 miljoen gulden aan R&D. Het klassement wordt aangevoerd door Philips, Shell, Akzo Nobel, Unilever en DSM met R&D-uitgaven in Nederland van respectievelijk 1400, 540, 450, 350 en 310 miljoen gulden in 1995.

Het groei-klassement
Het verloop van de R&D-uitgaven tussen 1990-1995 vertoont een heel andere rangorde. Software fabrikant Baan is kampioen met een jaarlijkse R&D-toename van 65%. Baan wordt gevolgd door Axxicon (kunststofmatrijzen voor compact discs met een wereldmarktaandeel van 50%), BESI (fabrikant van machines waarmee omhulsels van halfgeleiders worden vervaardigd), ASM Lithography (optische machines voor de productie van geïntegreerde circuits, met een wereldmarktaandeel van 19%), Draka (kabels voor energie-, communicatie- en datatransmissie) en Thomassen International (energie-apparatuur).
Achterblijvers bij de gemiddelde R&D-groei van 3,5% per jaar tussen 1990-1995 zijn DSM, Philips, Gist, Delft Instruments en Gasunie. Van die bedrijven daalden de uitgaven zelfs met enkele procenten per jaar. Hekkensluiter is Fokker als gevolg van het faillissement.

Wat zijn de determinanten van de investeringsbudgetten aan R&D en vaste activa van een concern? Investeringen zijn gericht op de toekomst. In de theorie wordt vaak verondersteld dat de onderneming beschikt over `perfect foresight', dan wel dat er bij R&D met zekerheid een winnaar is in een race, met een van te voren bekende prijs in de vorm van de uitvinding. Dat wil zeggen dat ondernemers van te voren (kansverdelingen van) netto opbrengsten en de discontovoeten over de hele termijn van het investeringsproject kennen, en daarmee impliciet ook de invloed van acties van concurrenten en nieuwkomers op die netto-opbrengsten. Een ondernemer met zoveel `foresight' is natuurlijk een ideaal-typische veronderstelling. In de praktijk zijn incidenteel rendementseisen bekend voor vaste activa. Dat betekent dat het bestuur van een onderneming in die gevallen een empirisch in te vullen toekomstvisie heeft, maar dat is geen `perfect foresight'. Echter, van R&D-investeringen zijn geen expliciete rendementseisen bekend. R&D dient om het concern in de toekomst strategisch te positioneren, maar het ontbreken van expliciete rendementseisen kan betekenen dat het management ten aanzien van productvernieuwing toch een veel minder concrete toekomstvisie heeft. In elk geval ontbreken systematische gegevens die zo'n op de toekomst gerichte investeringsstrategie empirisch kunnen toetsen.

Voor de empirische bepaling van de investeringsbudgetten gaat dit rapport ervan uit dat het ondernemingsbestuur naar de financiële kerngegevens kijkt van het eigen concern, en naar het investeringsgedrag van concurrenten. Dit zijn in elk geval gegevens waarover het bestuur beschikt als deze investeringsbeslissingen neemt.

Voor 49 giganten - grotendeels uit de Fortune Global 500 lijst plus enkele grote Nederlandse concerns- behorend tot de bedrijfstakken informatie-technologie, chemie, farmacie, voeding en wetenschappelijke- of medische instrumenten, is voor de periode 1985-1994 onderzocht in hoeverre hun investeringsgedrag in R&D en vaste activa kan worden verklaard uit hun netto winst, het schuldaandeel in het vermogen, en de rente. Het blijkt dat een verhoging van de netto winst of een verlaging van de schuldverhouding na een jaar leidt tot een vergroting van de investeringen in vaste activa. Dat geldt ook voor R&D, maar de invloed van de genoemde determinanten is daar veel minder sterk en met een grotere vertraging. De farmacie-concerns en producenten van elektronische componenten in de steekproef lijken er een heel simpele R&D-uitgavenstrategie op na te houden, namelijk een vast percentage van de omzet. Opvallend is dat geen negatieve invloed van de rentevoet op de investeringen in R&D en vaste activa kon worden gevonden.

Ook blijkt dat 20 concerns van elektronica en computers en 16 concerns van farmacie en chemie uit de Fortune Global 500 lijst, sterk reageren op elkaars R&D-investeringen. Deze uitkomst is een originele bijdrage van dit rapport. Voor zo'n sterke reactie hebben de ondernemingen verschillende argumenten. In de eerste plaats is het nuttig om de concurrenten te volgen in de technologische race. Bovendien moet het eigen concern de R&D opvoeren als concurrenten dat doen om de uitvindingen van die rivalen te kunnen begrijpen, en voortbouwend op die nieuwe kennis zelf nieuwe producten te ontwikkelen. Ten derde is het moeilijker expliciete rendementseisen te stellen aan R&D dan aan vaste activa, waardoor het belang groeit om naar de concurrent te kijken als maatstaf voor het eigen handelen. Wel moet worden aangetekend dat in het ongewisse blijft wat de R&D-criteria van de echte leiders zijn die de norm zouden moeten stellen.

Bij investeringen in vaste activa reageren de ondernemingen ook op elkaar, maar dat is significant minder het geval dan bij R&D. Redenen kunnen zijn dat de twee laatstgenoemde argumenten om R&D-uitgaven na te volgen niet opgaan voor vaste activa.

Voor *elektronica en computers* is een vorm van leiderschap aan te geven. Leiderschap is gedefinieerd als de volgorde waarin ondernemingen elkaars investeringsuitgaven in de loop van de tijd beïnvloeden. Bijvoorbeeld, Sony is een R&D-leider van Philips als een stijging van de R&D-uitgaven van Sony een jaar later leidt tot een verhoging van de R&D-uitgaven van Philips, terwijl het omgekeerde niet het geval is. Op deze manier is naar statistische criteria een leiderschaps-rangorde tussen die twintig concerns uitgerekend. Deze analyse levert in de sector informatietechnologie de volgende rangorde op van leiderschap tot volgerschap: Hitachi, Intel, Texas Instruments, Toshiba, Siemens, Compaq, Canon, AT&T, Apple, IBM, NEC, Sanyo, Motorola, Sony, Matsushita, Philips, Bosch, Honeywell en Digital. Opvallend is de positie van Ericsson. De statistische analyse wijst het bedrijf aan als dé leider in R&D, terwijl het de laatste plaats inneemt bij vaste activa.

De gevonden volgorde heeft een economische interpretatie. Bovenaan de lijst van leiderschap staan de concerns die gespecialiseerd zijn in elektronische componenten, dan komen de computerproducenten, dan de specialisten op het gebied van professionele en consumentenelectronica. Het kan bijvoorbeeld nauwelijks toeval zijn dat de consumentenelectronica-specialisten Matsushita, Philips, Sony en Sanyo dicht bij elkaar staan. Hetzelfde geldt voor de computergroep Compaq, Canon, AT&T en IBM. Het lijkt er dus op dat binnen de informatietechnologie de ondernemingen hun R&D-uitgaven doen in een volgorde die samenhangt met hun plaats in de bedrijfskolom. Bovenaan staan de `grondstoffen'-leveranciers en onderaan de concerns die zijn gespecialiseerd in eindproducten. De computerconcerns zitten er tussen in. Een oorzaak kan zijn dat nieuwe computers en softwaresystemen die door de computerspecialisten worden geleverd een belangrijke input zijn voor de productie van elektronische eindproducten.

De 16 giganten in de *farmacie en chemie* reageren ook sterk op elkaars R&D-investeringen. Daarbij leiden farmaceutische concerns de R&D-investeringen van de chemiegiganten. De reden hiervan is niet duidelijk. Interessant is het verschil tussen de chemie- en elektronica-concerns in reactiepatroon. Bij de elektronica- en computerconcerns is een volgorde in leiderschap aan te geven, terwijl chemie-concerns elkaars R&D-uitgaven wederzijds opjagen. Een mogelijke verklaring voor die simultaniteit bij chemie-concerns is dat zij onderling veel minder gespecialiseerd zijn dan elektronica-concerns.

Uit het rapport blijkt ook dat de concerns die het meest aan R&D uitgeven in de elektronica/computers respectievelijk chemie/farmacie, geen R&D-leider zijn volgens de gehanteerde definitie.

Hoe kunnen R&D-managers hun budget het best gebruiken?

Nadat het ondernemingsbestuur het jaarbudget aan R&D en de vereiste mate van onderscheid met bestaande producten heeft vastgesteld (in termen van kwaliteit en radicaalheid), hebben R&D-managers tot taak zoveel mogelijk nieuwe producten te ontwikkelen binnen de opgelegde grenzen van het budget en de vereiste kwaliteit. Dat kan door de ontwikkelingskosten zo laag mogelijk te maken binnen de gestelde restricties. Het rapport bespreekt welke instrumenten in de praktijk door de concerns worden gebruikt.

De belangrijkste bijdrage van het rapport op dit gebied is dat het de vele maatregelen uit de praktijk verbindt met het abstracte sleutelconcept in de endogene groeitheorie: de kennisproductiefunctie. Bovendien worden gelieerde concepten als vaste toetredingskosten met voorbeelden empirisch geïllustreerd. De kennisproductiefunctie verklaart de productie van nieuwe kennis uit de inzet aan traditionele productiefactoren en de voorraad van kennis. De inzet van traditionele productiefactoren arbeid en kapitaal betekent dat economische groei niet zonder kosten kan gaan, en dus dat nieuwe technologie niet uit de hemel komt vallen. Die kosten komen tot uitdrukking in het R&D-budget. Bovendien creëert kennis nieuwe kennis, omdat de kennisvoorraad een input is om nieuwe kennis te produceren. De vraag is hoe traditionele productiefactoren zo goed mogelijk kunnen worden benut, gegeven de restrictie van het R&D-budget, en hoe bestaande kennis zo goed mogelijk kan worden geëxploiteerd. Het blijkt zinvol de kennisvoorraad te splitsen in concern-specifieke kennis en kennis die extern is voor een bedrijf.

De twee eerstgenoemde instrumenten hebben betrekking op traditionele productiefactoren. Ten eerste, kan de kennisproductie worden opgevoerd door concentratie van R&D op enkele plaatsen, zodat schaalvoordelen van dure en snel verouderende wetenschappelijke apparatuur beter worden benut.

Het tweede instrument is de vervanging van onderzoekspersoneel door computers die goedkoper zijn, oftewel de substitutie van arbeid door kapitaal. Ieder jaar zakt de prijs van computers met meer dan tien procent, terwijl het loon met enkele procenten stijgt. De scherpe penetratie van computers in laboratoria blijkt uit hun intensieve gebruik bij het ontwerp van en simulatie met computermodellen van apparaten, componenten, moleculen en genen.

Ten derde draagt een betere benutting van concern-specifieke kennis bij aan goedkopere ontwikkeling van nieuwe producten. Daartoe kan het R&D-management een aantal instrumenten inzetten. In de eerste plaats concentratie van basis- en toegepast onderzoek (Research) op enkele locaties, zodat de onderzoekers gemakkelijk met elkaar kunnen communiceren. Bovendien levert een elektronisch netwerk tussen de verschillende concern-laboratoria een betere benutting van die kennis op. Tenslotte is job-rotation een instrument. Ouder en minder productief researchpersoneel kan elders in het concern te werk worden gesteld, waardoor de concernspecifieke kennis wordt gespreid en uitgewisseld over verschillende divisies.

De vierde manier is de onderzoekers betere toegang te geven tot externe kennis. Daarvoor worden vier instrumenten ingezet: verbetering van de toegang tot universitaire kennis, het sluiten van R&D-allianties, fusies en overnames, en samenwerken met toeleveranciers of afnemers.

Door intensiever contact met universiteiten kan de fundamentele wetenschappelijke kennis door een concern goedkoop worden gebruikt als grondstof voor eigen toegepast onderzoek. Vooral voor R&D-intensieve giganten is het gebruik van universitaire kennis belangrijk.

In een R&D-alliantie mixen een aantal concurrerende ondernemingen hun kennis. Het gebruik van alle kennis van die concerns verlaagt de kosten van productontwikkeling, voorkomt duplicaties en spreidt risico's. Anderzijds staan daar extra kosten aan coördinatie tegenover. Vooral in de informatietechnologie komen veel allianties voor: van de 2800 allianties in de wereld in de periode 1990-1994, waren 48 procent tussen concerns van de informatie technologie industrie.

Fusies of overnames voegen de specifieke kennis van de betrokken concerns samen, waardoor de toegankelijke kennisvoorraad toeneemt. De fusiegolf tussen farmacie-giganten is deels ingegeven door betere kennisbenutting.

Samenwerking ten aanzien van R&D tussen een groot concern en zijn toeleveranciers geeft een betere organisatie van de bedrijfsspecifieke kennis van de betrokken ondernemingen en drukt daarmee de ontwikkelingskosten van het gehele product. Vaak zijn die toeleveranciers kleiner dan het coördinerende concern. Dit komt vooral voor bij machines en voertuigen die uit vele componenten zijn opgebouwd.

R&D-samenwerking tussen een groot concern met zijn afnemers komt vooral voor in basisindustrieën. Bijvoorbeeld staal- en aluminiumconcerns werken bij hun productontwikkeling samen met auto-onderdelenfabrikanten en blikfabrieken.

Het bovenstaande geldt niet voor de ontwikkelings- of technische centra dicht bij de klant. Deze dienen om de producten van het concern aan te passen aan de nationale smaak of wetgeving. Bovendien zijn ze een uitkijktoren, die informatie over de regio doorspeelt naar het hoofdkantoor.

Waar investeren: Grote buitenlandse ondernemingen in Nederland

Nadat de investeringsbudgetten in R&D en vaste activa zijn vastgesteld, moet worden beslist over de internationale verdeling ervan. Dit rapport legt de nadruk op de determinanten die van belang zijn voor de beslissing van niet-Europese R&D-giganten om in Noordwest-Europa, en vooral Nederland, te investeren. En het noemt ter concretisering ook de namen van de concerns.

Voor R&D-intensieve ondernemingen uit Noord-Amerika of Japan, die een groot schaaleffect hebben op concern-niveau door ondernemingsspecifieke kennis, wordt de beslissing in Noordwest-Europa te investeren of vanuit het moederland naar Europa te exporteren in sterke mate bepaald door de productgebonden dimensie van de transportkosten naar Europa en de kosten van een fabriek in Noordwest-Europa (dit is de tweede dimensie van de vestigingsplaatstheorie die hiervoor is genoemd). De reden is dat de dimensie van de comparatieve verschillen tussen landen minder invloed heeft, omdat de verschillen in factorverhoudingen en instituties tussen de Verenigde Staten, Japan en Europa waarschijnlijk betrekkelijk klein zijn, vergeleken met de productdimensie. De factor-dimensie telt meer bij de locatiebeslissing tussen rijke en arme landen.

Er wordt voor export naar Europa gekozen als de transportkosten laag zijn en een product in Europa niet erg rendabel te produceren is vanwege de hoge vaste investeringskosten van een nieuwe fabriek, mogelijk in combinatie met een kleine Europese afzet. Dit is bijvoorbeeld de reden waarom Amerikaanse machinefabrieken sporadisch in Europa investeren, maar veel naar Europa exporteren.

Voor investeringen in Europa wordt gekozen in het omgekeerde geval. Bijvoorbeeld, als er direct contact met de klant nodig is bij de verkoop en onderhoud van auto's, wat overeenkomt met extreem hoge transportkosten tussen verkoper en koper. Daarom hebben alle grote automerken in alle Europese landen verkoop- en garage-netwerken. Ook Amerikaanse software moet dichtbij de Europese klant op maat worden gesneden. Daarom hebben de grote software-huizen vele Europese vestigingen.

Dit rapport noemt als comparatieve voordelen die Nederland als vestigingsplaats binnen Europa aantrekkelijk maken, zijn ligging aan zee en belangrijke Europese rivierdelta's. Bovendien heeft Nederland kennis opgebouwd over internationale marketing, financiering en logistiek. Hierdoor heeft Nederland zich ontwikkeld tot een poort van Europa. De ligging aan zee is aantrekkelijk voor buitenlandse chemie- en olieconcerns; de specifieke logistieke kennis is vooral van belang voor het aantrekken van giganten in elektronica en computers.

De aantrekkelijkheid van Nederland als vestigingsplaats voor internationale olie- en chemieconcerns blijkt bijvoorbeeld uit de productie-installaties van de Fortune-giganten Du Pont, Hoechst, Dow Chemical, ICI, General Electric, een BASF/Shell joint venture, Exxon, Texaco/BP en Kuwait Petroleum. De reden is dat de transportkosten van een chemisch product uit Amerika naar Noordwest-Europa vaak hoger zijn dan de directe aanvoer van ruwe olie uit Saoedi-Arabië naar Nederland, daar het product te maken en vervolgens via het infrastructurele netwerk naar de klanten in Noordwest- Europa te brengen.

Bovendien heeft Nederland zich ontwikkeld tot een Europees distributiecentrum van elektronica en computers. Er staan belangrijke Europese vestigingen van Canon, Digital, Apple, Texas Instruments, Compaq, Sun Microsystems, Toshiba, Sony en IBM. Volgens dit rapport bestaan daarvoor een aantal redenen. In de eerste plaats ligt een oorzaak bij de aard van deze producten. Zij bestaan uit vele gestandaardiseerde componenten, die tegen lage transportkosten te vervoeren zijn. Dit biedt concerns de gelegenheid de waardeketen in stukjes te verdelen, en elke component daar te produceren waar het het goedkoopst is. Die productieplatformen kunnen overal in de wereld staan. Echter, die componenten moeten uiteindelijk samen worden gevoegd tot een apparaat. Hierdoor ontstaan logistieke stromen over de hele wereld met centrale knooppunten. Nederland is binnen Europa zo'n knooppunt. De belangrijkste redenen zijn dat Nederland binnen Europa een voordeel heeft opgebouwd met kennis op de gebieden logistiek, internationale marketing en financiering en beheersing van vreemde talen, en daarnaast over een goede fysieke infrastructuur beschikt. Ook is de vestigingsplaats van de elektronica- en computer industrie in Europa gevoelig voor belastingfaciliteiten; deze zijn in Nederland gunstig.

Nederland kent ook R&D-centra van buitenlandse ondernemingen. Meestal zijn dat laboratoria van bedrijven die oorspronkelijk Nederlands waren en later door een buitenlands concern zijn overgenomen. Voorbeelden zijn Lucent (telecommunicatie-apparatuur), Solvay Duphar (farmacie), Paccar/DAF (trucks) en Sigma (verf). Dit is een aanwijzing dat opgebouwde regionale R&D-kennis een vestigingsplaatsfactor is, want na de overname zijn die R&D-centra blijven bestaan in Nederland.

Waar investeren: De grote (Brits-) Nederlandse ondernemingen

Op de Fortune Global 500 lijst staan Philips, Shell, Akzo Nobel en Unilever. Ondanks de internationalisatie en de trek naar Azië zien de besturen van Philips, Shell en Akzo Nobel Nederland als een gunstige vestigingsplaats. Dat geldt vooral voor R&D. Volgens dit rapport zijn de aandelen aan R&D in Nederland in de concern-totalen hoog: tussen de 35 en 50 procent. De aandelen van de vaste investeringen zijn lager, maar met een aandeel van bijna een kwart van Philips en 35 procent van Akzo Nobel toch aanzienlijk. Die voorkeur voor Nederland blijkt ook uit de hoge exportquota van de Nederlandse productie, voor Philips en Akzo Nobel bedraagt deze tussen de 90 tot 95 procent[1].

Unilever is het minst op Nederland georiënteerd: het Nederlandse R&D-aandeel bedraagt ongeveer een kwart en het aandeel in vaste activa 5 procent. Van de Nederlandse productie wordt minder dan de helft geëxporteerd. Unilever is een `multi-regionale multinational'. Veel voedingsproducten moeten voldoen aan de locale smaak. Daarom is veel onderzoek en productie ook locaal.

Volgens de gegevens in dit rapport trekken die concerns niet weg uit Nederland, want de Nederlandse aandelen in de R&D- en vaste activa investeringen zijn sinds 1980 niet gedaald.

De aandelen van Nederland zijn waarschijnlijk hoog omdat in ons land veel concern-specifieke kennis binnen de regio is opgebouwd en hier verankerd is. Deze niet gecodificeerde kennis geeft een nationaal concurrentievoordeel, mede omdat die concern-specifieke kennis deel uitmaakt van een heel netwerk van toeleveranciers in de buurt van het hoofdkantoor en centrale laboratoria. Voor R&D is die kennisvoorraad nog belangrijker dan voor vaste activa. Immers, het fysieke productieproces is deels in gebruiksaanwijzingen van de machines gecodificeerd. Dit verschil is ook een reden waarom de investeringsaandelen in vaste activa in Nederland kleiner zijn dan die van R&D. Het is overigens moeilijk te bewijzen dat die concern-specifieke kennis een belangrijke vestigingsplaatsfactor is.

De vraag komt op of de vestigingen van de Fortune-giganten in elektronica en het Philips-netwerk van concern en toeleveranciers samen, een kennis-cluster vormen die de Nederlandse concurrentiekracht extra versterkt. Dezelfde vraag geldt voor de vestigingen van de buitenlandse chemiereuzen enerzijds en de Nederlandse concerns Shell, Akzo Nobel en DSM anderzijds. Er zijn geen harde aanwijzingen dat dit het geval is. Voor de chemie geldt wel dat de concerns soms op hetzelfde pijpleidingen-netwerk zijn aangesloten, wat een schaalvoordeel geeft op de productiekosten.

[1] Van Shell zijn alleen gegevens over de R&D in Nederland bekend.

Macro-economische doorwerking

We verlaten de directiekamers en richten ons op de macro-economische doorwerking van ondernemingsbeslissingen. R&D-intensieve ondernemingen strijden op een beperkt speelveld, maar de invloed van hun investeringsgedrag strekt zich veel verder uit. Het speelveld is beperkt, want het aantal markten waarop R&D-intensieve bedrijven hun producten verkopen is klein. De markten van elektronica, computers, software, farmacie, chemie, machines en voertuigen dekken 90 procent van alle R&D door de bedrijvensector.

Echter, de uitstraling is groot, want de vragers naar die R&D-intensieve producten komen uit de hele economie. Bijvoorbeeld, elk bedrijf koopt computers en software; ziekenhuizen kopen medicijnen, dieetvoeding en medische apparaten; transportbedrijven kopen vrachtauto's, telecom-ondernemingen satellieten, en luchtvaartmaatschappijen vliegtuigen. Kunststoffen worden door vele bedrijven aangekocht, bijvoorbeeld als verpakkings- en isolatiemateriaal, auto-onderdeel, pijpleiding en kunstvezel.

Door die aankoop van nieuwe componenten of nieuwe machines verbeteren de ondernemingen in de hele economie hun productietechnologie of het geeft hen de kans op hun beurt nieuwe producten te lanceren of op de klant toegesneden producten te leveren. De procestechnologie wordt doelmatiger, aangezien door de nieuwe producten een betere combinatie van productiemiddelen mogelijk wordt. Daarmee is de waarde van het geïntegreerde productiesysteem groter dan de waarde van de som der delen. Dat verschil is groter naarmate de productiemiddelen sterker van elkaar verschillen. Immers, een radicale uitvinding leidt tot een efficiëntere nieuwe combinatie van productiemiddelen vergeleken met een marginale verbetering. Dus, de motor van economische groei bestaat uit twee hoofdonderdelen, te weten het groeitempo van de kennis, oftewel het groeitempo van het aantal producten; en de mate waarin de vernieuwingen een radicaal karakter hebben.

In dit licht kan de huidige verschuiving in nadruk van onderzoek (Research) naar ontwikkeling (Development) door vele R&D-intensieve giganten de mondiale economische groei op lange termijn schaden. Onderzoek is fundamenteler, staat verder van de klant en levert gemiddeld radicalere verbeteringen op dan ontwikkeling. De afgelopen jaren zijn vele R&D-giganten hun R&D-inspanning er op gaan richten om de wensen van hun klanten meteen te vervullen ten koste van onderzoek. Hierdoor neemt de groei van het aantal producten waarschijnlijk toe en dat werkt groeibevorderend (de eerstgenoemde component). Echter, de andere component van de motor van economische groei werkt juist groeivertragend. De wensen van de klant zijn vooral gericht op kleine verbeteringen op de korte termijn, zodat de nieuwe producten weinig verschillen met bestaande. Het gevaar is reëel dat het tweede effect het eerste domineert.

Tenslotte, goede informatie over de economische groei en inflatie is voor beleidsmakers wezenlijk. Het rapport toont aan dat de kans aanwezig is dat de inflatie wordt overschat en de economische groei wordt onderschat. Dit is het gevolg van de tweede component van economische groei: het onderscheidend vermogen tussen producten. Als statistici dat onderscheidend vermogen onderschatten, worden nieuwe producten ten onrechte te sterk beschouwd als vervangers voor bestaande producten. Die kans is niet gering in een economie-cultuur waarin men spreekt over dé consumptie en dé investeringen en waar de economie maximaal verdeeld wordt in enkele tientallen bedrijfstakken. In dat geval levert deze component te weinig bijdrage aan de economische groei. Gegeven de waarde-ontwikkeling van het nationaal inkomen, gaat die onderschatting van de reële groei zitten in een overschatting van de inflatie. Dat is belangrijk voor beleidsmakers, want een foute inflatie geeft ongewenste economische doorwerking, omdat de inflatie een determinant is van sociale uitkeringen en looneisen.

Aangrijpingspunten voor beleid

Welke inzichten op marktwerking biedt dit rapport voor beleidsmakers? Welke mogelijkheden zijn er voor een nationaal mededingings- en overig beleid voor grote R&D-intensieve export-georiënteerde ondernemingen?

Politiek en creativiteit

R&D is creatief en creativiteit geeft producten en processen die nieuw zijn. Dit rapport bespreekt specifieke dilemma's voor beleidsmakers die volgen uit dat nieuwheidsaspect. Die dilemma's zijn geconcentreerd bij de mededingingspolitiek, wettelijke aansprakelijkheid voor onvoorziene risico's, en het maken van standaarden voor producten. De manier waarop overheden hier knopen doorhakken, beïnvloedt volgens het rapport de omvang van de investeringen in R&D.

Nieuwheid geeft dilemma's voor mededingingspolitiek, bij de praktische bepaling van de optimale marktmacht. R&D-intensieve ondernemingen hebben meer marktmacht nodig dan ondernemingen die opereren op markten zonder vernieuwing. Zonder vernieuwing is een markt te definiëren waarop de mededinging betrekking heeft. Dan is geen of weinig marktmacht nodig afhankelijk van de mate van homogeniteit van de producten. R&D-intensieve bedrijven hebben meer marktmacht nodig, want zij moeten uit de winst de R&D-uitgaven financieren. Die R&D-uitgaven zijn op lange termijn gunstig, want ze leiden tot economische groei. Daar staat het korte termijn nadeel tegenover dat consumenten hogere prijzen moeten betalen en dus minder kopen. Dit geeft beleidsmakers een dilemma bij de keuze tussen lange termijn groei en grote marktmacht op de korte termijn.

De onvolledige mededinging wordt gecreëerd met wetten die het intellectuele eigendom beschermen, zoals het patentrecht bij uitvindingen op het terrein van de exacte wetenschappen en het auteursrecht voor software. Dat geeft dilemma's ten aanzien van de omvang van de straf bij overtreding, de lengte van de beschermingsperiode, en de aspecten waarop de bescherming betrekking heeft. Voorbeelden van het laatste zijn of geluid of kleur moeten worden beschermd, en of hetzelfde geldt voor de ontdekking van een gen. Teveel bescherming geeft teveel marktmacht, te weinig remt de particuliere R&D-investeringen. Als de overheid meent dat intellectuele eigendomsrechten te weinig bescherming bieden, kan worden overwogen de R&D-subsidies te verhogen.

Nieuwe producten voor de gezondheidszorg en transportmiddelen kunnen onvoorziene risico's brengen, zoals Softanonkinderen of motoren die na tien jaar blijken te ontploffen. Wie is dan aansprakelijk? Ook dat geeft een dilemma. Als het aanbiedende bedrijf aansprakelijk is, remt dit de investeringen in R&D. Het concern moet enorme verzekeringspremies betalen voordat een nieuw product kan worden gelanceerd. Het verwachte rendement daalt soms beneden het vereiste rendement, en dan heeft het voor een onderneming geen zin in R&D te investeren. Als daarentegen de klanten de risico's dragen, zal het concern wel in R&D investeren, maar het kan tegelijk ook zorgeloos worden, waardoor de maatschappelijke risico's van nieuwe producten onaanvaardbaar worden.

Nieuwe standaards voor producten worden gecreëerd en ook dat geeft een dilemma tussen doelmatigheid in het gebruik, en marktmacht. Nieuwe standaards zijn cruciaal in de informatietechnologie, waar de producten vooral hun waarde krijgen in een systeem waarbij de afzonderlijke producten op elkaar aansluiten, zoals printers en computers, compact discs en afspelers, en software applicaties en besturingsprogramma's. Die onderlinge aansluitingsmogelijkheid kan omvangrijke elektronische netwerken opleveren, zoals bij elektronische post en boekingssystemen van reisbureaus. Enerzijds moeten standaards worden gestimuleerd, want het geeft grote schaalvoordelen en het maakt het systeem veel waardevoller dan de som der delen. Aan de andere kant geeft het veel marktmacht aan de eigenaar van het systeem. Zo kunnen concerns enig verlies accepteren op het besturingsprogramma, maar veel extra winst incasseren op de applicaties. En de eigenaar van een elektronisch netwerk heeft een grote macht tegenover bedrijven die niet op het netwerk zijn aangesloten.

Investeringsinstrumenten

De concurrentie komt mede tot uiting in het investeringsgedrag. Het bestuur van een onderneming neemt belangrijke investeringsbeslissingen bij R&D en vaste activa in de concurrentieslag. Dit rapport vindt als determinanten voor de bepaling van de

De rol van industrieel ontwerp onderschat?

Economen en beleidsmakers onderschatten waarschijnlijk de rol van industrieel ontwerp voor de groei van de welvaart in brede zin in vergelijking met hun aandacht voor R&D. Industrieel ontwerp en R&D zijn beide creatieve activiteiten en als zodanig bestaan er veel overeenkomsten tussen industrieel ontwerp en R&D, zij het met graduele verschillen.

Evenals bij nieuwe producten gebaseerd op R&D, worden jaarlijks vele nieuwe ontwerpen gelanceerd die verschillen van bestaand ontwerp. Maar vergeleken met R&D, vereist industrieel ontwerp minder schaal, want er zijn minder investeringen in apparatuur nodig, terwijl de projecten kleiner zijn. In samenhang hiermee, verschillen de ontwerpen in het algemeen minder van elkaar dan producten die op R&D zijn gebaseerd. Hierdoor is het gemakkelijker een uitspraak te doen over het toekomstig rendement van een industrieel ontwerp dan van een R&D-project.

Echter, voor het grote belang van industrieel ontwerp pleit dat het industrieel ontwerp samengaat en zelfs een voorwaarde kan zijn, om een nieuw op R&D-gebaseerd product tot een succes te maken. In die gevallen kan de invloed van ontwerp op de groei aanzienlijk zijn, omdat design dan het knelpunt is. Bovendien is ontwerp soms een belangrijke concurrentiefactor voor bedrijven die weinig producten voortbrengen die zijn gebaseerd op nieuwe natuurwetenschappelijke inzichten, zoals meubel-, kleding- en speelgoedfabrikanten.

Tenslotte faalt de markt voor industrieel ontwerp door externe effecten, waardoor minder industrieel ontwerp plaatsvindt dan maatschappelijk wenselijk is. Voorbeelden zijn ecologisch verantwoord ontwerp, betere ergonomie en het plezier dat consumenten beleven aan winkelen. In die gevallen is sprake van maatschappelijk nut dat waarschijnlijk niet volledig door de verkoper in de prijs kan worden doorberekend. Bijvoorbeeld, de waarde van het vermijden van rugklachten door ergonomisch verantwoorde stoelen, wordt mogelijk niet voldoende verwerkt in de prijs van de stoel. En mooie etalages vol fraai ontworpen producten levert de winkel geen winst als men er van geniet, maar niet in de winkel koopt.

Er kunnen twee redenen worden bedacht voor de geringere aandacht van economen voor industrieel ontwerp in vergelijking met R&D. Ten eerste wordt aan R&D veel meer uitgegeven dan aan industrieel ontwerp. Maar het gaat niet om de absolute omvang van het bedrag, maar om het belang van een verandering in de uitgaven. Het is niet zeker of meer uitgaven aan R&D meer oplevert dan aan industrieel ontwerp. Ten tweede is R&D vooral gericht op nieuwe professionele apparaten en halffabrikaten, die hogere productiviteit geven. Daarentegen concentreert ontwerp zich op consumenten-welzijn, dat veel moeilijker meetbaar is en daardoor wellicht onderbelicht dreigt te raken.

jaarlijkse investeringsbudgetten aan R&D en vaste activa op concernniveau de netto winst, en het aandeel van de schuld in het eigen vermogen van het concern. Dat is sterker het geval voor investeringen in vaste activa dan voor R&D. Bovendien blijken de R&D-giganten op elkaars investeringen te reageren. Dit empirische gevonden verband duidt er op dat R&D-giganten met elkaar concurreren in een oligopolie. Die reacties zijn frequenter voor R&D dan voor vaste activa.

Dus, beleid gericht op hogere netto winst en een lager aandeel van de schuld in het vermogen stimuleert de investeringen en kan de concurrentie beïnvloeden. Instrumenten die de netto winst vergroten zijn het vennootschapsbelastingtarief en R&D-subsidies. De schuldverhouding kan worden verminderd door informatie-achterstand bij potentiële aandeelhouders vergeleken met de concernleiding te verminderen. Hierdoor wordt de onzekerheid over investeringsprojecten bij de eerstgenoemden minder. Dit leidt tot minder risico-mijdend gedrag van beleggers en daarmee een sterker neiging om aandeelhouder te worden. Hierdoor daalt de schuldverhouding.

Nationale weglekeffecten bij investeringen

Door de R&D-giganten in hun investeringsgedrag op concernniveau te analyseren, komen ook dilemma's naar voren voor nationale beleidsmakers bij investeringsstimulering. Er bestaan namelijk weglekeffecten naar het buitenland, dat wil zeggen dat een deel van de nationale impuls in andere landen zijn positieve uitwerking krijgt. Hierdoor kan de nationale opbrengst kleiner zijn dan de voordelen in de wereld, terwijl de nationale overheid de kosten draagt, bijvoorbeeld in de vorm van hogere belastingen.

Het eerste dilemma volgt uit het verschil in doelstelling van de beleidsmakers en de concerns. Een groot concern probeert succesvol te overleven in de concurrentiestrijd met rivalen in de hele wereld. Een nationale beleidsmaker beoogt de welvaart binnen zijn land te bevorderen over alle ondernemingen en bedrijfstakken heen. Het dilemma ontstaat als volgt. Stel, een nationale overheid slaagt er in de netto winst van een concern te verhogen; het is dan niet zeker dat het concernbestuur die extra winst zal investeren in datzelfde land. Vanuit de optiek van het concern zijn er wellicht andere landen waar een toekomstig hoger rendement te behalen is. Bijvoorbeeld, extra winst in Europa kan vanuit de concern-doelstelling soms beter worden geïnvesteerd in Azië, maar dat strijdt althans in directe zin met het belang dat Europese beleidsmakers moeten behartigen.

Het tweede dilemma volgt uit het gevonden imitatiegedrag bij investeringen. Stel dat het beleid er in slaagt de R&D-investeringen van een nationale gigant te verhogen; dit geeft in eerste instantie een verbetering van de concurrentiepositie van het concern, en daarmee voor het betreffende land. Echter, `buitenlandse' concurrenten antwoorden met een vergroting van hun R&D. Voor kleine landen zijn die weglek-effecten belangrijker dan voor grote. Immers, een klein land heeft vaak maar enkele grote `nationale' R&D-intensieve concerns, terwijl een groot land als de Verenigde Staten de hoofdzetel is van vele giganten. Bij kleine landen zijn bijna alle concurrenten `buitenlanders'. Hiermee wordt een deel van het initiële nationaal voordeel teniet gedaan. Anderzijds neemt de R&D binnen die bedrijfstak op mondiale schaal toe en dat is gunstig voor de groei.

Gebruik van kennis: mededingings- of technologiepolitiek?

Stimuleren van het gebruik van kennis is een pijler van het technologiebeleid, want hierdoor wordt het R&D-budget beter gebruikt. Echter, dit technologiebeleid kan botsen met mededingingsbeleid gericht op voorkomen van verstoring van marktwerking. Dat stelt het beleid voor dilemma's.

De marktwerking wordt niet verstoord als de overheid de productie van universitaire kennis stimuleert of een betere toegang geeft tot die fundamentele kennis. Dat laatste is bijvoorbeeld het geval bij uitwisseling tussen onderzoekers van universiteiten en bedrijven. Dat geldt grotendeels ook voor onderzoeksscholen betaald door bedrijven en overheid. Grotendeels, want de overheid maakt in dit geval wel een keuze tussen terreinen waarop die scholen zich bewegen, en dat is niet geheel marktconform. De marktwerking wordt ook niet verstoord bij samenwerking bij R&D tussen een grote onderneming met zijn toeleveranciers of afnemers. Hierdoor wordt de bedrijfsspecifieke kennis van die ondernemingen beter georganiseerd zonder dat het marktmechanisme wordt verstoord. Daarom is beleid gunstig als het is gericht op intensivering van universitaire research en de samenwerking tussen R&D-giganten en universiteiten, afnemers en toeleveranciers.

R&D-allianties, fusies en overnames geven wél dilemma's aan het beleid. Zij bieden het voordeel dat kennis beter wordt benut. Dit is toe te juichen, omdat het de ontwikkelingskosten verlaagt en de kans op duplicering vermindert. Aan de andere kant kan er teveel marktmacht ontstaan. Bij R&D-allianties is dat het geval indien de samenwerking bij R&D wordt uitgestrekt tot een productiekartel. Een R&D-alliantie brengt nog als extra gevaar dat het ondernemingen in de alliantie uitnodigt op elkaars uitvindingen te wachten en te profiteren van `free rider' winst. In het laatste geval kan een R&D-alliantie minder presteren dan als de aangesloten concerns onafhankelijk en concurrerend met elkaar R&D hadden uitgevoerd. Nationaal beleid kent hier beperkingen, want de allianties en fusies zijn vaak tussen concerns uit verschillende landen.

Vestigingsplaatspolitiek

De weglek-effecten van nationale investeringsimpulsen bij grote R&D-intensieve concerns hebben een tegenhanger: buitenlandse concerns kunnen zich in Nederland vestigen of er de activiteiten uitbreiden als gevolg van impulsen door buitenlandse overheden. Daarom moet naast mededingings- en technologiepolitiek bij R&D-intensieve multinationals ook vestigingsplaatspolitiek worden betrokken. De vestigingsplaats-instrumenten werken voor zowel nationale als buitenlandse concerns.

Nederland wordt als locatie aantrekkelijker door onderwijs in het algemeen, infrastructurele netwerken, instrumenten die de specifieke kennis versterken -waaronder die van de grote vijf concerns-, Europese economische integratie, behoud van politieke stabiliteit, en een laag vennootschapsbelastingtarief. Het laatste instrument is vooral effectief voor de elektronica- en computerindustrie. Het belastingtarief is zowel aantrekkelijk als gevaarlijk. Lagere vennootschapsbelastingtarieven zijn op twee manieren gunstig, want zij bevorderen de netto winst en daarmee de investeringen van een concern, en zij maken een nationale locatie aantrekkelijk ten opzichte van concurrerende buitenlandse locaties. Het gevaar van de inzet van het belasting-wapen is de beleidsconcurrentie, bestaande uit tegenacties van buitenlandse regeringen.

Belangrijkste conclusies

De meest originele bijdrage van dit rapport is dat R&D-intensieve giganten uit de Fortune Global 500 lijst sterk op elkaar's R&D-uitgaven reageren. Die `race' gebeurt in de elektronica- en computerindustrie in een volgorde die samenhangt met de bedrijfskolom. Chemie-giganten reageren simultaan. Een reden kan zijn dat chemie-giganten waarschijnlijk minder gespecialiseerd zijn in hun producten dan de grote concerns in de elektronica. Voor het beleid betekent dit dat een R&D-impuls bij de leiders in informatie technologie uitwaaiert over de elektronica-giganten in de hele wereld. Die leiders zijn vooral gevestigd in de Verenigde Staten en Japan. Voor de chemie levert een R&D-impuls een vermenigvuldiger-effect door de simultane reactie. In Europa heeft een eventuele R&D-impuls directe effecten, aangezien veel R&D-giganten hun hoofdkwartier in Europa hebben.

Een andere conclusie is dat op het `micro-niveau' van de R&D-giganten de investeringen in R&D en vaste activa deels verklaard kunnen worden uit hun vertraagde netto winst en het aandeel van de schuld in het vermogen. Die invloed is groter voor vaste activa dan voor R&D. Nationaal beleid dat aangrijpt bij deze determinanten lekt mogelijk voor een deel weg over de nationale grens.

Voor R&D-giganten zijn verschillende vormen van beleid relevant. Mededingingsbeleid is daar een van. Daarnaast worden genoemd:

- technologiebeleid, waaronder R&D-impulsen en instrumenten die het gebruik van kennis stimuleren, zonder dat de marktwerking wordt geschaad
- wetgeving ten aanzien van intellectuele eigendom en wettelijke aansprakelijkheid
- instrumenten die de vestigingsplaats beïnvloeden (met name interessant voor nationale beleidsmakers).

Dilemma's overheersen bij mededingingsbeleid. Dit blijkt bij de praktische bepaling van de optimale marktmacht, de waardering voor R&D-allianties, mega-fusies, en elektronica-standaarden. Aangezien het speelveld groter is dan de nationale grenzen is een internationaal gecoördineerd beleid zinvol.

Tenslotte laat het rapport zien dat de verschuiving van de nadruk op Research naar Development bij vele R&D-giganten, de economische groei op lange termijn kan schaden.

1. Introduction

In most developed countries, big research-intensive companies dominate business research and development (R&D). Accordingly, these firms are important players in the process of technical change and long-run economic growth. Indeed, according to the theory of endogenous economic growth, new technology is -in addition to market structure and internationalization- one of the three cornerstones of a triangle that determines the potential for long-term growth. In 1991, Grossman and Helpman described formally and consistently that imperfect competition is needed to generate profits needed to fund the development of new technology, which leads to economic growth. As many nations demand the new developed products, the question of internationalization follows. Markusen (1995), for instance, analyzed theoretically the choice between international trade of the new products and investment in foreign nations in order to manufacture near the customer.

However, the theories of economic growth, trade and foreign investment are abstract. They describe a stylized economy, which seems far away from the daily problems which worry businessmen and policy makers. Still, both businessmen and policy makers can benefit from the consistent theoretical reasoning, because theory describes the indirect consequences and feed-backs of their decisions, up till the macro-economic level and the international pattern of trade. This report attempts to narrow the gap between theory and practice a little.

In order to make this report appealing to both businessmen and policy makers, it takes the perspective of the boards of directors of well-known R&D-giants, when they decide on the amount and international distribution of investments in R&D and fixed assets. An original contribution of this report is the exploration of the question in how far giants respond to each others' investments in R&D and fixed assets. In order to carry out the analysis, a unique database has been built. This database only contains information drawn from public sources. Moreover, key concepts in the theory of endogenous growth and internationalization are illustrated with empirical evidence of these enterprises on policy-relevant issues of competition and internationalization.

The report organizes questions on market mechanism, investment in new technology, internationalization and economic development as follows. Section 2 highlights the markets of R&D-intensive enterprises, it shows that R&D is concentrated in big companies, and it mentions the role of company specific know-how and economies of scale in the laboratories as determinants of this concentration-rate. This section also explains that the Netherlands is no exception in this respect. Furthermore, it presents the Dutch R&D-scoreboard. Due to these observations, the further analysis is restricted to big corporations in the markets of information technology, health care and chemicals. With these three sectors, a considerable share of the world's business research is covered with a small number of enterprises.

Two important challenges that face the boards of directors in order to survive in the competitive game are how much and where they will invest. Section 3 explores the investment decisions on R&D and fixed assets on company level. The approach is rather pragmatical. The section starts with the simple strategy of investments which are proportional to sales, and discusses if last years' financial performance has an additional impact. Moreover, the influence of interest rates and reorganization in R&D-departments around 1990 are explored. Next, oligopolistic behavior is addressed. Do giants in information technology, and drugs and chemicals respond to each others' investments? And if so, who are investment leaders and who imitate? After the R&D-expenditures are determined by the boards, the R&D-managers must use their budgets best. Section 3.3 assesses the methods they apply in order to achieve this.

Section 4 addresses the international distribution of investments in R&D and fixed assets. This pattern also determines the international trade in goods. Hence, this section has as subject internationalization. First, this section addresses the determinants of the international distribution of fixed assets and R&D. The focus is on the determinants which are relevant for the investments of big non-European corporations in Europe. Moreover, the location decision of the five 'Dutch' giants is discussed. The emphasis is on the Netherlands as country to invest for 'Dutch' and 'foreign' companies.

Section 5 leaves the board-rooms of the directors. The corporations battle on a bounded playing field. But the impact of their investment behavior extends far beyond this field. New R&D-intensive products are often more radical than existing products and therefore they can accelerate economic development. Therefore this section discusses briefly the impact of the number of products on macro-economic development according to the theory of endogenous growth. The arguments are supported with empirical evidence. Also, this section gives reasons why the shift in emphasis from research to development of many R&D-intensive corporations may hurt future macro-economic growth. Furthermore it throws some light on possible measurement errors, which lead to an underrating of productivity growth and overrating of inflation.

As an extra, section 6 is added. It explores the role of industrial design. The development of a new design also takes launching costs and it is a product as well. Yet, design attracts far less the attention of policy makers than R&D. This section discusses similarities and differences of design compared with R&D, and poses the question if the role of design is underrated.

If possible, the report derives conclusions, which are relevant for policy makers. The approach of competing multinational enterprises as actors is useful for policy makers, because their point of view differs from policy makers. Policy makers often silently assume rivalling countries instead of competing multinational enterprises. It appears from bench-mark analyses, which compare nations with national indicators, such as labor productivity or investments in R&D and fixed assets. Also, the ratio of national to world export prices is such a measure, which is used as a predictor of national exports.

The approach of acting boards highlights instruments on competition-, technology and location policies, which are underrated from the point of view of competing nations. For example, on competition- and technology policies, the benefits of common policies among countries can easily be understood from the view of competing enterprises and not if another country is regarded as a rival or an example. Also, on internationalization, the approach of competing enterprises gives grasp on the Dutch rise of re-exports, some of the shift from manufacturing to the services sector in the Netherlands, and the use of policy instruments, such as investments in infra-structure, tax rates and European economic integration.

Also, EIM Small Business Research and Consultancy investigated[2] market structure, innovation and exports on a micro-economic foundation. Both studies are complements, because they study different groups of enterprises. This report focuses on big multinational companies from many countries which create new technology. In turn, EIM analyzed medium sized Dutch enterprises in their early stages of internationalization, which follow technology. This study illustrates the international market mechanism with strategic investment behavior, whereas the EIM stresses the home market as source of export performance. Their complementarity gives their value, because their conclusions on a national competition and technology policy may differ. Together they lead to conclusions on the importance and range of national policy instruments in an increasing globalizing economy.

[2] V. Dijken, Prince (EIM) 1997.

2. Markets of big R&D-intensive companies

Abstract

This section highlights the markets of R&D-intensive enterprises. Companies which supply new products in information technology, health and advanced mechanics are mainly product-innovators, because their products embody the new technology. Producers which are specialists in raw material processing focus their research especially on process-innovation, with sometimes much attention for the environment. This type of innovation can only be traded as a license.

Moreover, this section shows that R&D is concentrated in big companies, and it mentions the role of company specific know-how and economies of scale in the laboratories as determinants of this concentration-rate.

Due to these observations, the further analysis is restricted to big corporations in the markets of information technology, health care and chemicals. Then, a considerable share of the world's business research is covered with a small number of enterprises.

This section also presents the R&D-scoreboard of the companies which spend most on R&D in the Netherlands. During 1990-1995 the total business enterprise expenditures rose nominally with 3,5 percent annually. The individual companies show a wide variety in R&D-growth around this average. Most spectacular is Fokker's fall due to its bankruptcy. Also, the nominal R&D-expenditures of Philips, DSM, Gist, Delft Instruments and Gasunie dropped. In contrast, Axxicon, BESI, ASM Lithography, Draka and Thomassen International have annually increased their nominal research-investments with ten percent and more. Baan is the champion: it increased its R&D-expenditures with 65 percent per year during 1991-1996.

2.1 Markets and concentration of research

Introduction

Creation stimulates economic development. Especially new products which are based on scientific research and experiments can improve welfare. Because they differ often considerably from existing products, their application changes process-technologies, leading to cheaper production. Firms which apply the new devices can be found anywhere in the economy. Especially products in the field of information and communication technologies are pervasive, as they are bought by firms in all economic sectors. Moreover, new products increase welfare directly, when consumers buy them.

This section has several aims. First, it explores the markets of the enterprises, who supply the new products based on scientific research and experimental development. Moreover, R&D is a heterogeneous activity, so this section addresses which types of research are dominant in each market. Third, company-size is related to market power. Thus, this section shows the size of the companies which carry out R&D, and it mentions the causes for this size. Fourth, the launch of a new product requires high costs. Companies only invest in product development if they expect sufficient returns in the future. Therefore, this section investigates the link between the R&D-intensity of an industry and its profit rate. Finally, a conclusion is drawn for the rest of this report.

Markets supplied by R&D-intensive companies

R&D-activities are concentrated in a few markets of the economy. Table 2.1 shows that 95 percent of the R&D-expenditures by the business sector in the USA, Japan, Germany, France and the Netherlands together is spent by companies which compete in markets of information technology, health care, new materials, advanced mechanics and extraction and processing of raw materials. Information technology has high technological opportunities. It appears from the greatest share in R&D among the industries: almost 40 percent of all R&D-expenditures is spent on information and communication technology. Advanced mechanics are second, with an emphasis on cars and aerospace. This allocation holds probably for all rich countries, because the distributions of the R&D-expenditures are very similar for the USA, Japan, Germany, France and the Netherlands.

Table 2.1 Where companies spend R&D on

	Total[f]	USA[e] 1993	JAP[a] 1991	GER[a] 1989	FRA[a] 1990	NET[c] 1993
	%					
Information technology	37	37.7	40.1	32.7	31.2	35.7
Electronics	18	26.6	35.0	26.6	25.2	28.3
Computers	11	15.3	NA[d]	3.3	3.6	4.0
Telecommunication, software	3	4.4	1.9	1.2	1.4	2.5
(Scientific) instruments	5	7.6	3.2	1.6	1.0	0.9
Health/Biotechnology	13	15.2	8.5	6.3	10.1	19.5
Drugs	11	13.5	6.1	5.5	7.4	10.4
Food	2	1.6	2.3	0.7	1.8	5.3
Agriculture	0	0.1	0.1	0.1	1.0	3.8
New materials	12	11.0	12.6	17.3	11.6	20.2
Chemicals, fibers	10	9.9	9.9	15.8	9.3	15.1
Plastics, rubber	2	1.1	2.7	1.5	2.3	5.1
New mechanics	27	26.4	21.7	37.2	35.5	12.0
Aircraft	7	7.8	0	7.8	19.0	NA
Cars	14	15.0	13.3	16.1	11.5	5.7
Machines	5	3.1	7.0	10.8	4.1	3.6
Metal products	1	0.5	1.4	2.5	0.9	2.7
Better extraction	6	5.7	8.5	3.2	6.4	11.1
Basic metals	2	0.5	5.3	1.2	1.9	3.8
Mining, oil products	2	3.2	1.3	1.2	2.4	3.9
Energy/water, paper	2	2.0	1.9	0.8	2.1	2.2
Rest	5	4.0	8.6	3.3	5.2	1.5
Total	100	100	100	100	100	100
Amount $ billion[b]	-	122	50.7	21.8	14.4	2.3

[a] Source: OECD, Basic Science and Technology Statistics, 1993 edition, tables 9; electronics: rows 3+4; data-processing: row 20; telecommunication, software: rows 36+37; instruments: row 19; drugs: row 7; food: row 23; agriculture: row 1; plastics, rubber: row 25; chemicals: row 6; aircraft: row 10; cars: row 11; machines: row 21; metal products: row 17; basic metals: rows 15+16; mining, oil products: rows 2+8; energy/water, paper: rows 28+33; Other: not mentioned items (NB The `total'-row in the OECD-publication is larger than the sum of the listed items). We have assumed that commercial and engineering services belong to software.
[b] National currencies expressed in ppp$. For the USA we used the figure from OECD, STI-indicators, which is lower than the total figure from our US-source.
[c] Excluded basic research. Aircraft is included in the car industry. CBS, Speur- en Ontwikkelingswerk 1993, tabel 15, last column.
[d] Secret, spread over electronics (row 4) and machines (row 21).
[e] Source: US Department of Commerce, Survey of Current Business, June 1995, tables 9.1 and 9.2. The data are not fully comparable with those of the OECD, but the OECD does not provide data at a large level of aggregation for the USA.
[f] Computed by weighing the columns with total R&D-spending of the listed countries. The NA items have been guestimated.

Table 2.2 shows that firms in biotechnology, electronics, computers, drugs and aerospace invest heavily in research. The most important biotechnology companies in the USA spend about 40 percent of their revenues on R&D! In sharp contrast, most firms in services industries and construction lack direct profitable prospects of scientific research in the exact and natural sciences. They improve their performance when they apply new technology embodied in product-innovations.

The importance of R&D has increased during the last two decades. Table 2.2 shows that companies have spent more on R&D out of their revenues in almost all industries. This increase is striking in the markets of information technology, health care and biotechnology, which provided the best technical opportunities. Only the R&D-intensity of the aircraft industry in the OECD shows a decline.

Table 2.2 OECD's business enterprise R&D/production ratio[a]

	1973	1992
	%	
Information technology		
Electronics[c]	6.9	9.0
Computers	10.3	11.0
Scientific Instruments	3.9	6.4
Health/Biotechnology		
Biotechnology[d]	NA	> 40.0
Drugs	6.3	11.9
Food	1.6	2.5
New materials		
Industrial chemicals	2.3	3.3
Plastics	1.1	1.2
New mechanics		
Aerospace	17.9	12.4
Cars	2.4	3.4
Machines[b]	2.3	2.3
Metal products	0.4	0.7
Better extraction		
Basic metals	0.4	0.8
Oil refining	0.9	1.0
Paper	0.3	0.3

[a] Business Enterprise R&D/Gross production in the OECD. Source: OECD, 1995, Annex Table 8.5, p. 162-163
[b] Electrical and non-electrical machinery, un-weighted average
[c] `Communication equipment and semiconductors'.
[d] These companies are (between brackets R&D/sales ratio): Genetics Institute (83%), Biogen (65%), Immunex (54%), Chiron(45%), Genentech (41%). Business Week 3/7/1995, p.39

Table 2.3 *Goals of business research (Netherlands, Applied R&D, 1993)*[a]

	Product innovation		Process innovation		Share product innovation
	Total[a]	of which Software[c]	Total[a]	of which: Anti-pollution[d]	
	NLG million				%
Information technology	1187	300-500	374	11.7	76
Electronics	1066		305		
Computers	22		30		
Telecommunication, software	74[b]		23[b]		
Instruments	25		16		
Health/Biotechnology	713		211		77
Drugs	398		102		
Food	154		87	8.3	
Agriculture	161		22		
New materials	561		421		57
Chemicals, Fibers	414		318	55.9	
Plastics, Rubber	147		103		
New mechanics	458		125	3.9	78
Aircraft, Cars	254		27		
Machines	109		61		
Metal products	95		37		
Better extraction	103		448	33.4	19
Basic metals	23		39	2.6	
Oil products	31		154	2.6	
Mining	1		191	8.2	
Energy/water, paper	48		61	20.0	
Other	26		26	5.8	
Total	3048	900	1605	119	65

[a] Not listed as process-innovation, still very important: ISO quality- as well as environment standards. Source data shown: CBS, Speur- en Ontwikkelingswerk in Nederland 1993, tabel 15. Not listed fl 300 mln `not classifiable'. `Other'= building materials, construction, textiles, shipbuilding

[b] Assumed as equal to `Not classifiable'.

[c] We assume that all R&D aimed at original software belongs to product-innovation.

- `Total' derived as follows: 18% of R&D-employment by enterprises refers to software (source: CBS, R&D en software-onderzoek bij bedrijven in Nederland 1995, Voorburg, oktober 1995). If we assume that this share also holds for the spending on non-basic R&D (= NLG 4995 = 3048 + 1605 + 300 mln in 1993), then holds for `total' = 0,18 * 4995 = 900.
- Information: We provide a range, because the indicators contradict. The lowest estimate: 36% of R&D-employment on software works in the information industry (CBS, R&D en software-onderzoek, § 4.4 Kerntabel), hence: 0,36*900=325. On the other hand, Philips suggests that 55% of its R&D is spent on software (R&D-director Bulthuis in de Ingenieur, 17/2/1994). Moreover the CBS-enquiry indicates a large amount spent by the services industry (excluding the software-houses) on R&D on software (15% in total). This amount exceeds the category total of `other'. Both last-mentioned reasons make that NLG 500 mln can be considered as a maximum.

[d] Figures 1992: CBS, Milieukosten van Bedrijven 1992, tabel 10. `Overige metaalindustrie' divided over information and new mechanics according to 75:25 (=distribution process-R&D), `Other': non listed industries.

Product- and process innovation

Applied Research & Development is directly aimed at product- or process innovation. Table 2.3 provides evidence for the Netherlands, but we expect that the general conclusions hold for all rich countries.

Product-innovation is the launch of new products on the market. Buyers are 1) other firms anywhere in the economy, who use the new devices in order to produce cheaper or make better qualities, and 2) consumers who directly increase their welfare. Product-innovation dominates in information technology, advanced mechanics and health/biotechnology. In these fields companies shape new market niches, with as consequence the shrinking of the market shares of the incumbent competitors. Companies in the information technology industries carry out research in fields like electronic highways, digital TV, system architecture and optical reading. Not independently, a considerable part of their R&D is spent on original software. Generally, the information technology industries shift the emphasis of their research from single products, based on physics, to electronic process-technology and compatible systems, which need the application of software[3].

Also, enterprises which produce advanced structures, like aircraft, satellites, rockets, space-shuttles, cars, new industrial machines or packaging, mainly target their R&D at the launch of new products.

On top of that product-innovation dominates in biotechnology and food-processing. Researchers study building-blocks of living material, like genetics, protein engineering, bacteria, viruses and enzymes; molecular engineering of detergents or materials which affect our taste- and smell-organs; or with the composition of diet-foods, like the type of fatty acid, starch or eatable fibers.

Process-innovation targets at the improvement of the company's own production process. Hence, this type of innovation is not traded on markets in the shape of a tangible product. A process-innovation can only be traded as a license. Process-innovation dominates in extraction and processing of raw materials, such as crude oil or metal ores, and deals with the improvement of material-saving with minimal pollution of the company's own plants and crackers. These industries mainly compete on the reduction of processing-costs, for the products are almost homogeneous, such as naphtha or steel. Still the raw materials processing industries sometimes launch new products, such as lead-free petrol and seamless tins.

[3] See e.g. Philips' R&D-director Schuurmans in NRC 31/8/1996.

Product- and process-innovation are both important in the chemical-science based industries[4], where they have almost equal weight. New materials are product-innovations by definition. They are based on the design of new molecule-structures of material, which we cannot find in nature, like blends, composites or polymers. Process-innovation is important too, because many basic chemicals are fabricated in intricate processes, where low production cost is a key-issue.

Since the `polluter pays' principle, research at improving the environment is important for all industries. First of all it holds for the industries which specialize in process-innovation, such as the new material- and raw material handling industries. Some examples are given above. In the Netherlands 7,5% (Table 2.3 =119/1605) of all process-innovation is focused at less pollution. Many product-innovations contribute to less pollution too, like water-based paints, energy saving lamps, CFC-free refrigerators, light-weight cars, noise-sparse engines, recyclable packaging.

Why is research concentrated in big companies?

Measures of the degree of competition are the number of suppliers and their size, because they are indicators of market power. Table 2.4 shows that R&D-activities are concentrated in the USA. The top ten R&D-spenders carry out 23 percent of all business R&D. These companies are General Motors, Ford, IBM, AT&T, Hewlett Packard, Motorola, Boeing, Digital, Chrysler and Johnson & Johnson. And the 900 enterprises with the highest expenditures on R&D, have a share of almost 70 percent.

Also in Germany R&D is concentrated in a few companies. The top eight corporations, namely the Daimler Benz Group, Siemens, Volkswagen, Hoechst, Bayer, BASF, Thyssen and Bosch have a share of about sixty percent of Germany's total R&D

[4] The chemical sciences are rather intricate as regards the link between its fields of economic application, as is illustrated with the table below.

Scientific studies → Field of economic application↓	Biotechnology	Molecular	Structure	Design	Process Technology	Catalysis
Health	xxx	xxx	x	x	x	
Food		xxx	xxx	xxx		
New materials		x	xxx	xxx	x	
Energy	x	x			xxx	xxx
Raw materials	x	x			xxx	xxx
Environment	xxx	xxx	xxx		xxx	xxx

xxx: very important; x: moderate; blank: not important. Source: OCV, 1995, p.28-34

In conclusion, all chemical studies, excepted design, are important for the environment. Process-technology and catalysis focus on processing of raw materials, including energy. Biotechnology and molecular studies are more important for health and food products. Structure and design are most relevant for new materials.

in the business sector[5].

Section 3.2.2 shows that the top 20 companies in electronics and computers have a share of 56% in R&D in these fields in the North America, Europe and Japan, and the top 20 pharmaceutical companies a share of 63%; the top 17 chemical giants have a share of 30%.

Table 2.4 USA's concentrated research (1994)

	R&D-amount	R&D-share
	$ mln	%
Total enterprises[b]	123.8	100
- Top 10 companies[a]	28.2	23
- Next 890[a]	56.2	45
- Lowest R&D-spenders[c]	39.4	32

[a] Business Week's Annual R&D-survey (3/7/1995, p.38-40) includes 900 companies.
[b] OECD, Main STI-indicators, 1995/1
[c] This figure also includes the statistical difference between the `official' R&D-expenditures and Business Week's total composite. Computed as total enterprises - (top 10 + next 890).

There are several reasons why R&D is concentrated in a few companies. First, the high costs of scientific instruments and their short depreciation period create economies of scale in the laboratories, which supports this concentration of R&D in big companies.

Second, much agglomerated know-how and experience is tacit and locked in the company. This type of know-how is a specific asset for a company, because rivals have no access to it. If a company exploits a larger stock of firm specific knowledge than a competitor, it can develop a new product cheaper, under the assumption that both firms utilize other inputs equally efficient. The reason is that know-how is an input in the production process of a new product. This gives big companies, which dispose of large amounts of not-codified know-how, an advantage in competition against small- and medium sized rivals. The managers themselves also regard their firm's tacit knowledge as its key resource, which must be generated and used as widely and efficiently as possible[6]. Firm-specific knowledge also favors big companies because they have more information and experience on the clients' wants than smaller competitors. This gives giants more certainty and therefore they will sooner invest in R&D or advertise a new product[7].

Third, only big companies can fund and bear the risks of main new R&D-intensive

[5] CPB (1997)

[6] The Economist 24/6/1995

[7] See for instance, the beer-industry, where big players maintain market shares, because they already have large stocks of well-established brands (Thomas (1995)).

projects, because they can spread the risks across many projects. Section 3.3 discusses the first two arguments in detail in their relation with the so-called knowledge production function and the related costs of product development.

Are R&D-intensity and profit rates linked?

Table 2.5 Profitability

	Returns to assets 1994[a]	Profit margin 1971-1990[c]
Information technology	%	%
Electronics	2.0	.
Computers	2.3	19
Communication equipment	.	26
Electrical goods	.	11
Telecommunications	2.8	.
Scientific Instruments	4.1	.
Health/Biotechnology		
Drugs	10.5	51
Food	5.5	14
Beverages	7.0	47
Personal care	6.6	.
New materials		
Chemicals	3.1	27[d]
New mechanics		
Aircraft	3.5	19
Cars	1.8	15
Machinery	2.0	11
Better extraction		
Basic metals	-0.6	28[b]
Oil refineries	3.5	6
Total manufacturing		22
Total business sector	0.9	

[a] Fortune 7/8/1995. Computed as profits (net) to assets (=balance total) p.F-27. This gives very slight differences with the `return on assets' on p.F-29. We used this indicator, because we can compute the agreeing measure in our own data-set.
[b] =0,75 steel + 0,25 non-ferrous metals.
[c] All enterprises, hence no constraint on firm size. OECD, Working Party no.1, September 1995, Based on 14 OECD-countries. Annex table 2.2 (= price/marginal costs - 1)*100
[d] Industrial chemical.s

Companies only invest in product development if they get sufficient future returns on their investments in a new product. Therefore, we expect that the profitability of an industry depends on its R&D-intensity. Below, this relation is tested in a cross-section across industries. The R&D/production ratio in Table 2.2 is the explaining variable. The ranking of R&D-intensities across the industries is robust, because the ranking of 1973 is almost the same as in 1973.

Profitability is measured with two indicators, listed in Table 2.5. The first one is the returns to total assets in 1994 of the Fortune global-500. The other indicator is the profit margin during 1971-1990 of all enterprises in 14 OECD-countries.

Regression-analysis shows that no link is found between the R&D-intensities and both profitability indicators. Probably, this result is due to the neglect of other determinants, such as the impact of tangible capital, the debt/asset ratios and the degree of competition[8].

Still, some observations give a hint of relation between profitability and R&D-intensity. First, the pharmaceutical industry, which is very R&D-intensive and which also spends on clinical experiments and registration, enjoys the highest profit rates. Second, all R&D-intensive manufacturing industries (excepted steel) have higher returns than the returns of the total of the Fortune 500 giants of 0.9 percent, which includes corporations in the services sector, who hardly spend on R&D.

Finally, it strikes that the food, beverages and personal care industries have high returns. These industries spend only a few percents of their revenues on R&D. However, the launch of their new products can take large amounts of advertising in their company-image. Also, these expenditures are partly investment, which get a return. This suggestion is supported by the fact that the companies with the highest value of their name belong predominantly to the food- and beverage industries as Table 2.6 mentions.

In conclusion, R&D-intensive activities in the business sector are concentrated in the supply of a few markets of the manufacturing industry and in a small number of enterprises, which are predominantly big. However, the customers on these markets belong to many industries.

The remainder of this report uses these findings. It restricts the analysis to corporations in the markets of information technology, health care and chemicals. Then, a considerable share of the world's business research is covered with a small number of enterprises.

[8] A separate study is needed to investigate the relation between profitability and R&D-intensity adequately. The number of observations (=industries) should be increased, and omitted determinants, such as tangible capital intensity and intangible investments (like the costs of registration and advertising), should be added. This research has not been carried out mainly due to time constraints.

Table 2.6 Top-10 in Corporate Image (1995)[a]

Value of the name	$ bn
Coca-Cola	39.1
Marlboro	38.7
IBM	17.1
Motorola	15.3
Hewlett-Packard	13.2
Microsoft	11.7
Kodak	11.6
Budweiser	11.4
Kellog's	11.0
Nescafé	10.3

[a] Financial World quoted in WirtschaftsWoche 21.3.1996, p. 127.

2.2 The Dutch R&D-scoreboard

This section elaborates on the former one and assesses to which extent business research in the Netherlands is concentrated. Moreover, this section is more detailed, as it shows the names of the enterprises which dominate Dutch research and their R&D-expenditures.

Dutch R&D activities in the business sector are concentrated in a few markets and in a small number of firms. First, R&D is concentrated in a few markets of the manufacturing industry. Companies supply the same markets as firms in other highly developed countries, for the correlation of the Dutch industrial distribution of R&D expenditures with those of the other nations in Table 2.1 is high. Still, some differences point to the pattern of specialization of Dutch production[9]. Enterprises in the Netherlands invest relatively much on R&D in health products, new materials and products of the raw material processing-industries, while this country is a net exporter of these products. In contrast, Dutch R&D-expenditures are relatively low in new mechanics, while the Netherlands is a net importer of cars, aerospace and machinery equipment. Electronics does not fit into this picture: due to the Philips' main laboratory, the Netherlands spends relatively much on R&D in electronics, while this country has a trade deficit in electronic commodities.

Second, also Dutch business enterprise R&D is concentrated in a small number of firms, which are often big. Table 2.7 shows that 2 thousand firms in manufacturing have own

[9] For 1995 the Dutch export/import ratio is for 1) health products: food: 2.3 and agriculture 1.5; 2) new materials: chemicals 1.5; 3) processing: oil refining: 3.9. For metal manufacturing this ratio equals 0.75 (Source: CPB, Lange Reeksen 1950-1997). The export/import ratio of the electronic industry equals 0.72 (excluded re-exports) (CPB, Division Industry).

R&D-personnel, which implies that one out of three companies carried out R&D in 1994[10]. Of the companies with R&D-personnel, 1.7 thousand have a share of about five percent, while the top five enterprises have a share of 47 percent. The concentration of R&D in the top-five is falling gradually, because this share is declining as Graph 2.1 shows. This is partly due to former Philips' divisions with own laboratories which since 1969 were taken over or continued as independent companies. Examples are Duphar, HSA, Philips Telecommunication bought by AT&T, Neways Electronics and ASM Lithography. In the non-manufacturing business sectors the share of companies with R&D is much lower than in manufacturing, because only almost 600 non-manufacturing enterprises carried out research and experimental development in 1994.

Table 2.7 Dutch concentrated business research (1994)[a]

	R&D-firms	R&D-share
	number	%
Manufacturing	2010	82
– Top five	5	47
– Next 345[b]	345	30
– Lowest R&D-spenders	1660	5
Non-manufacturing	585	18

[a] Source CBS (1996). Total number of enterprises: p.123; Share top 5: p.40.
[b] Bartelsman c.s (1996) p. 54. The top 347 firms have a share between 90-95% of Dutch manufacturing R&D in 1993.

Which enterprises have the highest R&D-investments in this country? Table 2.8 lists the Dutch companies with more than NLG 25 million R&D-expenditures and Table 2.9 shows the foreign ones with more than NLG 10 million. Some enterprises are shown of which no data are available, but which probably meet these criterions. These expenditures need not be consistent with those published by Statistics Netherlands in Table 2.7.

[10] In 1994 there were 6,7 thousand enterprises in the manufacturing industry (source: CBS, Statistisch Zakboek 1997, p.165, firms with less than 20 employees).

Graph 2.1 Share (%) of top five companies in Dutch business enterprise R&D[a]

[a] Source CBS. Exact data: 1969-1990 in Minne (1995), p. 166; 1994: CBS (1996), p.40, Other ratios provided by CBS: 1991: 55%, 1992: 54%, 1993 52%.

Table 2.8 Top Dutch-based companies on the Dutch R&D-scoreboard[b,c]

Company	Product	Amount 1995	Growth 1990-1995
		NLG million	% annually
Philips	electronics, software	1400	-2[d] (-7)
Shell	chemicals	539 ('94)	5
Akzo Nobel	chemicals, drugs	453	4[a]
Unilever	food, personal care	350	5
DSM	chemicals	310	-5
Nedcar	cars	278	9
Océ	copiers	186	1
KPN	telecommunication	135	4
Hoogovens	metals	110	2
Stork	machines, engineering	108 ('96)	1
ASM Lithography	integrated circuits equipment	85	20 ('91-'95)
Gist	bio technology	84	-2
Baan	software	57	65 ('91-'96)
ASM International	semi-conductor equipment	58 ('96)	7 ('90-'96)
Campina Melkunie	food, bio-technology	44	3 ('91-'95)
Delft Instruments	scientific instruments	43	-2
Draka	cables for communication	37	29
Avebe	food, bio-technology	31	1
Pharma Bio-Research	drugs	30	NA
Laboratory Blood Transfusion	bio-technology	30	5
Thomassen International	energy equipment	27	10 ('93-'95)
Gasunie	natural gas	27	-1
Neways Electronics	electronic components	NA	
Heineken	beer, soft drink	NA	
Nutricia	clinical food	NA	
CSM Purac	bio-technology	NA	
Runners-up			
BESI	semi-conductor equipment	20 ('96)	50 ('93-'96)
Axxicon	matrices for CDs	4 ('96)	45 ('94-'96)
Shake-out			
Fokker	aircraft	125 ('90)	-100

[a] Growth based of company, because R&D-employment in the Netherlands developed proportionally as concern R&D-employment during 1990-1995.
[b] Nominal amounts. The figures are company data, excepted the top 5. They overestimate the expenditures in the Netherlands a bit, because some companies have some development centers in foreign countries.
[c] Only companies with more than NLG 25 million in this country
[d] Provided by Philips as a comment on an earlier version of this report. The levels of the expenditures on which this rise is based, are secret. The data base, which is the source of this report, provides an annual decline of 7% during this period. Hence, the level of the expenditures in 1995 in this table contains probably some error.

Table 2.9 Top foreigners on the Dutch R&D-scoreboard 1995[a]

Company	Product	Nominal amount	Employment
		NLG million	number
Solvay/Duphar	drugs	185	600
Lucent AT&T/Networks Systems	telecommunication	160	700
Paccar/DAF	cars	123	384
Dow Chemical	chemicals	60	221
Ericsson	wireless communication, software	50	270
Petrofina/Sigma	paint	41	200
Cap Gemini/Volmac	software	35 ('92)	180 ('92)
Cordis/Johnson&Johnson	medical instruments	32	42
Sandoz/S&G Seeds	seeds	30	211
Stork Wärtsilä	energy equipment	26	144
Medtronic Bakken research	medical instruments	23	125
Hoechst Holland	chemicals	22	100
Sara Lee/ DE	food	16	100
AT&T/NCR	computers	16	90
Hercules/Tastemaker	bio-technology	13	67
Yamanouchi	drugs	12	58
Medtronic/Vitratron	medical instruments	11	60
Yokogawa	medical instruments	10	28
Buderus/Nefit Fasto	energy equipment	10	30
IBM	software	NA	NA
Thomson/HSA	military equipment	NA	NA
Zeneca/vanderHave	seeds	NA	NA
General Electric	chemicals	NA	NA

[a] Foreign companies which spend at least NLG 10 million on R&D in the Netherlands. As far as data are available, the R&D-expenditures and R&D-employment are listed. NA: not available.

Total investments on business R&D in the Netherlands rose from NLG 5808 million in 1990 to NLG 6855 million in 1995. Probably the expenditures stabilized in 1996[11]. The average annual growth rate of 3.5 percent during 1990-1995 is hardly representative for the individual enterprises.

For example, Dutch-based companies show a wide dispersion in growth rates according to Table 2.8. Most spectacular is Fokker's fall due to its bankruptcy, although Stork has taken over some research activities. Also, nominal R&D-investments by Philips, DSM, Gist, Delft Instruments and Gasunie fell. Still, some stars are shining. For instance, BESI, Axxicon, ASM Lithography, Draka and Thomassen International have annually increased their nominal research-investments with ten percent and more. Baan is the champion in R&D-growth: its research-expenditures surged from NLG 5 million in 1991 to NLG 65 million in 1996. The top foreign companies in Table 2.9 are mainly

[11] CBS, Statistisch Bulletin 4, 30/1/1997

original Dutch companies, which have been taken over by foreign enterprises. For most of them, no data are available for the period 1990-1995.

In conclusion, business enterprise R&D in the Netherlands is concentrated in big corporations, just as in the USA and Germany. However, the share of the top-five companies is gradually falling, to 47 percent in 1994. The total rise in R&D-expenditures of 3.5 percent on average per year during 1990-1995 is not representative for the individual companies. The largest drop was almost 100 percent, while one company increased its research expenditures with 65 percent per year.

3. Investment behavior

Abstract

This section explores determinants of the budgets of R&D and fixed assets of big multinational enterprises. It shows that more net profits and a lower debt/assets ratio in particular stimulate investment in fixed assets. For R&D-expenditures this holds less. Also, the companies respond frequently to each others' investments. This holds more for R&D-expenditures than for fixed assets. Giants in information technology respond sequentially to the R&D-investments of rivals along the value chain. Therefore, specialists in consumer electronics are mainly investment followers. Hitachi, Intel and Compaq as investment leaders in R&D as well as fixde assets. In chemicals, the giants respond simultaneously. They mutual gear up each others' R&D-expenses. Pharmaceutical companies lead the R&D-investments of chemical specialists. These outcomes give dilemmas for national policy makers, because a part of original investment stimulants leaks to other nations.

Given the R&D-budgets, R&D-managers must use them best. This section discusses instruments to increase in-house efficiency and ways to enhance the exploitation of external know-how and experience. In particular, R&D-alliances and mergers and take-overs aimed at a better exploitation of know-how, give policy dilemmas.

On top of that, this section discusses major dilemmas for competition policy caused by R&D. The properties `creation' and `knowledge' of R&D-intensive products give policy dilemmas on the right balance between market failure and economic growth, on responsibility for unforeseeable health and safety risks, and on new standards in information technology. The amount of R&D-investment and the degree of competition depend on the way how these dilemmas are solved in practice.

3.1 Introduction

Among the main decisions of the boards of directors of R&D-intensive companies are the amounts of investment in R&D and fixed assets, because both have an impact on the future competitive position of the company among rivals. With R&D-investments, the company develops new products which are different from the products of competitors, which are already on the market. Investments in fixed assets increase the production capacity and innovate process technology, because the newest vintage of machines is most efficient. More capacity and cheaper manufacturing improve the competitive position too.

This section explores empirically investment behavior in R&D and fixed assets of giants in R&D. The approach is rather pragmatical. Section 3.2.1 starts with the simple strategy of investments which are proportional to sales, and discusses if last years' financial performance has an additional impact. Moreover, the influence of interest rates and reorganizations in R&D-departments in 1990 are explored. Next, section 3.2.2 addresses oligopolistic behavior. Do giants in information technology, and drugs and chemicals respond to each others' investments? And if so, do they respond sequentially or simultaneously? And who are investment leaders and who followers in a sequence? It is here that the original contribution of this section lies.

Company data base

For the purpose of this report a company data base has been set up, which contains information of about three hundred R&D-intensive enterprises. The enterprises with headquarters outside the Netherlands are mainly drawn from the Fortune list of the biggest 500 companies in the world[1]. On top of that, Dutch-based enterprises with research activities have been added.

The data base contains on company level, expenditures on R&D and fixed assets, net profits, sales, the debt/asset ratio[2], the number of R&D-workers and total company employment for a period, preferably since 1983, as far as these data are available. Also, for each company information on its strategic investment behavior has been gathered. Moreover, this base contains the corresponding data on the establishments of foreign R&D-intensive corporations in the Netherlands.

All information is drawn from public sources, such as Annual Reports, magazines and newspapers. Compared to official statistics, this has both advantages and disadvantages. Advantages are that 1) the analysis is less abstract than the anonymous data from official statistics, because specific enterprises can be identified; 2) the outcomes can be checked at the companies. Disadvantages are that[1] the data are not corrected for changes in division structure, because of e.g. mergers and take overs;[2] the definitions of the companies might be different from those of the official statistical offices.

[1] *Fortune, August 7, 1995*
[2] *Most often computed as complement of shareholders' equity/total assets*

The reasons for this pragmatic approach rather than the testing a proper forward looking theory are twofold. First, many theories assume perfect foresight of the boards or they assume a R&D-game where the prize is known beforehand. Ideally, companies only invest if the discounted returns in the future exceed today's sacrifices. This implies that the board of directors must have a correct outlook on (the probability distribution of) the revenues and the costs, the interest and inflation rates across a long time horizon. The revenues depend on future behavior of rivals and the prospected needs of clients. Of course, such well informed enterprises are an assumption. In practice, boards are bounded in their rationality, because they do not dispose of this information. Only occasionally, enterprises publish minimal needed rates of return for an investment in fixed assets. This implies that in these cases the board has an empirical outlook on the future. However, required minimal returns on investments on R&D are not known. This may imply that the boards have a far less specific future outlook on the returns of R&D-projects.

Second, testing of the forward looking theory is impossible due to a lack of consistent data on expectations of the determinants of investments. It silently supports the statement that boards lack perfect foresight.

After the R&D-expenditures are determined by the boards, the R&D-managers must exploit their budgets optimally. Section 3.3 discusses the methods which they apply in order to achieve this. Guide is the knowledge production function, which is the key to the endogenous growth theory. Both sections end with consequences for policy makers. Finally, the amount of R&D-investments are also determined by the way dilemmas related to creativity are solved in practice. This is the topic of section 3.4.

3.2 Strategic investments in R&D and fixed assets

3.2.1 Own financial performance as determinant

This section discusses to which extent investments in R&D and fixed assets of a corporation can be explained by lagged net profits and the debt/assets ratio additional to the simple strategy of investments which are proportional to sales. Moreover, the influence of interest rates and reorganizations in R&D-departments around 1990 are explored[12].

The exploration starts with the assumption that corporations pursue the *simple strategy* of proportional investments to their sales. The question is if companies deviate from this strategy if a determinant changes. The specification of the investment relation, which is tested, is the same for R&D and fixed assets, according to:

[12] This report provides a different approach as well as extensions to Minne (1995). Minne explains national R&D-investments with national macro-economic variables such as GDP and a national profit indicator, the so-called "other income". The disadvantage of this approach is that economic sectors which hardly carry out R&D, such as services, construction and agriculture, contribute to the 'explanation' of national R&D. Also, the 1995-report neglects the impact of the rest of the world on national R&D-expenditures.

In contrast, this report explores the profits and sales of the companies as determinants of their own R&D, which is a more plausible hypothesis. And the international dimension is taken into account by means of the reponse to the investments of rivals, who often have headquarters in foreign countries (section 3.2.2).

Extensions are at first the explanation of investments in fixed assets, and second the exploration of the debt/assets ratio and R&D-reorganizations as determiants of investments in R&D and fixed assets.

(1) $I/S_i = c + \alpha_1 P/S_{i,-j} + \alpha_2 dt + \alpha_3 D/TA_{i,-j} + \alpha_4 ds + \alpha_5 r_{-j} + \alpha_6 t$[13]

where:

I/S_i R&D respectively fixed investment to sales ratio of company i (%)

c constant

Determinants

Indicators financial performance company

P/S_i Net profits to sales ratio of company i (%)

dt Critical profit dummy for P/S<0 respectively P/S<2%

D/TA_i Debt/assets ratio of company i (%)

Other

ds Dummy indicating strategy shift R&D, since 1990

r Interest rate (%)

t Trend

j Time lag 1,2 years (lead:-1 for P/S and r)

The hypotheses are: $\alpha_1>0$, $\alpha_2<0$, $\alpha_3<0$, $\alpha_4<0$, $\alpha_5<0$. The simple strategy is valid if all coefficients are zero, except the constant. The relation has been explored by means of regression analysis of corporations, pooled by industry. Table 3.1 lists the industries and the companies (between brackets the regression period).

Each regression has been carried out with one and two years time lag of the explanatory variables, except the strategy dummy and the leading variables. For an elaborate explanation is referred to the annex, which provides many regression outcomes. By way of illustration, the results for R&D and fixed assets with the best fit, while the signs of the coefficients meet the theoretical prediction, are shown in Tables 3.2 and 3.3 respectively. In Table 3.2 the electronic component and the drug industries are omitted, compared with Table 3.3. For these industries, no determinant could be found with the expected sign. The economic interpretation of each determinant is discussed below. The measure of fit (R^2) is largely determined by company specific dummies in order to adjust for inter-company differences in the levels of the investment/sales ratio.

[13] Each company (except one) has a specific dummy to correct for structural differences between firms in their investment-ratios. This specification has also the advantage that heteroskedasticity is reduced by dividing the variables with historical trends by the sales.

Table 3.1 Companies in the regression equations (between brackets regression period)[a]

Electronics	
Consumer goods	Matsushita (78-94), Sony (77-95), Philips (77-95), Sanyo (86-95)
Professional goods	Hitachi (78-95), Siemens (78-94), Toshiba (78-95), NEC (78-95), Ericsson (78-94), Honeywell (87-94), Bosch (78-94)
Electronic components	Motorola (83-94), Intel (78-94), Texas Instruments (78-94)
Computers	IBM (83-94), Canon (84-94), Digital (85-94), Compaq (85-94), AT&T (85-94), Apple (85-94), Ricoh (91-95)
Software	Getronics (89-95), Sun Microsystems (86-95), Unisys (88-94)
Instruments	Fuji (84-94), Delft Instruments (87-94), Medtronic (84-95), Océ (78-95)
Drugs	Astra (83-94), Merck Sharp and Dohme (84-94), Roche (84-94), Glaxo Wellcome (78-94), Abbott (85-94)
Food/Soap	Gist (77-94), Unilever (79-94), Avebe (86-94), Procter & Gamble (78-94), Henkel (81-94)
Chemicals	Hoechst (78-94), BASF (78-94), Bayer (79-94), Dow Chemical (78-94), Akzo Nobel (78-94), Solvay (84-94), Avery (78-94), Hercules (83-94), Nalco (78-94), 3M (82-94), DSM (77-95)

[a] It concerns the R&D-equations, the corresponding data in the fixed assets equations contain almost the same companies.

Table 3.2 Determinants R&D (financial variables lagged 2 years)[a]

	Debt/assets	Profit	Critical profits [<2%]	Interest	Strategy shift	R^2
Electronics						
Consumer goods	-0.08 (2.4)[d]					55
Professional goods	-0.32 (11.3)	0.01 (0.2)	-0.26 (1.0)			87
Computers		0.06 (3.0)		-0.60 (2.8)[b]		92
Software		0.02 (0.3)			-2.05 (3.4)	97
Instruments	-0.04 (1.5)	0.11 (1.9)		-0.13 (1.3)[c]		86
Food/Soap		0.05 (1.9)		-0.04 (1.3)[c]		94
Chemicals	-0.03 (2.4)	0.09 (3.0)	-0.57 (2.6)			78

[a] t ratios between brackets
[b] real OECD rate after addition of a trend (see the annex)
[c] nominal OECD rate
[d] lag 1 year

Table 3.3 Determinants of fixed assets (financial determinants 1 year lagged)[a]

	Debt/assets	Profit	Critical profits [<2%]	Interest	R^2
Electronics					
Consumer goods	-0.16 (2.7)	0.27 (2.6)		-0.02 (0.2)[b]	56
Professional goods	-0.11 (2.6)	0.03 (0.3)	-1.41 (3.7)		56
Components	-0.19 (2.2)	0.12 (1.6)		-0.48 (1.7)[b]	71
Computers	-0.06 (1.6)	0.14 (2.5)	-0.29 (0.6)		77
Software	-0.10 (2.6)	0.02 (0.4)			55
Instruments	-0.07 (1.2)	0.03 (0.2)	-5.37 (2.6)		43
Drugs	-0.37 (2.6)	0.77 (4.9)			63
Food/Soap	-0.02 (0.7)	0.10 (1.1)	-3.93 (5.0)		66
Chemicals	-0.07 (1.9)	0.32 (3.5)		-0.25 (1.8)[b]	51

[a] t ratios between brackets

[b] real OECD interest, after addition of a trend (see the annex).

Does a higher *debt/assets ratio* lead to a drop in investments later? A positive answer is expected because a company takes risks sooner if it has more risk-taking capital at its disposal. A low debt/assets ratio reflects this ability to bear risks. Moreover, a higher debt/assets ratio coincides with a low capacity to borrow and a high interest burden. It turns out that a higher debt/assets ratio leads to a drop later in fixed investment and to a less extent in R&D. In all industries, except food/detergent, this impact is (almost) significant for fixed investments. In four industries, the debt/assets ratio influences R&D negatively. For example, a drop of 1%-point of the debt/assets ratio in professional electronics gives a fall of 0.32%-point in the R&D to sales ratio.

Do higher net *profits* stimulate investments *later*? Several arguments plead for it. First the company has more non-distributed profits available. And, the firm itself can better assess the information-advantage on the prospects of investment projects compared to external financiers, who will sooner avert risks. A drop in profits leads in many industries to a fall in investments indeed. In the chemical industry, for example, a present dollar rise in profits, leads next year to a $ 0.32 rise of investment in fixed assets and $0.09 more expenditures on research the year thereafter. The impact on marginal fixed investments is stronger compared with R&D-expenditures. The results indicate that the impact of profits on R&D is less pervasive than on fixed assets.

This analysis assumed that enterprises respond continuously to a shift in profits. However, it is imaginable that companies radically change their investment strategy when their profits cross a certain *critical value*. Are they getting more reluctant to invest when the profits are below this critical value? This is not the case in most industries, but there are important exceptions. If profits are lower than 2% of the sales, the R&D/sales ratio of the chemical industry is 0.57%-points lower than on the other side of the critical value. Furthermore, the ratio of fixed investments to sales in professional electronics is

1.4%-points lower if profits are below the critical value. For scientific instruments and food/detergent these ratios drop 5.4%- and 3.9%-points if there are insufficient profits. No significant impact is found at the critical value loss/profits, possibly due to too few observations.

Profits and critical profits are correlated by definition. This relation causes that the addition of the critical variable leads to a drop of the estimated impact of the profits. Take, for example, R&D in the chemical industry with the time lag of 2 years. A drop in profits of one dollar leads to a drop of $ 0.14 if the critical value of 2% is omitted. Inclusive this variable, one dollar less profits discourages R&D with only $ 0.09. This is the reason why the fixed investment equation with the best fit of professional electronics implies that net profits hardly have an impact, unless they cross the critical value.

Does a higher *interest rate* leads to a drop in investments later? A reason for `yes' is that higher capital costs discourage investment. Four interest rates are tested: nominal and real interest rate in the OECD. Also a time trend has been added in order to correct for a trend in the interest rate. A significant negative impact of the interest rate is hardly found in the regression-analysis.

Many companies tell in their Annual Reviews and interviews that they have *shifted* their *R&D-strategy* considerably since about 1990, because of several reasons. First by a shift of emphasis from fundamental research to development. Also, R&D-intensive companies saved on R&D-costs by a better exploitation of external know how. Examples are more collaboration, less duplication, cost-sharing with competitors, better utilizing fundamental knowledge in universities, and the organization of teams of employees from research, manufacturing and marketing to clear obstacles to product development and the use of computers. Moreover, the health industry (including drugs and medical instruments) has set up databases with patient-records in order to boost the effectiveness of drugs and other medical treatments[14] [15]. Does this strategy shift have led to a structural decline in the R&D/sales ratio, additional to the other variables? No evidence is found for a confirmation, excepted in the software-industry.

The foregoing assumed that the boards of directors only use information of the past in order to decide. Possibly, however, they know something of the future revenues of an investment project. The question of *foresight* been explored by considering a time horizon of one year: are next year's profits and interest rates determinants of this year's investment? Hence, it supposes that the enterprises can predict the profits from a new project and the interest rate. From this, they derive their investments. The regression

[14] Business Week 27/3/1995

[15] There have been savings on design because of by means of reducing designer-staff, outsourcing to independent designers (in co-production) and investment in Computer Aided Design (Business Week 5/6/1995).

results provide no evidence for an affirmative answer.

Investments by important Dutch companies

The conclusions for the R&D-giants, also apply for the Dutch companies, which spend most on R&D after the five "Dutch" big corporations. However, there are two differences compared with the foreign companies. First, the debt/asset ratio is a far less convincing determinant. Second, some impact of the interest rate is found (only for the nominal Dutch rate). The tables list the regressions with the best fit, while the signs of the coefficients meet the theoretical prediction. T-ratios are shown within brackets.

Investments in fixed assets

	Period	Debt/assets	Profit	Dutch nominal interest	R^2
	explaining variables lagged 1 year				
Océ	78-96	-0.2 (2.5)	0.3 (1.1)	.	48
KPN	90-95	.	4.8 (2.8)	.	66
Hoogovens	83-95	.	0.5 (1.7)	.	20
Stork	79-96	.	0.3 (2.6)	-0.2 (1.6)	49
Gist	78-95	-0.4 (4.8)	0.1 (0.6)	-0.2 (0.6)	77
Delft Instruments	89-95	-0,4 (1.8)	.	-1.9 (1.4)	49
Avebe	86-95	-0.2 (0.8)	1.5 (2.5)	-2.8 (1.4)	51

R&D-subsidies per company are not available. Instead, the impact of Dutch national government R&D-funding (scaled by GDP, lagged with 1 year) is explored[1]. Therefore the magnitude of this coefficient is difficult to interpret, but the sign is expected to be positive. A significant impact can hardly be found. It should be noted that the R&D-subsidies and the Dutch nominal interest rate are spuriously correlated. Therefore, it is vague which of the two is the real determinant.

R&D-expenditures

	Period	Debt/assets	Profit	Dutch nominal interest	Subsidy	R^2
	financial variables lagged 2 years, subsidy 1 year					
Océ	79-96	.	0.7 (1.4)	.	11.9 (1.6)	43
KPN	91-95	.	0.2 (5.0)	-0.02 (0.8)	.	97
Hoogovens[a]	83-95	.	0.1 (2.3)	-0.20 (1.3)	.	71
Stork	80-96	.	0.1 (2.9)	-0.01 (0.2)	7.4 (5.1)	85
Gist	78-95	.	0.02 (0.6)	-0.07 (0.8)	5.2 (2.4)	53
Delft Instruments	88-95	-0.1 (2.4)	.	.	19.9 (3.9)	79
Avebe	87-95	.	.	.	.	.

[a] Including a dummy since 1990 to correct for another way of R&D-registration.

[1] Source OECD, STI-indicators, 1996/2, Table 25 times Table 35.

The outcomes *across industries* differ, but robust conclusions on these differences are not allowed due to the few observations. A striking outcome is that the debt/assets ratio is the only determinant which significantly contributes to the explanation of R&D in consumer and professional electronics. Furthermore, according to the outcomes, makers of electronic components and drugs pursue the simple strategy of a constant R&D to sales ratio.

In conclusion, generally companies do not pursue the simple strategy that they invest a constant share of their sales in R&D and fixed assets. Most firms take at least one financial variable into account which leads them to deviate from this simple strategy. In particular, the company's own debt/assets ratio and net profits are significant investment determinants. A shift in a determinant leads after one year to a change in fixed investments and after two years to a change in R&D. The impacts of the debt/assets ratio and net profits are more pervasive and significant on investments in fixed assets than in R&D. This appears from a comparison between Tables 3.2 and 3.3. No additional significant impact with the expected sign is found for the interest rates and the reorganizations in the research laboratories since 1990.

3.2.2 Do companies respond to each other's investments?

Section 3.2.1 showed that the boards of directors let their investment decisions determine by their company's past financial performance. Do they also regard their near rivals' investment as a determinant of their own investments? And if so, who are the investment leaders? This section explores these questions for giants in information technology, and drugs and chemicals.

There are several arguments which plead for a response to each other's investments. First, in oligopoly, companies watch and respond to each other. In a technological race, companies cannot stay behind competitors in R&D-investment because otherwise they take the risk to be pushed out of future markets. Therefore they respond to each other's research plans. For instance, former Shell's research-director Beckers remarks: 'the companies watch each other accurately. ... If Philips drops in R&D, it is because all companies in that industry fall and they join in.' Philips' research-director Schuurmans adds that he has always in his mind: 'What is the competitor doing?'[16]. Also, companies may respond to each others' fixed investment in order to avoid cost disadvantages and capacity shortages, which might lead to a deterioration of their competitive advantage later.

For research, there are two additional reasons to follow rivals. A company needs to absorb the new inventions of its near competitors and suppliers when they have intensified their research efforts, in order to avoid being driven out of the market. The absorption requires more own spending on R&D. Second, it is much more difficult to

[16] Source NRC 31/8/1996, section Wetenschap & Onderwijs (translated from Dutch)

give an estimate of the required profitability on a R&D-project than on a fixed investment project. Then, a R&D-strategy which uses rivals as examples is an option. However, the norms of the leader remain in doubt.

More precisely, this section deals with the following questions. First, to which extent does the addition of last year's investments of near rivals contribute to the explanation of a company's expenditures on R&D and fixed assets? Second, there are more motives to follow research efforts than to respond to fixed investments, while only the oligopoly argument leads to a response to investment in fixed assets. Therefore, we ask whether R&D-expenditures are more followed than investments in fixed assets? Third, game theory discerns two types of investment response, namely sequential and simultaneous response[17]. In which industries dominates sequential and in which simultaneous response? And who are the leaders in expenditures on fixed assets and R&D respective-ly? Fourth, what is the ranking of leadership if fixed assets and research are combined? Fifth, are big 'Dutch' companies leaders or followers?

Method

In order to find the answers, we start with the main regression result of the former section: the investment to sales ratios of a corporation can be partly explained by its lagged profits and debt/assets ratio. Therefore, for each company equation (1) in section 3.2.1 is regressed with these determinants[18]. The R&D- respectively fixed assets equations are computed with a time lag of 2 years respectively 1 year of these explaining variables[19]. Next, the *basic equation* per company is defined as the one with net profits and the debt/assets ratio as far as a variable has the plausible sign: $\alpha_1>0$, $\alpha_2<0$. Then, investments by near competitors with a lag of 1 year are added successively to this basic equation. If the sign of these investments are positive and t-ratio > 1.6, the result is considered to be significant. The regressions per company are available on request.

In this way, for each pair of companies, their mutual response is statistically derived. The response is *simultaneous* if for both companies hold that their last year's investments has a positive significant (t-ratio > 1.6) impact on present investments of the other. In this case, both rivals gear up (or down) each others' investments. A simultaneous response is marked with two '+'s in a matrix which contains all possible pairs.

[17] See e.g. Aoki and Prusa (1997)

[18] Hence, $\alpha_i=0$ for i=2,4,5,6. The corresponding explaining variables had no significant impact. These variables are not tried out again, because there are not many years of observation per company, which limits the number of explanatory variables.

[19] These lag structures give the best results in the annex

Table 3.4 *Information technology: Giants' investments in R&D and fixed assets (1993)*

	R&D[a]	Fixed assets[a]
	PPP$ million[b]	
Electronic components		
Motorola	1,521	2,187
Intel	970	1,933
Texas Instruments	590	730
Computers		
IBM	4,431	3,232
AT&T[d]	3,111	4,142
Digital	1,530	529
Apple	665	213
Canon	565	825
Compaq	169	301
Professional electronics		
Siemens	3,622	2,282
Hitachi	2,718	3,337
Toshiba	1,693	1,926
NEC	1,492	1,400
Ericsson	1,111	387
Bosch	1,055	739
Honeywell	337	232
Consumer electronics		
Matsushita	2,181	1,677
Philips	1,595	1,209
Sony	1,259	1,454
Sanyo	464	356
Total 20 companies	31,079	29,091
Total N-America, Japan, Europe[c]	55,538	

[a] Source: Annual Reviews
[b] Source translation national currencies in Annual Reviews to PPP$: OECD, STI-indicators 1996/1, Annex C, p.72
[c] Source: OECD, STI-indicators 1996/1; sum of Japan, North America and EU: (% of BERD performed in electrical/electronics industry (table 39) * BERD in million current PPP$ (table 22)) + (% of BERD performed in office machinery and computer industry (table 40) * BERD in million current PPP$ (table 22)).
[d] AT&T is included in computers, because AT&T is the main rival of IBM.

A company is *leader* of the two, if its last year's investments has a positive significant impact on present investments of its rival, whereas this is not the case for the reverse relation (marked with a 'X' in the matrix of pairs). A *sequence* of leaders is derived by reshuffling the rows and columns of the original matrix to one which approximates best a recursive matrix (the least number of 'X's above the diagonal). This latter matrix provides the sequence of leadership.

'No response' is the case if the response is neither simultaneous nor sequential, assigned as an empty cell in the matrix.

Information technology

Table 3.4 shows in the first column the twenty corporations in the sample. Together these 20 companies have a share of 56 percent of R&D-expenditures on electronics and computers in North America, Europe and Japan. This figure confirms the concentration of R&D in big corporations. Also, it indicates that the analysis, which follows, is rather representative for the whole information technology industry in the OECD. Table 3.4 also shows that the board of directors of companies in electronics and computers spend even more on R&D than on fixed assets. In 1993, the twenty companies together spent $ 31 billion on R&D and $ 29 billion on fixed assets.

The companies in Table 3.4 are classified according to their key activity: electronic components, computers, professional goods and consumer electronics. Together, these four industries form a stylized value chain. Electronic components are the basic material in computers, and professional and consumer equipment. In turn, computers are a main capital input in order to produce final electronic goods. Equipment bought by the business sector is an investment; if households are the clients, it is consumption. The value chain is important in electronics, because the devices must be mutual compatible in order to assemble them in a next production stage. This requires standardization. The value chain of electronic devices has a consequence for R&D. Component makers generate the fundamental know-how and basic components; the final equipment producers must absorb this know-how, in order to use the components as inputs in their products.

Tables 3.5 and 3.6 present the response-matrices for investments in fixed assets and R&D in electronics and computers.

It appears that the giants respond frequently to the investments of rivals and they do it mainly sequentially. For fixed assets as well as R&D the sequential response is significantly higher than simultaneous response[20]. Often, imitation-behavior explains investments more than a company's own past financial performance. This follows from a comparison between the R^2-measures of the basic strategy and the equation with the added investments of a rival. Generally, the addition of the investments of rivals hardly disturbs the estimated impact of a company's own financial performance in the basic strategy.

The corporations respond significantly more to R&D than to fixed assets[21], which indicates that the arguments in favor of R&D-response outweigh those of fixed assets.

[20] The test statistic of a difference between 2 averages, which has been applied, is derived from Mood & Graybill, Introduction to the theory of statistics, 2nd Edition, p. 306 equation (6) and p. 263, equation (3). This statistic is:
$z=(p_1-p_2)/\text{sqrt}[\{n_1\ p_1\ (1-p_1) + n_2\ p_2\ (1-p_2)\}/\{(n_1+n_2-2)\}/\ \{n_1\ n_2\ /\ (n_1 + n_2)\}]$, where p_i (i=1,2) denote the occurrency rates, which are based on the response frequences. These rates are defined as the number of occurrences as share of the maximal possible response (=number of possible pairs). The number of occurrences takes the number of 'X'-cells and half the number of '+'-cells. The number of possible pairs n_i (i=1,2) equals the number of cells below the diagonal in the R&D-response matrix respectively the fixed assets matrix.

Response-frequencies (see Tables 3.5 and 3.6)

	Fixed assets	R&D
	frequency	
Sequential	49	65
Simultaneous	5	28
Maximal possible response	190	190

The difference between sequential and simultaneous response in fixed assets is significant, because z>2. Proof: $n_1=n_2=190$ (=20*20 companies - 20 diagonal cells). The occurrency rate of sequential response equals $p_1=0.26$ (=49/190) and of simultaneous response $p_2=0.03$ (=5/190). Thus: z=6.7 > 2 → significant.
The significance between sequential and simultaneous response in R&D is significant, because z>2. The occurrency rate of sequential response equals $p_1=0.34$ (=65/190) and of simultaneous response $p_2=0.15$ (=28/190). Thus: z=4.4 > 2 → significant.

[21] According to the test statistic of a difference between two averages, the difference between the response to R&D and fixed assets is significant, because z>2. Proof: $n_1=n_2=190$. The response rate in R&D respectively fixed assets equal $p_1=0.49$ (=93/190) and $p_2=0.28$ (=54/190). Thus: z=4.3 > 2 → significant.

Table 3.5 Response investment fixed assets in information technology[a]

	Leader																			
Follower	Co	In	Mo	Hi	AT	IBM	Di	Ca	Ap	To	Ne	Bo	Sa	Ma	Si	Ph	So	TI	Ho	Er
Compaq																				
Intel	X								X											
Motorola	X								X											
Hitachi			X																	+
AT&T																		X		
IBM		X	X																	
Digital																X				
Canon														X			X			
Apple	X			X						X				X						
Toshiba	X	X	X	X				X						+						
NEC			X												+					
Bosch							X				X					+				
Sanyo			X																	
Matsushita				X						+		X	X							
Siemens				X				X		X	+			X						
Philips				X		X				X	X	+			X				+	
Sony												X	X	X	X	X				
Texas I			X				X													
Honeywell					X		X									+				
Ericsson	X		X	+										X					X	

[a] +: simultaneous response; X: sequential response; blank: no response

The sequence of leadership in fixed assets follows from the first column in Table 3.5. For companies in electronics (without the computer specialists listed in Table 3.1), the ranking in leadership is unambiguous. The 'X'-cells are all below the diagonal, which implies that the companies on top of the list are leaders, because they directly and indirectly determine the expenditures of the companies further in the sequence. Intel and Motorola are the leaders. Their fixed investments are not determined by other companies, but their purchases of machinery and plants are imitated by rivals. Both companies are specialists of the basic material of information technology: semiconductors and other electronic components. On top of that, Motorola is the world's largest provider of wireless communication equipment. Hitachi, the world's biggest company in electronics, is third. The specialists in consumer electronics are followers, in the sequence Sanyo, Matsushita, Philips, and Sony.

The computer companies neither lead nor follow each other's fixed assets, because all common cells are empty. Compaq, the world's largest supplier of personal computers, is an important leader for the electronic industry. As it leads Intel, the number one in semiconductors for personal computers, Motorola, Apple, Toshiba and Ericsson. Apple's investment turns out to be interesting, because it leads Intel and Motorola.

Table 3.6 R&D-response in information technology[a]

	Leader																			
Follower	Er	Hi	In	TI	To	Si	Co	Ca	AT	Ap	IBM	Ne	Sa	Mo	So	Ma	Ph	Bo	Ho	Di
Ericsson														+				+	+	
Hitachi	X												+	+		+		+		
Intel				+																
Texas I			+										X		+					
Toshiba		X	X					+				+			+	+			+	
Siemens				X									X				+			
Compaq				X													X			
Canon	X	X			+							+				+			X	
AT&T					X	X		X				+				+	X			
Apple							X		X											+
IBM					X											X				
NEC		X			+	X	X	+	+	X						+	+			
Sanyo	X	+			X					X		X		X		+		+		
Motorola	+	+			X	X	X		X	X	X	X				+		+		+
Sony		X	X	+	+							X								
Matsushita	X	+	X	X	+	X		+	+	X		+	+	+	X			+		
Philips		X	X		X	+		X				+			X	X				
Bosch	+	+			X	X			X	X		X	+	+		+				+
Honeywell	+	X			+					X		X	X	X				X		
Digital	X						X		X	+				+		X		+		

[a] +: simultaneous response; X: sequential response; blank: no response

Table 3.6 presents the sequence of leadership in R&D. For electronic companies, excepted Sanyo, the ranking is also robust, because again all 'X'-cells are below the diagonal. Ericsson and Intel emerge as R&D-leaders for they do not follow other companies. Ericsson jumps out, as it is the only company which leads Hitachi's R&D. The component maker Texas Instruments is high on the list as well. The consumer electronics specialists are followers. Sanyo is also a net follower, because it follows five companies and leads three ones.

The computer companies respond moderately to each other's research efforts: 5 times leadership occurs out of 30 possible cases. It is noteworthy that IBM -the biggest spender on R&D- is no leader for rival computer producers! The impact of computer companies on Motorola is strong.

Table 3.7 How many times a leader and follower ?[a]

	Fixed Assets Lead	Follow	Lead minus Follow	R&D Lead	Follow	Lead minus Follow
	frequency					
Electronic components						
Motorola	7	2	+5	2	7	−5
Intel	2	2	0	4	0	+4
Texas Instruments	1	2	−1	3	1	+2
Computers						
IBM	1	2	−1	1	2	−1
AT&T	1	1	0	4	4	0
Digital	3	1	+2	0	4	−4
Apple	2	4	−2	6	2	+4
Canon	2	2	0	2	3	−1
Compaq	5	0	+5	4	2	+2
Professional goods						
Siemens	2	4	−2	5	2	+3
Hitachi	5	1	+4	6	1	+5
Toshiba	3	5	−2	6	2	+4
NEC	2	1	+1	5	4	+1
Ericsson	0	4	−4	5	0	+5
Bosch	2	2	0	1	5	−4
Honeywell	1	2	−2	1	6	−5
Consumer goods						
Matsushita	5	3	+2	3	6	−3
Philips	2	5	−3	2	6	−4
Sony	1	5	−4	2	3	−1
Sanyo	2	1	+1	3	5	−2
Total	49	49		65	65	

[a] Derived from Tables 3.5 and 3.6.

Hitachi, Intel and Compaq are the leaders if the outcomes for fixed assets and R&D are combined as Table 3.7 shows. Also, Motorola, Toshiba, Apple and Matsushita are leaders, who are mainly responsible for diffusion of the spill-overs across the companies. The reason is that they lead most frequent R&D and fixed assets, because their sum of the lead-columns in Table 3.7 is highest. In contrast, IBM, Texas Instruments, and Digital hardly encourage other companies to invest, because their sum is lowest among the enterprises. However, these companies are not main followers either. Sony, Philips, Honeywell and Bosch are real followers, because they considerably follow the investment expenditures of other companies, while they hardly lead them. The results for Ericsson are not consistent. This company is a follower in fixed investment, while it is R&D-leader.

This outcome derived in a statistical way, supports the idea that for giants in information technology sequential investment models in game theory are valid. Moreover, this sequence corresponds with the value chain with knowledge generating producers of components and knowledge absorbers of the makers of final equipment described above. According to Table 3.7, the makers of basic materials -components- are net leaders indeed, because Intel is an undoubted leader, while Motorola and Texas Instruments each neither net lead or follow (the sum of the net leadership in fixed assets and R&D is almost zero). They directly have an impact on the investments by the makers of consumer goods. See for example, the impact of Intel's research on Sony, Matsushita and Philips. Moreover, Hitachi also supplies basic commodities and it has a direct impact on investments of consumer good companies.

These leaders also have an indirect impact, because they affect other professional good suppliers, who in turn have an impact on the investments in the consumer good industry. For example, Hitachi leads NEC's R&D, who in turn leads R&D by Sony a year later, and consequently Sony's research stimulates Philips to invest a year after that.

There is no feedback, because according to Tables 3.5 and 3.6, the producers of consumer electronics do not lead Intel, Motorola and Texas Instruments (excepted Sanyo which seems to lead research of Texas Instruments).

The giants hardly respond simultaneously to their expenses on fixed assets. The simultaneous R&D-response is concentrated at Matsushita, Bosch and Toshiba. Consequently, these companies have been important players, who gear up (or down) R&D-waves. It is striking that computer makers are underrepresented in the gearing up process; IBM is even not involved.

There is little evidence for a relation between the size of R&D-expenditures and leadership. The heaviest investors in R&D -IBM, Siemens and AT&T- are no leaders, whereas leader Intel invested only US$ 1 billion in R&D.

Philips is the only Dutch-based company on the Fortune global 500-list in information technology. The outcome fits into the picture. As a maker of consumer electronics, Philips is a net follower of investments in research and fixed assets.

Three battling giants in food and personal care

The food- and personal care industries are not explored for leadership and imitation due to too little enterprises in the data base. The fiercest rivals on this playing field are Unilever, Henkel, and Procter & Gamble. The charts show their investment intensities in R&D and fixed assets[1].

Chart R&D intensity

Chart Intensity investment fixed assets

The development of the R&D-expenditures of the three corporations are highly linked. No clear leader can be discerned. The correspondence between the developments of fixed investments is much lower, just as companies in information technology and chemicals. The developments strike less than the levels: Unilever's investment intensities are much lower than of its nearest rivals.

Table 3.8 Pharmaceuticals: Giants' investments by main R&D and fixed assets (1993)

	Pharma R&D in company's total	R&D[a]	Fixed assets[a]
	%		PPP$ million[b]
MSD	100	1,173	1,013
Glaxo Wellcome	100	1,155	1,016
Pfizer*	100	961	634
Roche Holding	84	895	385
Abbott Laboratories	100	881	953
Eli Lilly*	100	755	534
Hoechst	52	752	781
SmithKline/Beecham*	100	747	609
Bayer	46	691	345
Johnson & Johnson*	58	682	313
Sandoz*	76	625	351
Rhône Poulenc*	60	584	566
Ciba Geigy*	54	561	321
American Home Products*	82	540	339
Boehringer Ingelheim*	95	418	173
Astra	100	360	255
Dow Chemical[d]	29	360	400
Akzo	47	205	106
Solvay	53	174	110
Yamanouchi*	100	171	88
Total 20 companies		12,690	9,292
Total N-America, Japan, Europe[c]		20,246	

* Company not included in the statistical analysis
[a] Source: Annual Reviews (if investment in fixed assets by the pharmaceutical division is not available, the fixed assets are computed from the company's total times the R&D share of drugs)
[b] Source translation national currencies in Annual Reviews to PPP$, STI-indicators 1996/1, Annex C, P.72
[c] Source: OECD Research & Development expenditure in industry 1973-1993, Chapter II, table A (p.21) + B (p.27) + C (p.32): Drugs & Medicins in millions of PPP$
[d] Source Annual Review 1993 mentions sales of pharmaceuticals of $ 3 bn. Estimated percentage R&D = 12%. Dow sold its drug division in 1995

Table 3.9 Chemicals: Giants' investments by main R&D and fixed assets (1993)

	Chemical R&D in company's total	R&D[a]	Fixed assets[a]
	%	PPP$ million[b]	
Du Pont de Nemours*	100	1,132	3,621
3M[e]	100	1,030	1,112
BASF	100	921	1,971
Dow Chemical[d]	71	892	992
Bayer	54	812	1,158
Hoechst	48	695	721
Ciba Geigy*	46	475	479
Rhône Poulenc*	40	390	377
ICI*	100	277	716
Akzo Nobel	53	231	443
Sandoz*	24	197	123
DSM	100	183	315
Roche Holding	16	170	276
Solvay	47	154	405
Hercules	100	76	150
Nalco	100	50	118
Avery Denisson	100	46	101
Total 17 companies		7,731	13,078
Total N-America, Japan, Europe[c]		26,073	

* Company not included in the statistical analysis
[a] Source: Annual Reviews (if investment in fixed assets by the pharmaceutical division is not available, the fixed assets are computed from the company's total * (1-R&D share of drugs)
[b] Source translation national currencies in Annual Reviews to PPP$, STI-indicators 1996/1, Annex C, P.72
[c] Source: OECD Research & Development expenditure in industry 1973-1993, Chapter II, table A (p.21) + B (p.27) + C (p.32): Chemical (excl. drugs) + Rubber & Plastic products in millions of PPP$
[d] Total R&D minus estimation R&D on drugs. See further Table 3.8, note d.
[e] High tech plastic based products, such as medical instruments, tapes, air filters

Drugs and chemicals

The sample consists of 16 corporations which produce drugs as well as chemicals. Drugs and chemicals cannot be separated in the analysis, because several chemical giants have large pharmaceutical divisions, such as Hoechst, Solvay and Akzo Nobel as Table 3.8 lists in the second column.

Just as for information technology, R&D for new drugs is concentrated in big corporations. Table 3.8 shows that the 20 major corporations which develop pharmaceuticals together spend 63 percent of all R&D-expenditures on drugs in North America, Europe and Japan. Table 3.8 also underlines the importance of R&D in the drug-industry, because the companies invest more in R&D than in fixed assets.

R&D for chemicals is less concentrated than for drugs. The 17 companies in Table 3.9 have a share of 30 percent in total R&D-expenditures on chemicals and plastics in North America, Japan and Europe. The manufacturing of chemicals is tangible capital intensive and less R&D-intensive. Therefore chemical giants invest considerably more in fixed assets. Moreover, section 2.1 shows that a considerable part of the R&D by the chemical industry is targeted at a better and cleaner production technology.

Tables 3.10 and 3.11 present the response-matrices for investments in fixed assets and R&D of 16 giants in drugs and chemicals. These giants respond frequently to the investments of rivals, while R&D-expenditures are almost significantly more imitated than investments in fixed assets[22].

The response in fixed assets is mainly sequential[23], just as in electronics and computers. But the response is more pronounced in drugs and chemicals[24]. Still, no robust leaders can be discerned, because Table 3.10 is not recursive. Moreover, the presented sequence has no clear economic interpretation. The simultaneous gearing up process is concentrated in the German giants BASF and Hoechst and the Belgian corporation Solvay.

In contrast to electronics and computers, simultaneous response to R&D-expenditures is more important in drugs and chemicals. Simultaneous response even dominates sequential response, although this difference is statistically not significant[25]. Table 3.11 shows that the mutual gearing-up process is concentrated in the group companies

[22] Proof: $n_1=n_2=120$ (=16*16 companies - 16 diagonal cells). The occurrence rate of R&D-reponse equals $p_1=0.53$ (=63/120) and the rate of fixed assets equals $p_2=0.42$ (=50/120). Thus z=1.7 → almost significant.

Response-frequences (see Tables 3.10 and 3.11)

	Fixed assets	R&D
	frequency	
Sequential	40	27
Simultaneous	10	36
Maximal possible response	120	120

[23] The difference between sequential and simultaneous response in fixed assets is significant, because the test statistic z>2. Proof: $n_1=n_2=120$. The occurrency rate of sequential response equals $p_1=0.33$ (=40/120) and of simultaneous response $p_2=0.08$ (=10/120). Thus: z=5.0 > 2 → significant.

[24] Significance response fixed assets in information technology and drug/chemicals
$n_1=190$, $n_2=120$, $p_1=0.28$, $p_2=0.41$ → z=2.2>2 → significant

[25] The difference between sequential and simultaneous response in R&D is not significant, because z>2. The occurrency rate of sequential response equals $p_1=0.23$ (=27/120) and of simultaneous response $p_2=0.30$ (=36/120), while $n_1=n_2=120$. Thus: z=1.2 < 2 → not significant.

consisting of European based Glaxo, Solvay, Hoechst, Bayer, Akzo, DSM and BASF and USA based Abbott, Dow Chemical, 3M.

An explanation for the more frequent simultaneous response compared with electronics and computers is that many corporations in drugs and chemicals are not very specialized as they have many overlapping divisions, while the corporations can hardly be ranked according to a stylized product chain. Instead, chemicals and drugs are produced in a few production stages, preferably integrated on one location. The reasons are that it saves energy costs of cooling and re-heating, and it enhances safety. This argument is supported by the fact that most very specialized corporations in the sample are hardly involved in the simultaneous process, like Hercules (special paints, paper technology, special food), Astra and MSD (both drugs), Avery Denison (high tech adhesives and films) and Nalco (environmental control).

Table 3.10 Ranking in leadership in fixed assets in drugs and chemicals

	Leader															
Follower	Av	3M	He	Gl	Bay	As	Do	MS	Ro	Ab	Ak	DS	So	Bas	Na	Ho
Avery											X					
3M	X															
Hercules	X															
Glaxo		X	X													
Bayer							+							X		+
Astra			X													
Dow		X			+								+			
MSD				X			X									
Roche			X	X	X		X					X	+	+		+
Abbott								X	X					X	X	
Akzo					X				X							X
DSM						X					X					
Solvay				X	X		+		+		X	X		+		+
BASF				X				X	+			X	+		+	+
Nalco		X		X									X	+		
Hoechst				X	+	X	X	X	+			X	+	+	X	

[a] +: simultaneous response; X: sequential response; blank: no response.

Although there is less leadership in R&D than in electronics and computers, it appears that the more a company is specialized in drugs, the higher the probability that it is a R&D-leader. For instance, the pharmaceutical specialists Abbott, Roche, Astra, MSD and Glaxo are among the first in the sequence in Table 3.11, whereas the basic chemical specialists Dow, DSM and BASF are in the arrear[26]. A possible explanation is that the drug companies have a higher R&D-intensity than chemical corporations.

Table 3.11 *R&D-response in drugs and chemicals*[a]

	Av	Ab	So	Ro	As	Ms	Gl	He	Ho	Bay	Ak	Do	Ds	Bas	3M	Na
Avery					+											
Abbott									+	+	+		X	+	+	
Solvay		X					+		+	+	+		+	+	+	
Roche	X		X			X	+							+		
Astra	+			X												
MSD	X				X			X								
Glaxo		X	+	+					+	+	+	+	+	+	+	
Hercules																
Hoechst		+	+	X			+			+		+	+		+	
Bayer		+	+	X	X		+	X	+			+	+		+	
Akzo		+	+	X			+		X	X		+	+	+	+	
Dow	X						+	X	+	+	+		+	+		
DSM	X		+	X			+	X	+	+	+	+			+	
BASF		+	+	+			+		X	X	+	+	X		+	
3M		+	+	X			+		+	+	+	X	+	+		
Nalco																

[a] +: simultaneous response; X: sequential response; blank: no response

Furthermore, it appears that the biggest corporations are no investment leaders, as is the case for companies in information technology.

The Dutch giants Akzo Nobel and DSM are no investment leaders in R&D and fixed assets. By contrast, both companies are better characterized as investment followers.

[26] Pharmaceutical companies lead the R&D-expenditures of other chemical corporations, while this relation is not found for investment in fixed assets. This is the result of a regression analysis with the rank number of leadership according to Tables 3.10 respectively 3.11 as the dependent variables and as determinants the share of R&D for drugs in company-R&D in % (Table 3.8), and company size in 1993 expressed in PPP$ billion. The table below lists the results.

Rank number	Share drugs in total R&D	Sales 1993	R^2
Fixed assets	0.00 (0.0)	0.1 (0.7)	3
R&D	-0.07 (2.8)	0.2 (1.1)	42

From the regression result follows that high shares of R&D for drugs corresponds with a high ranking (=low rank number). There are no significant other effects.

The reason is that their rank numbers in the Tables 3.10 and 3.11 are high. Still, their R&D-investment behavior has a large impact on Solvay, Hoechst, BASF, Dow Chemical and Bayer, because this group mutual gears up its R&D-investments.

However, R&D-response is still significantly higher than the response on fixed assets. But the outcome supports the idea of simultaneous investment behavior in game theoretic models. The corporations mutual gear up their investments in R&D. In this case there is no leader, but both companies respond to each other.

Conclusion

According to the statistical analysis, the giants in electronics, computers, drugs and chemicals respond frequently and significantly to changes in the R&D-investments of rivals. The response is less intensive for investments in fixed assets. This result supports the argument that the absorption of inventive results of competitors is a reason for R&D.

Sequential investment response prevails in electronics and computers. The ranking of leadership is related to the value chain: from components via computers to consumer electronics. Less leadership is discernable in drugs and chemicals. Still, it turns out that the more giants specialize in drugs, the higher the probability that they are R&D-leaders. More characteristic for the chemical industry is simultaneous R&D-response without leadership. In particular, German and Dutch giants gear up each others' R&D-investments. The size of companies has no impact on the rank ordering of leadership. A possible explanation of sequential versus simultaneous response is that IT-companies are probably more specialized than chemical giants.

The Dutch giants Philips, Akzo Nobel and DSM have a low position on the scoreboard of leadership. This is mainly due to their specialization: consumer electronics respectively (basic) chemicals.

3.2.3 Significance for policy makers

Sections 3.2.1 and 3.2.2 show for R&D-intensive giants, that higher net profits and a lower debt/assets ratios lead to more investment. This holds more for investments in fixed assets than for R&D. And, these sections also indicate that companies in the information technology industry and drugs and chemicals strongly respond to each others' R&D-expenditures. However, this holds less for investment in fixed assets. This section addresses the question of the significance for national policy makers of these findings. How can they stimulate investments and what are the dilemmas facing policy makers?

In order to stimulate investments, policy makers can use instruments which have an impact on the investment-determinants. Governments can help to reduce the debt/assets ratio. Possibly they stimulate the transfer of information on the prospects and risks of new projects from the board of directors to potential shareholders. This may lead to long term shareholder-ship of investment trusts funds and pension funds. Little know-how can make them risk-averting. Also, institutional regulations which make it attractive to distribute less profits to the shareholders contributes to a lowering of this ratio. Moreover, the government can consider to facilitate intangible assets (like the value of goodwill and intellectual property rights) as part of the total assets, with as consequence that the debt/assets ratio drops. Finally, the establishment of funding investment banks which supply venture capital may contribute to reduce this ratio. Net profits can be increased by lowering the corporate tax rate and an increase in R&D-subsidies.

For policy makers it is also relevant that the giants respond to each others investment expenditures. If policy makers succeed to increase the investments of a giant, this will lead to extra investments on top of the original increase due to the response of rivals. This effect is especially important for R&D-expenditures.

European countries gain from extra R&D on information technology triggered in the USA or Japan. The reason is that most giants have the USA and Japan as home base. There are few European giants, and the statistical analysis showed that these are no leaders in investment either. Fixed investments can help to support a wave; modestly, however, because the interdependence of fixed investments is much lower.

European governments may consider to trigger a R&D-wave in chemicals, because many giants have European headquarters and the corporations they gear up each others' R&D-investments. In contrast there are hardly big Japanese corporations in these industries.

National policy makers, in particular those of small nations, face dilemmas, when they consider to stimulate investment by big R&D-intensive corporations. These dilemmas are caused by differences in goals and the playing field of the board of directors compared with policy makers. The boards watch and respond to rivals all over the world in their markets. In turn, policy makers regard economic activities across markets within their own country as the major subject of interest.

The first dilemma raises if a national government succeeds to increase net profits of a company or establishment. Then, it is not ensured that the board will invest the extra cash flow in that country. There may be locations in other countries with more profitable prospects. For instance, a company may gain to spend extra profits earned in Europe, in Asia. However, this is not primarily the target of European policy makers.

The second dilemma is due to the investment response. An investment-stimulus to a national giant improves that company's competitive advantage against 'foreign' rivals. However, these competitors will respond and this partly compensates the original advantage. For the world economy, however, these international spill-overs are favorable, because they produce an international multiplier on the original stimulus. Therefore, in both cases, the country which stimulates investment of a national giant does not need to gain fully from such a policy. In these cases, international policy coordination can be considered.

3.3 Best use of R&D-budgets

Introduction

The former section addressed the decisions of the boards of directors on the amounts of the R&D-budgets. This section assesses how R&D-managers can best use the budgets[27] and it derives some tasks for the government. Guide is the key concept in the theory of endogenous economic growth, namely the knowledge production function. This function links the output of new ideas or technology to labor and capital and stocks of know-how. Therefore, new technology does not fall from heaven, because it requires scarce resources. Furthermore, knowledge creates knowledge, because know-how is an input as well as output[28]. The main contribution of this section is to link this theoretical concept to measures which are used in practice.

The instructions of the boards of directors

The board of directors must take some strategic decisions, which are constraints for the R&D-managers. First, the R&D-manager receives a budget, which is spent on wages and equipment according to:

(2) $\text{Budget} = w\, L_{RD} + p_i\, I$

where w the wage rate of research personnel, L_{RD} research employment, p_i respectively I the price and volume of equipment. The existence of this budget implies that economic growth requires the input of scarce resources. Moreover, the boards must decide how radical the new brands should be. Radical new products are intensive in Research, differ strongly with existing brands and need high development costs. According to economic theory, these characteristics are related to high expected returns across a long time horizon. In contrast, new products which are improvements on existing brands are intensive in Development, can easily be substituted for existing brands, have low development costs and have low expected profit margins. Many R&D-intensive companies are shifting the emphasis of their R&D from the more basis Research-component to Development, which targets at improvements. Finally, the R&D-manager must know the size of the market. In general, the largest size is preferable. The reason is that development costs of a new brand are sunk costs, because they are fixed as soon as the manufacturing of the new brands starts in the plants. Therefore, economies of

[27] This section extends the R&D-definition which is used in the former section, to all expenditures which are required to get a new product to the market. Therefore it includes also other costs such as registration, advertising, prototypes, insurance costs for unforeseeable defects.

[28] See Grossman and Helpman (1991)

scale can be gained, if there are many potential customers. This scale effect is largest if a product is developed with the global citizen in mind[29].

The problem of the R&D-managers

R&D-managers maximize the output of new brands with the required degree of substitutability and the given market size, conditional on the budget constraint. The number of new brands depends on the so-called knowledge production function. This describes the creative process which transforms research personnel, equipment, company specific and external know-how to the output in number of new brands.

More precisely, this creative process can be written as:

(3) $$\Delta n = [\gamma\, L_{RD}^{\lambda}\, I^{\mu}]\; n_{-1}^{\rho}\; n_{*}^{\delta}$$

where Δn the number of new brands, γ an efficiency indicator and n_* external know-how[30]. This formulation contains dynamism, because the production of new knowledge in this year is added to the stock of know-how which is productive next year, as $n = \Delta n + n_{-1}$[31]. Hence: knowledge creates knowledge. Restraints on the parameters are $0< \lambda, \mu, \rho, \delta <1$ and $\gamma>0$. The economic significance of these parameters appears in the discussion below.

The managers maximize equation (3) conditional on the restraint of equation (2). This leads to the development costs of a new brand according to[32]:

(4) $$p = [1/\gamma\, (w/\lambda)^{\lambda}\, (p_i/\mu)^{\mu}]\; n_{-1}^{-\rho}\; n_{*}^{-\delta}$$

Table 3.12 R&D-expenditures per patent application (Germany, 1992)[a]

	DM mln
Information technology	

[29] For example, Microsoft introduced Windows 95 on the same day all over the world; Ford develops the 2000-car type for the global client (Business Week 20/11/1995), and in 1995 a cosmetics-brand was launched worldwide for the first time (by Calvin Klein) (Business Week 3/4/1995).

[30] In order to simplify the reasoning, we assume that investments in laboratory equipment proportional to the stock of tangible laboratory capital. Then, investments can be regarded as the relevant input instead of the capital stock.

[31] This implies that it is tacitly assumed that the stock of company specific knowledge coincides with the number of products which the company has developed during its lifetime. This assumption is often made in economic theory and it does not disturb the quality of the reasoning compared with more general formulations.

[32] Relation (3) is the dual of the knowledge production function (2). Note that equation (2) times equation (3) produces the budget restraint (1).

Electronics	2.9
Scientific Instruments	1.9
Health/Biochemicals	
Drugs	1.2
Food	4.1
New materials	
Chemicals	2.5
Plastics	1.1
New mechanics	
Aerospace	11.8
Cars	4.9
Machines, metal products	1.0
Better extraction	
Basic metals	1.0
Electricity, gas, water	3.2
Paper	1.1

[a] OECD (1996) p.83, column 16.

Evidence on sunk development costs

Empirical evidence shows that the costs of product development are high. A first estimate is the R&D-expenditures per patent application, which amounts to at least DM 1 million according to Table 3.12. These investments are outstanding in aircraft, cars and food. And they are also considerable in electronics and chemicals. A drug-patent application takes relatively low research costs. Drug companies apply for patents soon, because a new drug can easily be copied.

The R&D-expenditures per patent application underrate total development costs. At least, expenditures on marketing and prototypes should be added. In particular, the expenditures on marketing a new product are huge in the food-industry. On top of that, new drugs, aircraft and cars require registration costs to meet health and safety standards. For example, the real entry costs of a new drug, including clinical research and registration costs are on average NLG 500 million, which implies that the average R&D-costs of a patent application of NLG 1.5 million almost can be neglected.

Table 3.13 has another disadvantage as it shows averages. Generally, the positive outliers are more revolutionary inventions than average new brands. Therefore, break-through products give higher returns than inventions which can easily be substituted for old brands. Official data on these outliers lack, but there is plenty of ad-hoc evidence. The examples in Table 3.13 illustrate that main new products need investments of several hundreds of millions of dollars, spread over many years to get them to the market.

Table 3.13 Development costs with new product and development period

Enterprise	Product	Amount	Development period	Costs in year
Information technology				
IBM/Siemens/Toshiba	256 mega-bit chip[h]	$ 1 bn	NA	'94
IBM	OS/2 Operating system[d]	$ 2 bn	NA	90s
Océ	Copier 9800[c]	NLG 250 mln	8	'94
Microsoft	Promotion Windows 95[f]	$ 200 mln		'95
	Major Hollywood movie[q]	$ 150 mln	NA	-
	Average Hollywood movie[s]	$ 53 mln	NA	'95
Health				
Pharmacy	Average main new drug[a]	NLG 500 mln	10	'94
SmithKline Beecham	Anti-tobacco chew campaign[r]	$ 70 mln	NA	'95
New materials				
Unilever	Omo Power[b]	NLG 300 mln	NA	'94
Aerospace				
DASA/Fokker	Aircraft 120 seats[e]	$ 2 bn	NA	'95
Boeing	Superjumbo 700 seats[i]	$ 15 bn	NA	'95
Rolls Royce	Trent-800 Jet engine[k]	$ 750 mln	7	'95
Pratt & Whitney (UT)	PW4084 Jet-engine[l]	$ 500 mln	NA	'95
General Electric	Boeing 777-engine[m]	$ 1,5 bn	NA	'95
Fokker Space	Robot arm satellite[o]	NLG 300 mln	NA	'95
Cars				
Ford	Ford's 1st global car: 2000 type[n]	$ 6 bn	6	'95
Ford	Car engine[n]	$ 1 bn	NA	'95
Volkswagen	Golf (remake)[u]	$ 1.8 bn	NA	'97
General Motors	Astra (remake)[u]	$ 1.7 bn	NA	'97
DAF	DAF 65, 75, 85 types[p]	NLG 600 mln	NA	'92
Paccar/DAF	DAF 95 XF[t]	NLG 190 mln	2,5	'97

[a] Entry costs: Including R&D, pre-clinical research and registration (FD 3/2/1995). Built-up of period to enter the market: Basic research, pre-clinical studies, three phases of clinical studies, registration. Each stage takes 1-2 years, thus: 6*1,5=10 (Nefarma (1995) 'Dit is Nefarma'); [b] FD 22/2/1995; [c] Océ's president Pennings in Algemeen Dagblad 22/2/1995; [d] The Economist 10/6/1995; [e] FD 8/9/1995; [f] Advertising and marketing expenses. BW 28/8/1995; [h] NRC 20/10/1995; [i] The Economist 17/6/1995; [k] BW 27/3/1995; [l] BW 17/4/1995; [m] BW 17/4/1995; [n] BW 3/4/1995; [o] FME Metalectro Profiel February 1996; [p] FD 15/3/1996; [q] Average Cleopatra (1963), Waterworld (1995), Superman (1978), True Lies (1994), Terminator 2 (1991). Source Baseline, quoted in WirtschaftsWoche 14/3/1996 (prices 1995); [r] especially TV-advertisement BW 29/4/1996; [s] Production costs $ 35 mln, Marketing costs $ 18 mln, The Economist 30/3/1996; [t] FD 17/1/1997; [u] BW 10/3/1997.

Best use of the R&D-budget

R&D-managers optimize their budget if they reduce the investments needed in order to develop a new brand which meet the required substitution-elasticity with existing brands and the size of demand. Equation (4) provides three ways to achieve this: increase in-house efficiency and exploit company specific and external know-how. On top of that, the R&D-budgets are optimized if research is organized in such a way, that the chances of a successful product launch are high.

Improve in-house efficiency

The instrument is expression $p = [1/\gamma\ (w/\lambda)^{\lambda}\ (p_i/\mu)^{\mu}]$ in equation (4). However, the impact is easier to understand with its counterpart $\Delta n = [\gamma\ L_{RD}^{\lambda}\ I^{\mu}]$ in equation (3). This expression is a traditional production function with labor and capital as inputs which are partly substitutable[33], increasing returns if $\lambda+\mu>1$, and γ in the role of a general efficiency parameter. For the company, the wage rate (w) and the price of equipment (p_c) are given.

First, economies of scale on equipment can be utilized. The economies of scale are caused by the expensive scientific instruments and their short depreciation period as a consequence of fast technical progress. Concentration of research leads to a better utilization of these increasing returns in the creative centers as section 2.1 mentions. For example, Organon, Akzo Nobel's pharmaceutical division, is concentrating its R&D. The enterprise mentions as a major cause that concentration speeds research efficiency, due to a better use of scientific instruments for research for combinatorial chemistry and gene-therapy[34]. On top of that, aid by computers also leads to a drop in development costs. Computers belong to the equipment in the creative centers and they have penetrated the creative centers, due to the possibility to substitute computers for R&D-personnel. The price of computers falls annually with more than ten percent compared with wages, and this price development triggers a substitution between equipment and labor. Chrysler provides a nice example of the impact of computers in their creative centers. Computer equipment enabled Chrysler to draw a new engine on screen rather than building prototypes. It led to a drop in development costs of an engine from \$ 1 billion to \$ 600 million[35]. Better organization methods and personnel management contribute also to more in-house efficiency.

Exploit company-specific know-how

The instrument to exploit company specific know-how is expression $p = n^{-\rho}$ in equation (4). Much know-how in the company is not codified and only employees have access to it. The importance of this company specific know-how as an input in the knowledge production function is that it leads to ever falling costs of product development with a

[33] in this case defined with an elasticity of 1

[34] FD 2/10/1996

[35] Business Week 25/11/1996

the same amount of R&D-personnel and equipment, as long as the stock of company specific know-how grows. This is the case as long as knowledge production surpasses know-how depreciation, because this net present knowledge production is added to the stock of know-how in the next year. Equation (3) silently assumes that there is no depreciation on company specific know-how. Researchers who succeed to increase ρ, exploit their company's tacit know-how better, are more productive and contribute to higher profits.

Concentration of research in the main laboratories is an instrument to achieve a higher δ according to section 2.1. In a central laboratory, research personnel can meet easily and exchange recent know-how and experience. Some recent examples support this reasoning. First, in addition to the most efficient use of scientific instruments, Akzo Nobel argues that it concentrates its research, because the available know-how can be better exploited[36]. Glaxo-Wellcome also has concentrated its R&D in the United Kingdom, due to these same reasons. Although concentration is helpful for Research, it should be noted that this is not the case for Development as section 4.1 explains.

Also, companies exploit company specific know-how by means of job-rotation of experienced, but less creative, R&D-personnel. In this way, research know-how is spread across the plants and sales and purchase divisions.

Mix company specific and external knowledge

A main instrument to produce new brands cheaper is to seek access to know-how outside the company and mix it with company specific knowledge and experience. According to equation (4) the instrument is $p = n^{-\rho}\, n_*^{-\delta}$. A better access to external know-how appears from a rise in parameter δ. If a company succeeds to increase δ, it enjoys a short term benefit, because the development costs drop. Moreover, it gives long term advantages, because a rise in δ also leads to more knowledge production according to (3), which are added to the stock of company specific know-how next year. This increased stock of know-how accelerates the fall in developing costs. In practice, companies get access to external know-how and mix it with their own knowledge in the following five ways.

i Draw from the knowledge of universities

Universities are important for research in the business sector, because universities produce fundamental scientific insights which is external know-how for the company. Therefore, R&D-corporations can gain from drawing from this stock of fundamental know-how, by means of learning and exchange of experience with universities. Computers can play a role in this respect. For instance, the drug maker Merck, Sharpe

[36] FD 2/10/1996

and Dohme is developing a world wide computer system for tracking clinical and statistical data. This system aims to improve the quality and capacity of Merck's research[37].

ii Share your know-how with rivals

In a R&D-alliance competing companies mix their know-how. The use of their total know-how reduces the costs of knowledge production, avoids duplication and spreads risks. However, an alliance takes extra costs of coordination. This strategy is successful if all members aim at joint maximal profits in the stage of product development, while they are fierce competitors in the manufacturing stage[38].

Table 3.14 provides empirical evidence of strategic technology alliances. They emerged in the 1970s and their importance surged in the 1980s. However, during 1990-1994 the rise decelerated. Since 1970, the share of information- and bio-technologies rose, while the share of new materials and advanced mechanics dropped.

An explanation why companies in the field of information technology opt for alliances is that they make components in production chains, which should be standardized in order to make them mutually compatible. Therefore it requires cooperation in order to assemble the components into information and communication systems of the rivalling giants. In contrast, the new material industries have production processes in a few stages and they hardly need compatibility. Consequently, they have less reasons to cooperate and coordinate their research.

A R&D-alliance is unstable for its members and risky for society as a whole. A successful alliance requires that all members observe the treaty. However, individual members have better prospects if they wait and see for the research results of their rivals. Then, they can ride free on these results. If members cheat each other, the alliance may collapse. Then, the outcome may be less favorable for society, as possibly the alliance has produced less research output than the sum of the output of the companies without the alliance.

Table 3.14 Strategic Technology Alliances[a]

	1970-74	1975-79	1980-84	1985-89	1990-94
Total number	163	493	1432	2641	2789
Distribution	%				
Information technology	22	24	38	40	48
Micro-electronics	1	8	13	7	10

[37] Annual Review 1993, p.9

[38] Theoretical discussions on the welfare effects are given in Kamien c.s. (1992), Suzumura (1992) and Rozenkranz (1996). See also the survey by v d Klundert (1997) Chapter 5.

Computers	6	5	6	5	7
Telecommunication	1	3	8	10	11
Software	4	2	4	12	17
Consumer electronics	6	4	4	2	2
Scientific/Medical instruments	4	2	3	2	1
Health	6	18	23	23	21
Bio-technology	4	15	22	22	19
Food, Beverages	2	3	1	1	2
New materials	37	21	16	18	17
New materials	12	5	8	11	7
Chemicals	25	16	8	7	10
New mechanics	35	37	23	19	14
Aerospace	8	10	4	4	7
Cars	14	14	5	6	2
Industrial Automation	4	6	10	7	4
Heavy electric machines	9	7	4	2	1
Total	100	100	100	100	100

[a] Including R&D-cooperation, development of prototypes, and bilateral exchange of technical know-how. The alliances are not restricted to a specific area. John Hagedoorn (MERIT, RUL) kindly provided these data from the MERIT-CATI-database. See also Hagedoorn (1992, 1995).

iii Merge and Take-over

Mergers and take-overs prevent free riding behavior[39]. Consequently, they are more stable. Mergers and take-overs bring disadvantages as well compared with strategic alliances. First, the merged companies may get undesirable market power. Moreover, a merger is rigid and forever compared to the flexible and temporary alliances. At present, the pharmaceutical industry is outstanding in mergers[40] and takeovers[41] with combining know-how as one of their major purposes. They expect to innovate more efficient and avert risks, due to more know-how.

iv Share your know-how with suppliers

R&D-corporations have vast networks of suppliers. The central company can exploit the

[39] The Economist 9/9/1995

[40] Recent mega-mergers are Smithkline (US) - Beecham (UK), Bristol Myers (US) - Squibb (US); Pharmacia (SWE) - Upjohn (USA); Ciba-Geigy (SWI) - Sandoz (SWI).

[41] The biggest take-overs: 1 Glaxo bought Wellcome for $ 14.8 bn in 1995, 2 Merck bought Medco ($ 6.0 bn in 1993), 3 Hoechst bought Marion Merral $7.1 in 1995), 4 American Home Products bought American Cyanid ($9.8 bn in 1994), 5 Roche took over Syntex ($5.3 in 1994) (FD 11/3/1996). Hoechst bids NLG 6 bn for Roussel (NRC 11/12/1996)

experience built up in their user-producer relations by extending co-makership to co-developership. Then, the helicopter-view of the coordinating corporation on international marketing of final products, general production processing and assembling, is mixed with specialized know-how of its component suppliers, who are often smaller in size. For example, Paccar/DAF reduced the development costs of its new 96 XF truck considerable in this way[42]. Also, Océ cooperates engineering and research with its 300 suppliers in the neighborhood of its Venlo-headquarters. Océ also aims at a better exploitation of external know-how by means of cooperation with foreign companies. Océ itself concentrates its research on its stronghold: photo-copying[43].

v Share your know-how with clients

As counterpart of the former way, big companies in raw material processing industries can seek cooperation forward in the value chain. For example, the Dutch steel- and aluminum producer Hoogovens cooperates its research with component makers in the car industry, in the beverage industry (tins), and the construction industry (aluminum window frames)[44].

Increase chance of a successful launch

R&D-activities are an adventure, because the innovator does not know in advance if a new product will be successful. Hence, failures occur often[45]. Therefore, methods which enhance the probability of a successful brand-launch contribute to the best use of the R&D-budget. Practical methods are, for example, surveys among clients to inform the creative centers, cooperation between research and industrial design departments, or exchange of ideas between the researchers and the staffs in the plants. Companies can be very successful in this respect. For example, Océ and Philips Medical Systems have increased the probability of a successful hit with a new product from 30% formerly to 80% at present[46].

Evidence of higher R&D-efficiency

[42] According to DAF's director marketing and sales, van den Assem, in FD 17/1/1997. On top of that, development costs dropped by working with small teams, and by staying aloof of vulnerable electronics in the motor compared with rival truck producers.

[43] Interview director J. Pennings in NRC 10/2/1995

[44] Jaarverslag 1994 p.18

[45] Examples of failures are Philips in mainframe computers and Sony in betamix-video. Moreover some of the US' enterprises with the highest R&D per employee in 1984 collapsed later, such as Xonics (X-ray gear), Software Publishing (maker of Harvard Graphics), Transition Electronics (integrated circuits), Chip & Technologies (chips for PC-clone makers) and S3 (multimedia chips) Source: Business Week 3/7/1995.

[46] Berenschot's de Vaan in FD 14/9/1995

All determinants together have probably increased the efficiency of the creative centers indeed. It follows from a large number of examples of a shortening of the period of product development, while R&D-employment hardly changed. For instance, Siemens reduced its development-period with 2/3[47]. Today, the product development cycle in personal computers has diminished to 6-9 months; all the money must be even made in the first 4 months in order to break even[48]. Philips aims to reduce the period of product development of new audio-apparatus from 1-2 years to 3-6 months[49].

The pharmaceutical company SmithKlene Beecham shortened its development period of a drug from 9 years (1990) via 8 (1996) to 5.5 years[50]. Another spectacular example is the discovery of genes. It took 10 years to discover and understand the cyctic fibrodid gene at a cost of more than $ 150 million. Now, the cost is as low as $ 300 per gene[51].

In the car industry there are many examples which point to shorter development periods. It takes Ford today 6 year to develop the 'global-car', Japanese car-makers are faster with 4 years[52]. General Motors goals in a recent Reorganization Plan 'to speed development of new models by 25%, to 36 months, slash engineering costs by 30%'[53]. Chrysler says that it took in 1993 38 months to develop the 'Intrepid'-car from concept to showroom, the new Dodge Durango takes just 28 months today[54]. The Volvo-800 series had a lead time of 10 years before production; this period has shortened for new models to two years[55].

Government tasks

How can governments help to gain benefits for the economy without disturbing the market mechanism? Governments attack the no-disturbing condition if they intervene selective in the in-house efficiency of the corporations. Still, governments have available the general instruments wage policy and subsidies of equipment, which belong to the standard collection of macro-economic instruments. They have an impact on the

[47] WirtschafsWoche 26/10/1995

[48] Business Week 15/1/1996

[49] NRC 28/11/1996

[50] Business Week 4/3/1996

[51] Business Week 10/3/1997

[52] Business Week 3/4/1996

[53] Business Week 14/8/1995

[54] Business Week 25/11/1996

[55] Business Week 13/11/1995

costs of development as well.

The exploitation of know-how is a challenging subject for policy makers. There are two main questions governments face, namely what is their best role with regard to universities and should they encourage R&D-sharing and cooperation between companies?

Way i, the role of the government with regard to universities is hardly disputed. Governments are the major founders of universities. And production of fundamental know-how is a specialty of universities. Therefore, government policies determine the stock of basic knowledge which is part of n_*. Second, governments can help to give the business sector better access to university know-how, for example by facilitating to employ part-time professors, who also work in laboratories in the business sector (increase of δ). Third, education of graduates is mainly a task of universities and graduates are potential R&D-personnel. These government roles may be hardly disputed in general terms, problems arise if the instruments are specific. For instance, this discussion gives no clear answers to questions such as: what is the role of centers of excellence, which studies should be encouraged, how high is the optimal university budget?

A better knowledge infrastructure in general is a robust way to reduce development costs, while the market mechanism is not disturbed. Hence, all measures which increase the public stock of know-how and improve access to it are favorable. For example, governments may consider a task to codify know-how, which is still external to the business sector. Examples are the set up of electronic standardized libraries or data bases of health treatments.

Policy makers face dilemmas if they assess R&D-alliances and mergers (ways ii and iii). Ideally, an alliance should be encouraged. In this case, firms spend such an amount on R&D which maximizes their expected joint profits, while firstly they share their research results in order to exploit knowledge spill-overs and prevent duplication, and secondly compete fiercely in the manufacturing stage[56]. However, alliances have two potential disadvantages. First, there is the possibility that less research output is produced than without the alliance, due to wait and see behavior of free riders. Second, there is a danger that the collusion of the members in the R&D-stage is secretly extended to the manufacturing and price-setting stage, which ends in a cartel.

The same type of arguments holds for mergers and take-overs. It is desirable that

[56] For the reasoning see Kamien c.s. (1992). A better exploitation of knowledge spill-overs by sharing know-how in the pre-competitive stage has possibly been the reason why the European Union recently has relaxed the restrictions on the transfer of technical know-how, such as patents and know-how licenses. Since 1996 they do not need to be reported to the EU. Before 1996 however, the EU stressed concentration, and the Commision obliged the companies to report technology-transfers if their market share was high (FD 1/2/1996).

know-how is shared, but the danger is too much monopoly power.

Governments can encourage R&D-cooperation between independent suppliers or clients -often small and medium sized companies- and a coordinating R&D-giant (ways iv and v), because knowledge production is more efficient. The companies do not exchange their know-how, but organize their firm specific knowledge and experience better. The market power hardly changes due to this type of cooperation.

In conclusion, R&D-managers use their budgets best by means of more in-house efficiency and exploitation of company specific and external know-how. Also, they organize the creative process in such a way that the probability of a product hit is increased. There is ample evidence that these strategies are applied in practice. This section derives two reasons why R&D is concentrated in big corporations as mentioned in section 2.1, namely economies of scale on scientific instruments and the exploitation of company specific know-how.

Governments have especially tasks to provide the corporations access to a sufficient amount of new fundamental know-how and the supply of well-educated graduates. Also, governments should encourage co-developing between a central cooperation and its network of independent suppliers or clients. However, governments face dilemmas as regards technology alliances and mergers or take-overs.

3.4 Policy dilemmas and creativity

The major dilemma

Considering R&D-intensive companies, policy makers face a major dilemma between two conflicting targets: more static or more dynamic efficiency; in other words: more competition or more R&D-driven economic growth.

Policy makers stimulate competition because it gives higher static efficiency and more welfare. Rigidities on the product markets are diminished, such as artificially high profits, concentration and cartels. A policy of free international trade gives support, because it predicts less market power to enterprises and lower prices to the clients[57]. In practice, governments also carry out competition policy on markets of R&D-intensive products. For example, in the markets of information technologies, undesirable market power is prevented by forbidding mergers or take-overs[58] and by breaking up

[57] The argument is as follows. High protection makes that only national enterprises sell on their home markets. If the trade barriers are lifted, the number of suppliers increases in each country with the number of foreign rivals. In turn, national enterprises start to supply foreign clients. Economies of scale can be better exploited, which leads to lower prices and a shake out of companies.

[58] Recent examples: The USA-government took action to abandon the bid of Microsoft for Intuit (The Economist, 27/5/1995); and the European Union forbade the merger between Deutsche Telekom and France Telecom to Atlas, as it gave this combination too much market power (The Economist, 27/5/1995).

companies[59]. Instead, price regulation dominates in the pharmaceutical industry. It occurs directly[60] and indirectly as governments stimulate consumption of cheaper generic drugs instead of the more expensive trade marks[61]. Yet it remains difficult to develop a successful competition policy for existing products, because the outcomes of government intervention often depend on slight and unmeasurable differences of company strategies in imperfect market structures[62].

Economic growth is also a target of policy makers. This can be achieved with investment in R&D as section 5 explains. However, R&D-investments require limited competition. Therefore, a successful robust competition policy is even harder to design for companies, which frequently launch new products. More precisely, the properties `creation' and `knowledge' of R&D-intensive products give policy dilemmas on the right balance between market failure and economic growth, on responsibility for unforeseeable health and safety risks, and on new standards. The amount of R&D-investment and the degree of competition depend on the way how these dilemmas are solved in practice. This section explores the dilemmas between competition and R&D-investments.

Intellectual property rights

Creativity and know-how give dilemmas on competition policy with regard to the practical determination of the optimal market power. R&D-intensive companies need more market power than companies which operate on markets without innovation. Without innovation, a market can be defined to which competition is related to. Then, no or little market power is required depending upon the homogeneity of the products (for example, perfect competition for homogenous products or monopolistic competition for differentiated ones).

R&D-intensive companies need more market power, because they have to fund the R&D-investments. R&D-investments are favorable for the long term, because they stimulate economic growth. This gain should be balanced against the short term disadvantage of static inefficiency, which makes that consumers must pay higher prices and consequently buy less. This gives policy makers the dilemma to choose the between the long term gain of economic growth and large market power in the short run. This

[59] Recent examples are the split of AT&T (Lucent: telecommunication equipment, AT&T-services: telecommunication services, NCR: computers) (NRC 9/10/1995), Unisys (computer systems, automation services and maintenance) and Microsoft (operating system company and company producing applications) (The Economist, 8/1/1995).

[60] The European Union e.g. forbade artificial high prices of the contraceptive Marvelon (FD 7/12/1995).

[61] e.g. in the USA. Source: The Economist 29/4/1995

[62] For example, even in the simple case of a duopoly the outcome differs considerably if the companies regard the prices or the output of the rivals as given (Bertrand respectively Cournot-competition).

problem is large if the sunk costs of product development are high compared with the marginal manufacturing costs of a product, such as of drugs or software.

`Knowledge' even aggravates this dilemma. Market power needed to stimulate invention can be acquired by keeping the blue prints secret. However, blue prints belong to the stock of know-how, and section 3.3 demonstrates that it is desirable to give rivals maximal access to external know-how instead of keeping it secret.

Intellectual property rights reconcile the need of the creative process for market power and the demand for public knowledge. These rights make new ideas excludable, because the inventor gets a monopoly to use his idea in a country during a limited period, while the application for this right simultaneously makes the new know-how accessible to the public. Therefore, rivals can also acquire this know-how and use it as an input in their own knowledge production process (see equation (2) in section 3.3, where n_* increases).

In practice, there are dilemmas as regards the implementation of intellectual property rights, such as how high must infringement be penalized, how long is the best protection-period, and what should be the coverage of new ideas and countries? The areas covered have been extended in the course of time: from patents which are based on new insights in the exact and natural sciences, via copyright on software, to trade marks for logos, colors[63], and company names[64]. And finally, will sounds[65] be protected in the future? Moreover, protection of patents and trade-marks has been extended from individual nations to the European Union[66].

An effective patent law is critical in the drug- and biotechnology industries, because it takes high fixed costs to launch a new medicine, while the marginal manufacturing costs are low. Such a producer needs effective protection in order to grasp the returns on the R&D-investments. Generally, the patent protection is effective, but there are two questions.

First, the period of protection of a trade-mark drug is perhaps too short to allow a sufficient return to the inventor before the medicine becomes generic, because the price of a generic drug is mainly determined by the manufacturing costs. In fact, there are only 8-10 years of effective protection, because the maximal protection-period is 20 years and it takes 10-12 years to get a new drug to the market after the patent application. 8-10 years of patent protection is for major drugs perhaps too short to give sufficient returns on the investments of product development to the drug-inventor.

[63] For example the colors of Ikea, Camping Gaz and KPN. To which extent can the Dutch telecommunication company KPN claim all variants of green ? The court ruled that only a specific number from a specific color book is a trade mark (NRC 29/7/1996)

[64] The values of company names are high, see section 2.1

[65] Can the sound of a Harley Davidson be protected (NRC 9/11/1995)?

[66] First the European Patent Office has been established, and since 1996 there is European trade-mark protection.

Therefore a supplementary certificate has been introduced by the European Patent Office to ensure a maximal period of protection of 15 years[67].

Second, the coverage of protection is in discussion. In particular, can discovered genes be protected[68]. The production of genes may become a key activity for many drug companies. Companies only spend funds on the discovering of new human genes and their functions, if it is profitable. A dilemma is originality: is the patent system the effective instrument to ensure protection of a discovered gene, or are the findings too obvious to allow protection[69]?

Copyright is another intellectual property right. Effective copyrights are needed to prevent too low investment in software development, because almost all costs consist of sunk development costs, while software can be manufactured free, as manufacturing coincides with electronic copying on our own computer, video player, or tape recorder. A consequence of ineffective copyrights is frequent illegal copying[70]. The result is that software firms are discouraged to invest in the development of new programs.

Legal responsibility

The second dilemma related to creativity is that new products may have unforeseeable risks for health or safety in the future. In particular, new medical products, cars and airplanes can cause damages which are hardly foreseeable, when the product is launched. Then, the question arises who is legally responsible for illnesses and defects? The law faces dilemmas, and the solution has an impact on the market structure and R&D-investments.

The first dilemma is the choice between economic growth and market concentration on the one hand, and the prevention of social damage and smaller enterprises on the other. If the law obliges the inventor to bear unforeseeable failures[71], economic growth will diminish and the markets will become highly concentrated. The reason is that the

[67] Bureau voor de Industriële Eigendom, Annual Review 1995, p.37

[68] Niaba, 12/12/1995

[69] Business Week 22/5/1995

[70] Examples: 1) In the Netherlands e.g. Buma/Stemra, which carries out copyrights on music, complaints that each month 250 thousand illegal compact discs are sold. As a consequence, the legal industry looses about NLG 120 million of sales each year (FD 25/4/1996). 2) The damage sustained by illegal professional copying of software is highest in the USA with $ 2,9 bn (35% of software illegal). The share of illegal copies in Western-Europe is higher, and in developing countries it predominates (Russia 94% and China 98%). (Source: Business Software Alliance, quoted in WitschaftWoche 14/12/1995, p.39)

[71] Outside the pharmaceutical industry the question of legal responsibility is important for producers of medical devices and cars. Recent examples in the USA: 1) lawsuit in the USA against a producer of silicon breast implants, which had damaging health effects; 2) General Motors was fined $ 150 million in order to pay a man, who was hurled out off his car and got paralysed (FD 5/6/1996).

entry costs increase considerably because they also include the enormous premiums needed to insure compensation claims. These costs make that expected returns are lower, which deters R&D-investments and consequently slows economic progress.

Also, these sunk entry costs give scale effects which only big companies can bear. If in turn legislation obliges the clients to bear the risks, the costs of market entry are lower, which speeds R&D-investment, while market entry of smaller firms is facilitated. However, in this case companies may become careless, which damages health and safety.

Second, governments can regulate the timing of market entry in order to demand more information on the risks of new products. The dilemma[72] is that an early permission to enter may be harmful, but in turn patients can also be helped sooner. Finally, health and safety can be improperly called upon by governments, which have as real aim to protect incumbent companies by making it impossible for a newcomer to enter the home market[73].

New standards

New standards give policy makers the third dilemma related to creativity. The standards of R&D-intensive products are set by mankind and not by nature[74]. Policy makers face dilemmas if they set standards, technical norms or health prescriptions. On the one hand, standards should be encouraged as they allow the exploitation of economies of scale. But they are a barrier to market entry for those who do not fit to it[75]. Sometimes governments even set standards to protect incumbent companies on the home market against the entry of foreign rivals with other standards.

Standards are critical in the information technology industries, because the products are not useful on their own, but only in a combination with other ones. Therefore, standards are required to make them mutually compatible. Compatibility of hardware, software and systems lead to network-externalities. The dilemma is that there are social advantages that network-externalities are exploited, while it also may give too much market power to the leader in the standards.

This appears, for example, in the case of complementary network externalities. These

[72] Recent examples: 1) The EU obliged Ciba-Geigy (new genetic manipulated maize) and Monsanto (soy) to make the health consequences clear of these new products. Then can be decided if these products can be sold in Europe (NRC 28/6/1996), 2) when is new AIDS-drug allowed to enter the market?

[73] Japan e.g. is accused of this strategy.

[74] For instance, standards for television receivers, video recorders, chipcards

[75] For example, Libertel says it cannot get access to the new Digital Communication System-frequency, which probably will develop to a new standard. Therefore, Libertel claims to be in a bad position against newcomers in mobile telephone networks (FD 2/12/1996)

arise when `the link between consumer utility or productivity, and the number of users occurs through the variety of complementary goods'[76]. For instance, compact discs (software) profit from compatible CD-players (hardware). The dilemma is that the advantage of more consumer welfare and higher productivity must be compared with the disadvantage of too much monopoly power of the hardware producer. For the latter can control the system and may spread its monopoly over software. In practice, this is carried out by selling the operating system (hardware) at a loss, and make money on the software applications.

Moreover, it is desirable if a group uses a network (like Internet, booking system, electronic mail), because the value of that network depends on the number (approximately squared) of users. However, at the same time, these direct network externalities bias towards a monopoly of the users.

Conclusion

In conclusion, creativity poses additional dilemmas for policy makers who aim at optimal competition. These dilemmas arise from the intellectual property rights, legal responsibility and new standards. Moreover, the external knowledge related technological alliances and mergers of R&D-intensive companies also provide policy dilemmas as section 3.3 demonstrates. For policy makers this implies that no general applying rules on competition can be given for R&D-intensive companies. The best is to develop a specific policy for each case, because the impact of the instruments differs across the industries, while countries differ in their preference for private or social risks and safety. And, last but not least, an international coordinated competition policy is significant, because the playing field of the R&D-giants is larger than the national borders.

[76] Gandal, 1995, p.599

4. Internationalization

Abstract

This section explores the determinants of the international distribution of the investments of big R&D-intensive companies, with an emphasis on investments in the Netherlands. The pattern of fixed investments by non-European giants in the Netherlands is largely explained by

- the ratio of the transport costs to Europe and the fixed investments needed to build a European plant
- the exploitation of the Dutch specific natural endowments of its location at sea and river deltas
- specific agglomerated know-how on logistics, international marketing and financing and the mastering of foreign languages
- specific agglomerated know-how in the field of agricultural industry
- a favorable corporate tax rate.

Based on these determinants, this section makes plausible why

- the European distribution centers of computer and electronic giants are concentrated in the Netherlands
- many foreign giants in chemicals and oil-refining have Dutch manufacturing facilities, while less food-processing giants are found in this country
- companies in the metal-product and machinery industry are almost absent.

National regulations and demand for regional service have the same impact as high transport costs. Therefore, most foreign pharmaceutical companies and car makers have sales and service centers for the Dutch (or Benelux) market. Finally, major software companies have establishments in the Netherlands as European call-center, while they also follow their multinational clients to their Dutch production facilities in order to implement their software. The Netherlands accommodates foreign development centers, which help to adapt products to European or Dutch specific needs and which are at the same time watchtowers of the foreign headquarters.

The 'Dutch' giants use the same determinants as their foreign rivals, when they decide on the international distribution of their plants. Asia is attractive, because the Dutch companies avoid transport costs to this continent, while the Asian plants can fully exploit economies of scale due to the fast growing markets. Moreover, the giants can exploit Asian labor advantages. Especially Philips can exploit differences in international labor endowments by means of slicing up its value chain. Unilever has scattered locations over the world, possibly because of regional tastes, national health standards, and perishability of food. Still, Philips, Akzo Nobel, DSM, Shell and Unilever have a preference for the Netherlands as a place to invest. This section argues that this is due to specific company know-how which has been agglomerated in this country since long.

Instruments help policy makers to make the Netherlands an attractive place to invest. Principally, these instruments hold for Dutch as well as foreign giants. They are investments in general education; infra-structural networks; instruments which strengthen agglomerated regional know-how; instruments which promote stability; European economic integration and low corporate tax rates. The use of the last instrument provokes other European governments to retaliate.

4.1 Introduction

After the decision of the boards of directors of the big R&D-intensive enterprises on the amount of investment in fixed assets and R&D for their companies, they decide on the international distribution. These two decisions determine the international trade flows of goods too. The reason for the distribution-decision is that the same trade-mark products are sold in many countries. Therefore, each board faces the decision to export the products from its home country to foreign clients or to produce them in foreign countries ('foreign direct investment', FDI).

Foreign direct investment

The companies choose to produce their product in a plant near the foreign customer frequently. For instance, the inward flow of direct investments of manufacturing industries into Europe is high. Since 1990 it amounts to about $ 20 billion annually, after a considerable rise during 1983-1990[77].

Export

However, the companies also choose to export their products. This leads to intra-industry trade. This is international trade of products which belong to the same industry. For example, Germany imports Peugeots and Renaults and France imports Volkswagens and Opels; or the Netherlands imports Camembert, while it exports Gouda cheese to France. This intra-industry trade has risen considerably in the course of time due to an increasing number of products. It is a main reason why international trade grows faster than manufacturing production. At present, about three quarters of international trade in manufactured goods of the developed OECD-countries consists of intra-industry trade, with Japan as notable exception (Table 4.1). Its determinants are the preference of customers to choose from a large number of products in combination with economies of scale in the firms which produce them. Intra-industry trade is in particular important if countries hardly differ in endowments, which in fact is the case for the rich OECD-countries.

[77] Source: OECD, 1996a, p.66

Table 4.1 Intra-industry trade of manufactured goods[a]

	1980	1992
	%	
USA	68	73
Japan	32	37
Germany	69	78
Netherlands	77	81

[a] =100*(1-(Σabs(E-M)/Σ(E+M)) where E: exports of a product group and M: imports. The outcomes depend on the level of aggregation. It this case it is probably the 3-digit ISIC classification. Source: OECD (1995), pp. 86, 88 and 171

Topics of this section

This section addresses the determinants of the international distribution of investments in fixed assets and R&D. The focus is on the determinants which are relevant for the investments of non-European corporations from the Fortune 500 list in Europe. Moreover, the location decision of the five 'Dutch' giants is discussed. The emphasis is on the Netherlands as country to invest for 'Dutch' and 'foreign' corporations.

The structure of this section is as follows. Section 4.2 discusses the determinants provided by economic theory. Section 4.3 focusses on location Holland. Section 4.3.1 explains the determinants for foreign companies to opt for an establishment in the Netherlands, while section 4.3.2 highlights the preference for a location in the Netherlands of the five 'Dutch' giants. Finally, section 4.4 explores how can governments stimulate R&D-intensive corporations to invest in their country. The discussion is amply illustrated with empirical evidence.

4.2 Determinants of the international distribution of investments

What determines the international distribution of investments in fixed assets and R&D? Economic theory discerns two dimensions[78]. The first dimension concerns country-linked factors, the second is product related.

The first dimension encompasses comparative advantages in factor endowments and institutions. Countries differ in endowments, such as labor characteristics, natural resources, specific agglomerated know-how and institutions. Then the international distribution of investments is linked to the comparative advantages of these countries. Consequently, the international distribution of investments largely coincides with the international pattern of specialization in international trade.

The second dimension is the ratio between the transport costs to export a product and the investments in a production facility, which manufactures this product locally. The

[78] See e.g. Markusen (1995) and Markusen and Venables (1995)

theory predicts that this dimension is important for companies with large scale effects on intangible assets on company level, such as R&D-intensive companies.

If countries are similar, the second dimension dominates. However, if countries differ considerably such as rich and poor countries, the first dimension is most important.

In principle, the determinants of the international distribution of investments in fixed assets are the same as for R&D-laboratories. However, the weights of these determinants differ considerably. Therefore, is started with the determinants of the distribution of fixed assets. At the end, the main determinants for the international pattern of R&D-centers are highlighted,

1st dimension: Factor endowments

Countries differ in labor endowments such as schooling, wage-levels and labor attitudes, like the status of work and holiday periods. These differences can be exploited by R&D-intensive corporations by choosing the international distribution of their investments optimally. The possibilities to exploit international differences in labor characteristics are best if the company can slice up its production chain in many components, while the transport costs of these devices are low. These conditions holds for electronics and computers in particular. There is a long chain of production stages from the basic components to the information technology system delivered to the final user. For example, important stages are the production of many components, their assembling, which also needs central distribution centers, and sales centers in the neighborhood of the buyers of the systems.

Corporations have a preference for locations with a supply of natural resources, which fit the production stage best. These locations are in particular attractive if the country, which exploits its climate, soil, raw material or geographical location, has agglomerated know-how in the same area where it is best in its natural endowments.

For example, Sweden is an attractive location for investors in wood-products. This country has large woods. It has exploited this natural endowment. Sweden has built up much experience in harvesting of trees and making wooden products. Finally, famous trade-marks, such as IKEA and Lundia, have been launched with sales centers near to the European consumers. Consequently, Sweden has built-up specialized skills based on a specific natural endowment, which covers the range from bare trees to many products for the consumer. Moreover, the business sector in this country invests more than other rich countries in the wood-sector and Sweden has a large surplus on its balance of trade in wood-products.

The Netherlands is another example. This country is attractive for international transport and processing of goods brought from sea. The Netherlands is located at deep sea and two main river deltas. Dutchmen have exploited this natural endowment. Since the 17th century, they have agglomerated much know-how in the area of international logistics, marketing and financing. Their international orientation is supported by mastering foreign languages. Also, the business sector and the government have invested much in harbors and networks of canals, roads and railways into the continent, which support the advantage of the geographical location. The Rotterdam harbor has grown to the number one in the world. This country is a net exporter of trade- and traffic services.

Agglomerated regional specific know-how attracts foreign investors to that place, because they also want to save costs by means of exploiting that special endowment[79]. The headquarter of many R&D-intensive companies is often the center of a network of regional jobbers, co-makers, co-developers and universities, which clusters regional know-how on the industry where the corporation operates. This type of know-how is anchored in the region, because much know-how is not codified and workers, who possess the experience, abhor to move outside their region. The investments of foreign investors in that region stimulates the clustering of know-how and concentration of activities.

The location of the headquarters and main laboratories of big R&D-intensive companies is persistent due to the link with this specialized regional know-how. However, often the historical start of their location cannot be fully explained by economic arguments. The conditions for a favorable start can be made, but what actually happens is also due to chance. Small accidents[80], such as the dwelling place of very innovative individuals, or a sudden opportunity somewhere, determine the place where for the first time the production of an entirely new product is started by an enterprise which later grew to a corporation. On this place, specific know-how of this new product is gradually agglomerated and locked in the headquarters.

Chance is a frequent reason for the original location of a new enterprise and concentration later if the products contain little material or material which is in abundance available in large parts of the world. This holds especially for R&D-intensive products, which are human capital intensive, such as software, drugs and electronics.

1st dimension: Institutions

The boards also take differences in national institutions into account when they decide on the international distribution of investments. There are three important institutions in this respect. First, regulations on health and safety cause the boards to favor

[79] For example, a survey carried out by Coopers and Lybrand (quoted in FD 25/2/1995) among 55 US-companies indicates that 20% can be saved on costs by concentrating activities in one center, in particular financial accounting, computing and marketing. Devereux and Griffith (1996) analyzed this problem with econometric methods.

[80] See Krugman (1991) for the theory and examples for the USA at p. 59-67

investment in small-scale plants and regional sales centers in every country in order to meet its national prescriptions. Second, companies prefer locations in stable nations. Political reliability, stable and transparant regulations, the absence of strike traditions and stable currency rates attract foreign investors, because they want to avoid risks on their long-run investments. Third, the boards appreciate nations with low corporate tax rates.

Foreign investment or local contracting?

After the board of directors of a non-European company has decided to supply Europe from plants on this continent, its members face the choice between supply from an own plant or to contract a local agent, who produces and sells the corporation's products [a]. R&D-giants will almost always prefer an own production facility. This brings several advantages. The expensive company image can be better exploited. Own production is probably more efficient and meets the needed quality-standards, because firm-specific experience can be used. Moreover, an own plant prevents that the European contractor exploits the giant's firm-specific know-how, free ride on it and emerge as a rival later. These advantages outweigh the advantages of a local agent. If the giant contracts an agent, it can abstain from investment in the building of a network of customers and no new facilities are needed, because the agent has already local market information and a plant.

[1] Horstman and Markusen (1996).

2nd dimension: Costs of transport or investment in plants?

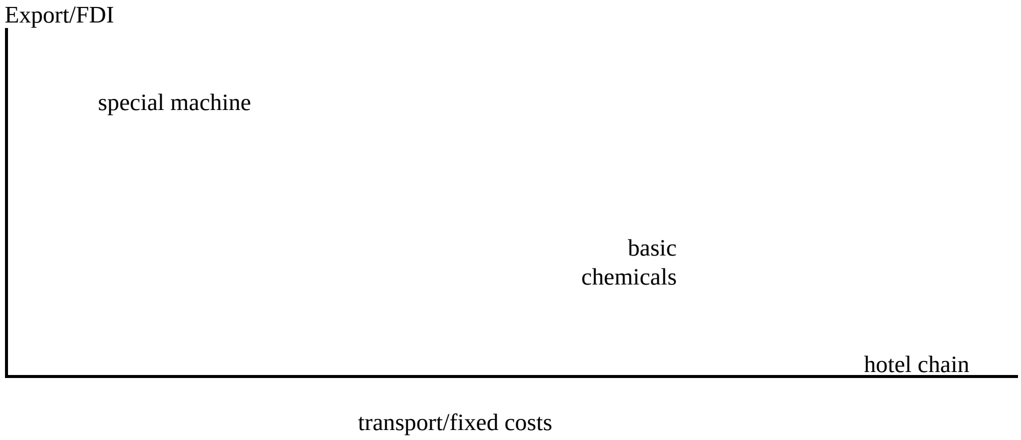
The ratio between the transport costs of exports from the home country to invest in a plant near the foreign client is the main determinant of the international distribution, if countries are similar. This condition is approximately met for an American company which sales its products in the Northwestern part of Europe. In other words: the ratio to export to Europe to investing in Europe (Export/FDI) depends for a large part on the ratio between the transport costs from the USA to Europe and the fixed costs to set up a European plant (transport/fixed cost ratio). The relation is declining: foreign investment is preferred to exports, the higher the transport costs and the lower the investment costs of a European plant.

Chart 4.1 illustrates the international allocation decision for some products. Makers of special machines prefer exports. These are made in small series, often they are unique products. The transport costs to export such a machine from the USA to Europe are small compared to the alternative to invest in a new European plant. Therefore US producers of special machinery will most often export their product to Europe and abstain from direct investments.

By contrast the Export/FDI ratio is zero for an American hotel chain. Such a chain cannot export its product by definition, which implies that the transport costs are infinite. A guest in Europe can only enjoy the concept of this chain after the US-company has invested in hotels in Europe which copy those in the USA.

Producers of oil-products and basic chemicals have an Export/FDI ratio in between. It is often cheaper to produce these products near the clients, while the crude oil is directly exported from Arabia to Europe than to produce these chemicals in the USA and export them with bulk-carriers. Therefore, most US oil and chemical giants have European establishments.

Chart 4.1 Exports or FDI depends on transport and fixed costs



Market size also has an influence on the transport costs/FDI ratio and consequently the decision where to invest. The boards prefer investment in the home-country and export, if the foreign market is small, so that economies of scale in a foreign plant cannot sufficiently be exploited. However, if the foreign country grows fast, its market size passes the critical value where foreign investment becomes attractive at a certain year. The high rate of growth of Asian markets is a reason why Asia is becoming an attractive place to invest for Western corporations.

Location of R&D centers

What do these determinants imply for the international distribution of R&D-centers? The location of the main laboratories are persistent due to agglomerated regional know-how. However, the boards will choose for development-centers near the clients, foreigners or not. There are two reasons to invest in development centers in foreign nations. First, development is often necessary in order to adapt products to regional demands. Sometimes these are due to national legislation on health and safety. This requires knowledge transfer between the client and the producer, which preferably can take place near the client's home. Moreover, development-centers can be watchtowers, if located near the main laboratories of competitors and their linked regional cluster of activities. These watchtowers draw from the regional new know-how and transfer it to the main laboratories and company's headquarters, which can exploit this knowledge[81].

4.3 Location Holland

4.3.1 Foreign R&D-intensive giants in the Netherlands

Which determinants are especially important to explain the pattern of establishments of foreign enterprises in the Netherlands? As starting point, we assume that the boards of directors regard the Netherlands as part of Northwestern Europe. Then the ratio of transport costs to Europe and the fixed costs to build a plant there, is the dominant determinant. Within Northwestern Europe, the Netherlands has two specific comparative advantages based on natural endowments. First, its exploitation of its geographical location at sea and river deltas. The exploitation is observable from a dense network of roads, canals and pipelines into Northwestern Europe and specific know-how on logistics, international marketing and financing, and the mastering of foreign languages. Second, its agricultural-industrial cluster, originally based on climate and soil. Also, the Netherlands supplies agglomerated specific know-how and experience locked in the clusters of its big R&D-intensive corporations, Unilever being a part of the agricultural-industrial cluster. Table 4.2 summarizes the impacts of these determinants on the decision of foreign companies to invest in Location Holland. It appears at once that these impacts differ per industry. Finally, this country has its own regulations on health and safety and a national tax system, which have a different impact on incoming foreign investment per industry. Health regulations are important for food and drugs, safety standards for vehicles and the corporate tax rate for electronics. These determinants are discussed in more detail in the rest of this section.

[81] Examples are the laboratories of some Japanese companies, such as NEC, Toshiba and Hitachi, in the Western hemisphere (NRC 31/8/1996). See also the recent expansion of Philips' Technical Center at Singapore. Also it is striking that Japanese car-makers have no manufacturing centers in Germany, while Toyota (at Kerpen), Mitsubishi (at Trebur), Mazda (at Oberursel), Honda (at Offenbach), Subaru (at Ingelheim) and Nissan (at Geretsried) have R&D-centers in Germany (Source WirtschaftsWoche 6/3/1997). Probably, these centers are watchtowers.

Table 4.2 Impact determinants on foreign investment in the Netherlands

	Transport/fixed costs ratio leads to	Dutch regional determinants within Northwestern Europe	
		Sea, rivers know-how on logistics	Networks with Dutch-R&D giants in center
Machines, Metal products	European imports		
Chemicals, oil	Manufacturing	Transport	Shell, Akzo, DSM
Cars	Service		
Software	Service	Languages	
Computers, electronics	Re-exports	Logistics	Philips
Food, bio-technology, drugs	Manufacturing	Logistics	Agricultural-industrial cluster (Unilever)

Metal products and machinery

The Netherlands is not very attractive for foreign producers of metal products and machinery. First, companies outside Europe can often ship their products cheaper to Europe than to invest in European plants. Second, the Netherlands lacks a comparative advantage in know-how on machine manufacturing in Northwestern Europe, where Germany is the leader. In fact, the Netherlands hardly hosts foreign enterprises.

Chemicals and oil refining

For non-European oil- and basic chemical companies the Netherlands is an attractive country to invest. First, it is often cheaper to invest directly in plants in Europe, because it is cheaper to import the crude oil directly from e.g. Arabia and produce the product near the European customer than to manufacture the product in the home country and consequently export. Moreover, the Netherlands has an advantage due to the exploitation of its location at sea. The Netherlands also has dense chemical clusters around Shell, Akzo Nobel and DSM. There are no clear indications that the know-how of these clusters contribute to the attraction of foreign investors to the Netherlands[82].

Indeed, there is a concentration of manufacturing plants of foreign companies in the chemical- and oil-refining industry in the Netherlands. Large plants of basic chemicals are present of the Fortune-giants Du Pont, Hoechst, Dow Chemical, ICI, General Electric and refineries of e.g. Exxon, Texaco/BP and Kuwait Petroleum Company. However, there are exceptions. Not all establishments of R&D-giants have high export-ratios. BASF and Bayer, the Fortune's number 3 and 4 in chemicals, have chiefly manufacturing plants and service and distribution centers for the Benelux. The

[82] Of course, all companies can benefit from the infrastructure of pipelines of chemicals in the Netherlands.

Foreign investment in the Netherlands dependent on company's or on national investment?

This section assumes that the investments in the Netherlands by foreign corporations depend on the amount of the investments at company level and on the spatial allocation decision. The latter decision depends on the attractiveness of the Netherlands. This box explores if the investments in Dutch establishments depend on the investments at company level and the general investment climate in the Netherlands. This climate is approximated in two ways: by the absolute level of Dutch national investments in fixed assets and the relative level in Europe.

The tables provide the regression results of five big companies for variants with positive signs of the determinants. No robust conclusions can be drawn, because of the small number of observations. Still, the results suggest that the company's investment and Dutch national investment climate both have an impact on the investments by foreign enterprises in this country.

Dutch company investments due total the company investments and Dutch national investments[a]

	Company's investment	Absolute national investment	R^2	Period
IBM	0.8 (6.8)	.	81	82-95
Siemens	.	1.7 (3.0)	41	82-96
Fuji Photo	1.0 (0.5)	21.1 (3.0)	92	89-95
Merck, Sharpe and Dohme	0.2 (3.2)	0.5 (2.5)	65	84-95
Hoechst	0.3 (0.6)	0.3 (0.7)	17	82-95

[a] Company investments scaled with the sales of the establishments, respectively company. The national investment scaled with Dutch GDP Source: CPB, CEP 1996, p. 392. Determinants not lagged. t-ratio between parentheses.

Dutch company investments due total the company investments and Dutch national investments relative to EU[a]

	Company's investment	Relative national investment[b]	R^2	Period
IBM	0.8 (6.8)	.	81	82-95
Siemens	0.4 (0.8)	.	5	81-96
Fuji Photo	6.4 (3.9)	.	75	89-95
Merck, Sharpe and Dohme	0.2 (2.6)	.	40	84-95
Hoechst	0.4 (1.1)	0.3 (0.6)	17	82-95

[a] Company investments scaled with the sales of the establishments, respectively company. Determinants not lagged, t-ratio between parentheses;
[b] Investment-ratio Netherlands minus Investment-ratio EU-15. Scaling factor: GDP. Source: CPB, CEP 1996, p. 392.

Consequently, for the Netherlands matters to which extent the winners of the global battle have establishments in this country. If the Netherlands only hosts losers, its national performance deteriorates compared with countries, which accommodate the winners. This loss may even occur if the general investment climate in the Netherlands is favorable.

reason is that these companies have their headquarters in Germany. It should be noted, however, that BASF and Shell in a joint venture invest NLG 935 million in 1997 in a plant at Moerdijk, which produces basic chemicals for the plastic industry[83].

Cars

The boards of directors can only opt for foreign investment if the transport costs of their products are infinite. For R&D-intensive products, this argument holds for the service which is needed in order to use them. Cars need dense dealer- and garage networks for a client wants to buy and let repair his car near his home. Also, Dutch regulations of safety and local road- and vehicle taxes contribute to favor local establishments. Due to these reasons, almost all important foreign car makers have establishments in this country, many employing a few hundred people.

The cars themselves are mainly imported. The Netherlands lacks a comparative advantage of know-how on passenger car-assembling. Within Northwestern Europe, the United Kingdom is leader in this field with many plants of corporations from the USA and Japan[84].

Software

Also software-application needs local service. Therefore, non-European companies invest in Europe. Indeed, the three biggest software companies: Electronic Data Systems, Microsoft and Oracle, have important large Dutch establishments which together employ a few thousand people. They serve mainly as national sales and service centers for Dutch companies and establishments of foreign multinationals in the Netherlands, because many software companies follow their clients to their foreign locations in order to implement their automation programs[85]. Of them, the Oracle establishment in the Netherlands is the headquarters of Europe/Middle East/Africa[86]. Cisco Systems established its new European Telebusiness Center at Amsterdam in 1996[87]. For this company, the Netherlands, with its skills to master foreign languages, is a European favorite for call-centers.

[83] FD 11/07/96

[84] The United Kingdom hosts important plants of Ford, Honda, Toyota, Nissan and Daewoo, which export 75% of their production to the continent (Business Week 3/4/1995)

[85] For example Syntegra (British Telecom), BSO/Origin, Cap Gemini stress this reason to operate worldwide (FD 18/4/1996).

[86] EDS has its European headquarters in Hampshire (UK), Microsoft in Paris.

[87] NRC 31/8/1996

Computers and electronics

The Netherlands has strong advantages as location of international distribution centers for computers and electronics due to several reasons. First, Europe requires establishments of foreign companies as central knots in logistic networks, because the production is sliced op in many stages. These stages are connected by flows of transports to industrial logistic chains[88]. If these chains overlap, their synergies may lead to a regional agglomeration or cluster-effect: the central knots in an Industrial Logistic Networks, where 'Just In Time'- deliveries are needed. Europe is an important market of computers and electronic systems. Consequently, in Europe central distribution knots are required. Second, the Netherlands has built up large experience on international distribution, which causes that the Netherlands is a favorite location to invest in European distribution centers. Third, the Netherlands has low corporate tax rates, while the location of electronics and computers in Europe is very vulnerable to this rate[89]. The Netherlands can fully exploit these advantages, because these products are standardized, due to the need of compatibility. Therefore, national regulations have no impact on the European location. Finally, it is doubtful if the Philips-cluster has attracted foreign companies, because clear indications lack.

In fact, the Netherlands has developed as a central knot of logistic chains in Europe. It appears from European distribution centers of the Fortune-players Canon, Digital, Apple, Texas Instruments, the number one in personal computers Compaq and runner-up Sun Microsystems. Moreover, the electronic giants Toshiba and Sony have European distribution and financial centers in this country. IBM has a European Logistic Service center and provides on top of that international information technology services to IBM-establishments outside the Netherlands for network facilities and software. Together IBM exported NLG 601 million in 1995 (more than a quarter of the revenues of IBM Netherlands). On top of that, IBM exports via its company 'International Maintenance Part Logistics'[90].

The final assembly takes place in the neighborhood of the final client, anywhere in Europe. Therefore, the export ratios of international distribution centers are extremely high. These are re-exports, because the companies mentioned above hardly manufacture

[88] AT Kearney (1995)

[89] In 1994, the corporate Dutch tax rate of 35% was lower than of Germany, Belgium and Luxembourg. Moreover, Europe is for US' corporations a favorable location, because the corporate tax rate of 39% in the USA surpasses the EU-15 rate of 37%. Until 1993 the European tax-rate attracted Japanese companies to Europe, because the Japanese corporate tax rate of 50% was much higher than in Europe. Since 1994 this European advantage disappeared, because the Japanes rate fell to 33.9/37.5% in 1994 (Source: Hoeller cs (1996), p. 46) The sensitivity-analysis is based on 500 US companies in 60 countries. Source: Grubert and Mutti (1996). See also Devereux and Griffith (1996).

[90] Derived from IBM Netherlands, Annual Review 1995, p.8-10, p.20, 31

devices in the Netherlands. The main value which is added in the Netherlands, consists of application of know-how on logistics and international marketing and financing as well as the transport service.

The electronic industry is by far the industry with the highest re-export in the Netherlands, with the highest growth-rate. In 1992, re-exports of electronic products took 55% (equalling NLG 15 billion) of total Dutch exports of electronics. The emergence of the Netherlands as European distribution center of these products appears from the high export growth of re-exports in electronics. Since 1973 these re-exports grew annually on average 11% in nominal guilders[91]. Probably this growth rate is even higher in real prices, because the price of electronics has dropped. The most important competitor of the Netherlands is Ireland, which also is a central knot in computer assembling and distribution in Europe[92].

On top of that, some foreign companies in information technology have large manufacturing plants in the Netherlands with high export ratio's, such as ABB, Ericsson, Lucent and NCR (electronics), Xerox (copiers) and Fuji Photo. Moreover, Siemens has large production and distribution facilities at the Hague and Zoetermeer. They, however, sell most of Siemens' products in the Netherlands.

Still, too much optimism for the Netherlands as European distribution center of electronics is not permitted. Some giants are almost absent. Examples are the investment leaders Hitachi and Intel. Moreover, Sanyo and Matsushita, two of Philips' major rivals, have no main establishments in this country. And for Fujitsu, the world's 2nd in computers, holds the same for its key activity[93]. What is the reason for their absence? Why has this country missed its chances for these companies? The answers, which may throw light on the disadvantages of Location Holland, are unknown.

Food, drugs and bio-technology

Foreign producers of health products have to take different determinants into

[91] Source: CBS/CPB Input-output tables, row 33

[92] Ireland's export/import ratios of electronics and computers are respectively 1,2 and 2,0 (1993). Therefore, this country is specialized in these high-tech products. However, this pattern of specialization cannot be explained with an abundance of high skilled labor, or high investments in R&D. By contrast, Ireland spends only 1,0% of its GDP on business enterprise R&D (OECD average 1,4% in 1994) (data-source OECD, Main Science and Technology Indicators 1996-2). The strength of Ireland is assembling and international distribution of these products, also due to a low corporate tax rate of 10% of manufacturing activities (Hoeller cs (1996), p.46). Examples with European production platforms in Ireland are Microsoft and Oracle (source Annual Reports) and Intel (Business Week 20/7/1997).

[93] Fujitsu is active in the Netherlands via its 80% share in ICL, a specialist in automation. Also, since 1996 Fujitsu has at Hoofddorp a sales center for Europe, which pursues to extend to an accounting center for Northwestern Europe. At present, the establishment employs 25 people.

consideration as they decide on the international distribution of investments. For some products, economics of scale can be exploited fully. Then, the Netherlands is a favorable location for manufacturing plants for exports to Northwestern Europe. This is due to Dutch agglomerated know-how and experience in the agricultural-industrial field, and international distribution.

In contrast, other determinants lead to plants or service centers of foreign companies to supply the Dutch or Benelux markets. These determinants are perishable food and national regulations on health. Consequently, many small and some big foreign establishments can be expected.

The outcome meets the expectations. In food, the Netherlands accommodates large plants of Philip Morris, Nestlé and Henkel. The Philip Morris establishment at Bergen op Zoom exports 90% of its production[94] and Nestlé 66%[95]. Moreover, Sara Lee has important establishments since it took over Douwe Egberts. Nevertheless, most food and soap companies of the Fortune-list have no large establishments in the Netherlands, such as Conagra, Ferruzzi, Proctor & Gamble and KAO.
Most big drug suppliers have a sales center in the Netherlands to supply the local market, due to differences in European standards. Still, there are some important plants and European distribution centers. Merck, Sharpe and Dohme at Haarlem exports medicines; 85% of its Dutch sales, equalling NLG 1,8 billion, are exported to 130 countries[96]. The Japanese drug maker Yamanouchi has its European headquarters at Leiderdorp. Moreover, Solvay Duphar produces in the Netherlands and exports a lot of its production. Furthermore, Cordis, a world leader in medical heart devices, has a main location at Roden with a high export ratio. This company was recently taken over by Johnson & Johnson, the Fortune's number 1 in medical products.
There are also Dutch plants of major bio-technical companies from the USA, such as Amgen, Genzyme, Centocor and Chiron Therapeutics. Genzyme and Chiron have their European headquarters in the Netherlands and Centocor has a large plant. These companies also carry out R&D in the Netherlands.

In conclusion, the ratio between transport costs of a product and the investments to build a plant to provide the European client, is a main determinant of the pattern of foreign production facilities in the Netherlands. But this ratio does not explain the whole pattern. Additional determinants are the exploitation of the Dutch geographical location and the agglomeration of regional specific know-how of international distribution. Due to these reasons, most of the R&D-intensive affiliates earn a large share of their revenues from

[94] NRC 7/12/1995

[95] 1995. Source: Annual Review Nestlé Netherlands 1995 p.18.

[96] Figure of 1994. Sources: MSD Social Annual Review and Advertisement MSD in NRC 17/11/'94 + FD-yearbook 1994, p.32

exports. Additionally, national regulations and service-demand lead to small scale establishments which mainly provide the Benelux market. It is doubtful if the clusters of the big Dutch companies in chemicals and electronics have contributed to attract foreign enterprises to the Netherlands.

Surveys

Surveys also ask for the attractiveness of the Netherlands as location. Coopers & Lybrand carried out a survey among 55 big US-companies (quoted in FD 25/10/1995), and KPMG asked for the attractiveness of Amsterdam as location compared to London, Brussels, Frankfurt and Berlin (quoted in FD 9/11/1995).

These surveys point to the same factors, which stimulate foreign enterprises to invest in the Netherlands as in this report. This country performs well with its physical infra-structure to the large markets in its neighborhood, and the ability of Dutchmen to speak foreign languages. The agglomeration-effect is silently supported, because Amsterdam is said to benefit from Schiphol Airport nearby. They also mention the influence of the favorable fiscal climate (taxes and subsidies) in the Netherlands and praise its stability. Mentioned disadvantages of Amsterdam as location are a shortage of skilled labor, the Dutch strong currency, inflexible labor laws and the untransparent fiscal system.

A survey by AWT (1993) among a small sample of foreign enterprises with establishments in the Netherlands points to a comparative advantage of this nation in the fields of distribution and the international orientation of Dutchmen (p.24).

R&D-centers of foreign companies in the Netherlands

Why do foreign companies invest in R&D-centers in the Netherlands? Section 4.2 explains that main laboratories of companies remain located near the headquarters largely due to an agglomeration of regional specific know-how. In fact, there are no main research laboratories of foreign enterprises in the Netherlands.

However, regional knowledge still explains the persistence of research activities of foreign companies in the Netherlands. The laboratories have been erected by originally Dutch companies, which have later been taken over by foreign enterprises. These owners have kept exploiting Dutch experience by leaving the laboratory in this country. This holds for Solvay/ Duphar (drugs), Lucent (telecommunication), Paccar/ DAF (trucks), Buderus/ Nefit Fasto (heaters), Petrofina/ Sigma (paint), Cap Gemini/ Volmac (software), Sandoz/ S&G Seeds, Stork Wärtsilä (energy equipment), Sara Lee/ Douwe

Egberts (food), Medtronic/ Vitatron (medical devices), Zeneca/ van der Have (seeds), Thomson/ HSA (military equipment) and ITT/ Koni (shock absorbers)[97]. Due to these take overs, some Dutch know-how is probably transfered to the foreign headquarters.

Corporations have reasons to establish development centers in several countries in order to adapt products to local wants or to use them as watchtower according to section 4.2. Examples of European development centers in the Netherlands are the laboratories of Dow Chemical, Ericsson, IBM (software for internal IBM use[98]), Yamanouchi, Yokogawa and Hercules/Tastemaker. These companies carry out a few percentage points of their company-R&D in the Netherlands. Moreover, most drug companies of the Fortune Global 500-list have a Dutch technical center, which carries out development, often in cooperation with local hospitals.

4.3.2 'Dutch' giants: their investment and exports in the Netherlands

There are three Dutch R&D-intensive giants: Philips, Akzo Nobel and DSM. Moreover, Shell and Unilever are Anglo-Dutch with headquarters in the United Kingdom and the Netherlands. Every company sells its products in Europe, America and Asia as Table 4.3 learns. In particular Philips, Shell and Unilever sell their products globally, while Akzo Nobel and DSM concentrate on European markets. Therefore the boards of directors of these companies must choose to export their products from their European home, or to invest in other continents. In order to decide, they take the same determinants into account as their colleagues of non-European rivals. How have the 'Dutch' giants decided on the international distribution of their investments and why? If the boards have decided in favor of Europe, they consider the advantages of the Netherlands. Why do they invest in the Netherlands? How high are the shares of activities in the Netherlands in fact? And, are these companies leaving this country? These questions are explored below.

Table 4.3 International distribution of sales 1996

	Philips	Shell ('95)	Unilever ('95)	Akzo Nobel	DSM ('95)
	%				
Europe	52	47	52	61	75
North America	20	22	19	23	12
Asia	17	19	14	NA	NA
Rest world	9	12	15	16	13
Total	100	100	100	100	100

[a] Philips Jaarverslag 1996, p.54; Shell Annual Review 1995, p.50; Unilever Annual Review 1995, p.5, Akzo

[97] See section 2.2 of this report for empirical data on these companies.

[98] IBM Netherlands, Annual Review 1995, p.12

Nobel Annual Review 1996, p.77 (netto omzet naar bestemming); DSM Annual Review 1995, p.52

Table 4.4 International distribution of investments in fixed assets 1996

	Philips	Shell ('95)	Unilever ('95)	Akzo Nobel
	%			
Europe	62	40	50	67
North America	13	26	17	24
Asia	19	25	16	NA
Rest world	6	9	17	9
Total	100	100	100	100

[a] Philips Annual Review 1996, p.55; Shell Annual Review 1995, p.59; Unilever Annual Review 1995, p.38, Akzo Nobel Annual Review 1996, p.77. DSM provides no data (excluding acquisitions)

The reasons of the international distribution of fixed assets

How have the boards decided on the international distribution of investments in fixed assets in 1995? Table 4.4 shows that all enterprises have invested in each continents in 1995. DSM does not provide data, but it is certain that by far the largest part of the investments are in Europe. There is a high correlation between the geographical distributions of the sales and the investments, but there are significant differences as well. Next is discussed, how the determinants have contributed to explain the international distribution of investments.

The close link between the distributions of sales and investment can be explained by the combination of two conditions. First, a new plant can produce at optimal scale on each continent, because the demand for the company's products is sufficiently large. Second, endowments, institutions and technology hardly differ across the world. Given these conditions, a company can save transport costs of exports if it manufactures near the customers. The correlation between both distributions should be higher for Unilever, because many food-products must be produced near the consumer, because they can perish. The observed correlation between the distributions suggests that both conditions are fulfilled in a general way. However, they need adjustment, in order to explain the differences between the distributions.

Possibly, the condition of a sufficiently large market for a plant does not hold for many products of Akzo Nobel and DSM in Asia. The same holds for all companies in many poor countries in 'Rest world'[99]. Then it is cheaper to export the products to those countries, instead of investing there. This can be a reason why Akzo and DSM sell a

[99] On top of this, the lack of political stability in many countries in 'Rest world' contributes to favor export to FDI.

larger share of their products in Asia, than they invest, and why the analogous holds for 'Rest world' for all companies, except Unilever.

The condition of equal comparative labor endowments also needs adjustment. Generally, the wages per hour worked in Asia are lower than in Europe, while Asians work with the same technology as workers in Europe and North America. Consequently, manufacturing and assembling is cheaper in Asia. Therefore, the big five prefer to supply the fast growing Asian market from plants near by. On top of that, Philips favors Asian locations as production platforms of components for its electronic systems sold in Europe and America, because Philips can slice up its value chain considerably. Therefore, attractive labor in Asia contributes to explain why the share of investments in Asia exceeds the share of sales on the Asian market.

For Shell matters that natural endowments differ across the world. Shell has a preference for locations near the oil-fields and at sea to bring the crude oil to refineries near the market. The abundance or oil-fields outside Europe, might be the reason why the share of investments in Europe is lower than Shell's sales. Within Europe, the Netherlands is one of the favorable places to invest in oil refineries and basic chemical plants.

The institutions in the regions where the big five operate, agree by approximation. However, differences in tax-rates are worth mentioning. First, the corporate tax rate is lower in Europe than in the USA, which makes Europe attractive. And the Netherlands is a European favorite, because its corporate tax rate is lower than the European average. In particular Philips can benefit, because it operates in electronics, an industry which is vulnerable to this tax rate. The chemical- and oil companies take account of (the threat of) national energy taxes if they decide on the international distribution of their investments.

The role of agglomerated Dutch specific know-how

The determinants explored above do not show a high preference for the Netherlands as location within Europe. This section mentioned as favorable conditions the location at sea which is favorable for Shell, the Dutch corporate tax rate, and the stability of the Netherlands praised in the surveys. These reasons are not sufficient to explain why the companies invest much in Location Holland. The remaining reason why the Netherlands is an attractive location to invest is the advantage of un-codified know-how which is agglomerated in the Netherlands since the Dutch giants started their operations. Each headquarter is a center of a network of regional jobbers, co-makers, co-developers and universities, which clusters with the firm specific know-how of the company. This type of know-how anchors the company at its birth-place persistently. Viewed from the Netherlands, this type of knowledge is a comparative advantage.

Section 4.2 states that the place of birth of many R&D-intensive companies is due economic conditions and chance. To which extent is this true for the 'Dutch' big five?

And can the persistent impact of agglomerated regional know-how be demonstrated with the Dutch pattern of specialization?

Agglomeration of regional know-how around Philips

Agglomeration of know-how can be illustrated with the Philips-network in the Netherlands. Philips as user shares and exchanges much know-how and experience with a network of more than fourteen thousand Dutch suppliers[1]*. From this large number follows that there is probably much specific know-how on electronics in this country shared by these enterprises with Philips at the center.*

Among these business relations, some companies jump out. Philips is a shareholder and main customer of Neways Electronics. This company with a research center at Nuenen, has taken over several Philips' divisions in 1992 and 1995[2]*. Moreover, ASM Lithograpgy (Veldhoven) has emerged as the world's number 3*[3] *in the production of wafer steppers (semi conductor machinery), based on equipment developed by Philips. Still Philips is one of its shareholders. Furthermore, the software maker Origin acquired the Philips' division "Communication and Data-processing" in 1996, while Philips is its largest shareholder. Philips took over the medical device specialist Pie Medical (Maastricht) in 1995, after a long period of cooperation*[4]*. In 1997 a development center and a plant of LEDs is built at Eindhoven in a joint venture with Hewlett Packard, which exploits know-how of both companies*[5]*.*

Hence, the province of Limburg is a center of gravity of these activities. This is underlined, as another main laboratory of Philips is at nearby Aachen (Germany).

Philips diffuses knowledge with the public knowledge infrastructure as well. For example, Philips cooperates with the "Stichting Fundamenteel Onderzoek naar de Materie" and three Technical Universities[6]*. And, forty Philips-employees are professors at Dutch universities*[7]*. Also, Philips supplies know-how to small and medium sized enterprises with regional Innovation Centers as vehicles*[8]*.*

We have doubts to which extent other agglomerated electronic know-how in the Netherlands belongs to the Philips-cluster. It concerns know-how of former Philips' divisions with R&D-activities, which have been taken over by foreign companies later. Such as the telecommunication division at Hilversum by AT&T (at present Lucent) in 1988, and the military equipment division HSA at Hengelo by Thomson in 1989. Also, we do not know if there are knowledge transfers between the European distribution centers of Philips' rivals in the Netherlands and the Philips-network. There is no clear evidence that the Philips-network has attracted other electronic companies.

[1] Director Social Affairs Philips Netherlands, de Haas, in FD 23/2/1996
[2] NRC 14/2/1995 and NRC 13/9/1995
[3] NRC 7/12/1995
[4] NRC 2/11/1995
[5] FD 17/1/1997
[6] Director Philips Research in De Ingenieur 7/2/1996
[7] Philips CEO Timmer at annual FEM-meeting 15/11/1995, The Hague
[8] Ministry of Economic Affairs, 3/6/1994.

The economic conditions in the Netherlands were becoming favorably for entrepreneurs since 1870, when the industrial revolution started in this country. But additionally, the places of birth of Philips, Unilever and Shell are rooted in the entrepreneurial spirit of their founding fathers, who were Dutchmen by accident. The availability of natural resources and technical know-how in the Netherlands at the year of first market entry were far less a cause.

The main reason for the location of Philips in the Netherlands is the initiative of their founders Gerard and Anton Philips and the financial help of their father, a tobacco-trader at Zaltbommel in 1890. A successful market entry was enhanced, because the Netherlands lacked the entry barrier of a patent law. This country did not protect the Edison bulbs in contrast to Germany and the United Kingdom around 1890. This gave the Netherlands a comparative advantage as location for newcomers. Bulbs hardly need materials and the know-how was acquired during Gerard's study-trips to the United Kingdom and Germany, where AEG and Siemens were emerging[100].

Light-town Breda?

Philips provides a nice illustration of chance as a determinant of location, because accident has caused that it is Light-town Eindhoven instead of Light-town Breda. The location of Philips' headquarters at Noord Brabant is determined by a comparative advantage of cheap labor of this province within the Netherlands. The choice for Eindhoven is due by chance. Breda had an equal opportunity. The Philips-family had even bought land there. No documents are left, which give the reason for Eindhoven as the final choice. Possible explanations are tobacco-connections of the Philips' family in Eindhoven's neighborhood; or the sudden opportunity that an unoccupied textile-factory at Eindhoven was for sale[1].

[1] Sources: Heerding (1980) p. 326-328 and Brugmans (1960), p. 336.

The persistent impact of agglomerated specific know-how on electric light in the Netherlands can be observed from its balance of trade. In 1993 the Dutch exports of lamp-varieties of NLG 1147 million exceeded the imports of these products of NLG 562 million considerably[101].

Also the Dutch part of Unilever has its roots more in commercial than in technical spirit.

[100] See Heerding (1980). For the study-trips, see p.91; for the impact of the absence of the patent system, see: p. 292-293.

[101] Source CBS, Jaarstatistiek van de Buitenlandse Handel 1993, A-nrs 8539(1-4)...

The butter-traders van den Bergh and Jurgens at Oss[102] launched a new product: margarine. The location is not determined by the inventor or natural endowments. Jurgens bought the patent from a Frenchman and the animal fat was imported from the USA. From the start, the export ratio of margarine was high: the plant at Oss exported 90% of its production in 1897. The influence of agglomerated know-how on margarine production in the Netherlands is still visible in its balance of trade. In 1993 the Netherlands exported NLG 290 million of margarine-brands, while its imports amounted only NLG 67 million[103].

The roots of Shell in the Netherlands are also due to the commercial know-how of Dutchmen, and not to the availability of natural endowments or technical knowledge in the Netherlands. The raw material was found in Indonesia, at that time a Dutch colony. Companies from the USA provided the know-how of drilling and refining. The headquarters and sales center moved to the Netherlands in 1896. At the Hague, it was easier to get access to information of world oil prices and tanker freight fares[104].

However, the location of Akzo Nobel and DSM (the former Dutch State Mines) are mainly determined by the availability of natural endowments, namely salt at Boekelo respectively coal at Limburg. These endowments were inputs in large production processes for chemical products, which were entirely new in the period between the two world wars. On top of that, what would become as another division of Akzo later, started as an independent producer of artificial fibers at Arnhem during this same period[105]. At present, the Netherlands is still specialized in salt products and artificial fibers, which suggests that agglomerated specific know-how persistently contributes to this performance. In 1993, the Netherlands exported NLG 115 millions of salt products and imported for NLG 31 millions[106]. For artificial fibers the corresponding figures are NLG 1808 millions of exports and NLG 1172 millions of imports[107].

Evidence on preference for Location Holland

Have the giants preferred location Holland indeed? Are these companies leaving the Netherlands? Three indicators provide evidence: the share of fixed investments in the company's total, the production in the Netherlands compared with the sales of the company's products on the Dutch markets, and the export ratio of the Dutch plants.

[102] Brugmans (1961) p. 332-335

[103] Source CBS, Jaarstatistiek van de Buitenlandse Handel 1993, A-nrs 1517.....

[104] Brugmans (1961) p. 338-343

[105] Brugmans (1961), p. 477-480

[106] CBS, Jaarstatistiek van de Buitenlandse Handel 1993, A-nrs. 250100...

[107] CBS, Jaarstatistiek van de Buitenlandse Handel 1993, 2-digit group 54.

The shares of investments in fixed assets in the Netherlands in the company's total indicate that the companies are not leaving this country. Chart 4.2 shows that Philips invested about a quarter of its total in the Netherlands during 1976-1983 and this share fell a bit to about 20% in recent years. Akzo Nobel and Unilever pursue a constant share strategy of about forty respectively five percent. Although, it is striking that Akzo Nobel dropped its Dutch-share considerably in 1996.

Preference for the Netherlands can be derived from the ratio of the manufacturing production in this country and the sales of its specific products in the Netherlands. Most often, these products are manufactured in facilities in other countries. The value of the Dutch production of Philips, Akzo Nobel and DSM exceeds many times the value of their sales on the Dutch market as Table 4.5 shows. These high ratios suggest that the companies have a preference for the Netherlands as location of their plants. Moreover, there is no evidence of a withdrawal from the Netherlands, because the production/sales ratio has increased during the last decade.

Table 4.5 Production/Sales ratio in the Netherlands

	1987	1995
Philips	4.8	6.5
Akzo Nobel	3.4	3.6
DSM	3.1	5.1

The same can be demonstrated in a slightly other way. The Dutch plants of Philips, Akzo Nobel and DSM have very high export ratios as Table 4.6 shows: they almost sell their whole Dutch production to affiliates and other clients in foreign countries. These companies have hardly Dutch clients, excepted intra-company deliveries in the Netherlands. This high export ratio is due to the specialization on specific products, which is needed in order to exploit economies of scale in the plants.

The Unilever plants export a much lower share of their production. This is mainly due to differences in regional tastes. 'Consumption is local': Germans like sausages and potatoes, Italians prefer pasta, Indonesians rice, and Chinese noodles. In order to meet the differences in demand, Unilever has developed into a 'multi-regional multinational enterprise'. There is no reason for high Dutch exports, because 'the Dutch taste doesn't make the whole world happy'[108]. On top of that, many food products are often perishable. Both factors have the same impact as high transport costs. Then, foreign investment near the clients is preferred above exports from the home-country.

Chart 4.2 Dutch share in company-investment (%)[a]

[108] Quotations (translated from German) from WirtschaftsWoche 27/2/1997 in an interview with Unilever's CEO Tabaksblat: 'Die holländische Gesmack macht nicht die ganze Welt glücklich'.

Philips

Unilever

Akzo Nobel

Shell

[a] Based on the expenditures. AKZO's share since 1991 based on the development of research employment.

Table 4.6 Export/Production ratio in the Netherlands[a]

	1987	1995
	%	
Philips	93	96
Akzo Nobel	86	88
DSM	86	95
Unilever	43	44

Research and Development

How and why have the boards of directors chosen for the Netherlands as location of R&D? Chart 4.2 shows that the shares of Dutch R&D in the companies' total is high. Moreover, this share is not declining, which indicates that these giants are not leaving the Netherlands with their R&D. Only Philips, dropped its share in recent years.

Philips has spent almost half of its R&D in the Netherlands since 1976, with an emphasis on basic research. However, during recent years, this share has dropped to 36% in 1995 (equalling about 8 thousand R&D-employees). This decline has two causes. Philips has saved in particular on basic research, which especially hits the main laboratories. This reallocation continues as Philips is still dropping its research personnel at its central laboratory with 7%[109]. Furthermore, Philips extends its development centers near their clients in foreign nations, in particular where their demand is booming. For instance, its Singapore headquarters increases its R&D-personnel from 15 to 70 employees[110]. The Netherlands is Philips' center of other creative know-how. This country hosts Philips' Center for Manufacturing Technology too. This center, which employs 700 people, implements the new scientific ideas from Philips Research into mass production[111]. On top of that Philips' Corporate Design Center with 350 personnel[112], is mainly active in this country.

The Dutch share of the R&D-expenditures of Akzo Nobel is also high and has slightly risen since 1984 to about 50 percent according to Chart 4.2. Recent R&D-reorganizations indicate that this rise may continue, because Akzo Nobel is centralizing its research at Arnhem, Oss and Scotland. Akzo Nobel mentions as reasons that centralized research can better exploit available know-how as well as economies of scale. The latter regards Akzo Nobel important, because the fixed costs of scientific

[109] NRC 5/10/1996

[110] FD 1/10/1996

[111] FD 22/3/1995, NRC 22/3/1995

[112] Philips (1995), p.17

equipment are rising due to new research methods, such as gene-therapy, and the use of robots[113].

Shell carries out almost half of its R&D in the Netherlands. This share is high indeed, if it is taken into account that this corporation thinks in hemispheres in its Annual Reports, while it has its roots in two countries. Furthermore, this share has risen during the last decade. The main reason is the closure of two laboratories outside the Netherlands, and not a large increase of R&D-spending in the Netherlands[114]. Moreover, the positive trend may reverse. Shell drops its R&D-employment due to shift in emphasis from research towards development[115]. This shift from research to development hits in particular the main research centers, and favors local development centers.

Unilever has five main laboratories in the United Kingdom, the Netherlands, the USA and India. Unilever spent NLG 350 million in the Netherlands, of which NLG 250 million on research at its main Dutch laboratory at Vlaardingen in 1995[116]. Chart 4.2 shows that Unilever spends about a quarter of its R&D in the Netherlands, which is a smaller share than Shell, which is also Anglo-Dutch. The research efforts of Unilever in the Netherlands have increased a bit since 1990, mainly due to the erection of the Bio-technology Application Center at Naarden in 1995, which builds a bridge between research and mass commercial production[117]. Finally, DSM it the most Dutch of the companies. Consequently, the company carries out almost all its R&D in the Netherlands.

That agglomerated regional know-how is a determinant for location can also be demonstrated by the comparison of the Dutch shares of R&D and fixed assets. Chart 4.2 shows that the Dutch R&D-shares exceed those of fixed assets. The reason is that research benefits more from agglomerated company-specific know-how than equipment. The know-how needed to tend machines can easier be transferred and learned from instructor's guides.

In conclusion, the Dutch big five corporations have a preference for manufacturing in the Netherlands. This holds even more for main research. There are no signs that both

[113] FD 2/10/1996

[114] Source: Shell. It should be noted that the share of R&D in the Netherlands of Shell (and probably Unilever) also depends on the exchange rate between the pound and the guilder.

[115] NRC 4/10/1995, FD 5/10/1995, FD 6/11/1995

[116] J. Nieuwenhuis, chairman directors Unilever Research Laboratory Vlaardingen, "Een reactie op de regeringsnota Kennis in Beweging", Vlaardingen, 20/10/1995

[117] FD 10/11/1995, Algemeen Dagblad 21/6/95

activities leave this country. The preference for Location Holland in mainly due to agglomerated tacit know-how in the clusters with these enterprises at the center. Originally, Location Holland has been determined by chance. There are no clear indications that the clusters of the Dutch chemical corporations and Philips have attracted foreign companies to this country.

4.4 Implications for location policy

There is not such a thing as the market mechanism of R&D-intensive corporations in a single country. But their global battle does have consequences for every country, which demands their products or which hosts their establishments. These consequences follow from the two types of investment decisions of the boards of directors, namely the companies' expenditures on R&D and fixed assets and their international distribution of investments.

This section explores how policy makers, and in particular those of the Netherlands, can influence the decision on the international allocation decision of R&D-intensive corporations. A distinction between foreign and home companies is not needed, because all boards are led by the same determinants. Table 4.7 summarizes the determinants and the related policy instruments, which are discussed below.

Table 4.7 Policies with an impact on location decisions

Determinant	Instrument
Regional related factors	
Labor	education
Special natural endowment: location at sea	infra-structure
Agglomerated regional special know-how	enhancing regional clusters
Institutions	
– Taxes/Subsidies	tax policy
– Stability currency	monetary- and fiscal policy
– Health and safety	national regulations
Transport or local plants	
within Europe	infra-structure
	electronic traffic control
	remove trade barriers
trans-continental barriers	fortress Europe

Regional related factors

Education is important to attract investments of R&D-intensive companies due to two reasons. First, better education produces skilled people, who are required by the R&D-intensive corporations to develop, produce and sell their high quality products. Second, higher skilled people have more purchasing power than low skilled citizens. And more purchasing power leads to a larger market size, and large markets attract investors.

A better exploitation of specific natural endowments also attracts investors. For the Netherlands this implies that investments in tangible and communication infra-structural networks into Northwestern Europe are needed to a level which avoids future bottlenecks.

Governments can strengthen regionally clustered know-how in fields where the nation has already a comparative advantage. It makes the activity more persistent in the region. Instruments should shape better conditions, but not disturb the market mechanism. Such instruments are the supply in the regional cluster of education and university-research which meet the needs of the clusters. For example schools and universities near the headquarters of the R&D-intensive companies. Also, the exchange of ideas should be stimulated. The benefits of the exchange of know-how within the region leads directly to a better exploitation of know-how. Moreover, the gathering of know-how from outside the cluster is very important, because it also leads to more agglomerated regional know-how. The reason is that the external knowledge contributes to this year's increase in the output of ideas, while these new ideas belong to the agglomerated tacit stock of knowledge next year.

However, this kind of policy stimulates foreign companies to erect watchtowers in the shape of development and sales centers, which have the task to transfer know-how to their foreign headquarters. This transfer may hurt the future competitive position of the region.

The Netherlands has advantages in the fields of international distribution, the agricultural-industrial cluster, and networks with the `Dutch' big five manufacturing companies in the center. It is doubtful whether there are links between the stock of know-how of the electronic distribution centers and the know-how of the Philips cluster. The same holds for the knowledge in the plants of foreign companies which produce basic chemicals at the Dutch shore and the agglomerated know-how of Shell, Akzo Nobel and DSM in this country. As far as there is too little knowledge exchange indeed, it may be a concern for policy makers.

In theory, governments can help to start a regional cluster with government procurement of a new project. An actual dilemma is the government as the leading edge customer of electronic highways. The arguments pro government procurement are: 1) a first mover advantage can be built up, with acquired experience which is locked in the national borders, 2) the country contributes to a better exploitation of external know-how which is linked to the network, 3) the electronic network may replace passenger traffic which is beneficial to the environment. Against it plea that 1) it takes enormous amounts of money and high risks, so that the social returns can be disappointing, and 2) foreign governments may retaliate, which could make the outcome even worse.

Policy makers have a direct responsibility for institutions. First, the corporate tax rate is an important instrument for R&D-corporations. First, low tax rates stimulate investments in R&D and fixed assets via the net profits according to section 3.2. On top of that, low average corporate tax rates attract foreign investors[118]. The average tax rate on profits is more important than the marginal rate, which affects only the capital costs[119]. A disadvantage of the corporate tax-instrument is that it may lead to competition between governments with the tax-rate at stake.

Second, high stability attracts investors, because they avoid risks. Surveys tell that the Netherlands is a favorable location in Europe, due to its stability. Therefore, an economic policy which pursues stability is favorable[120].

Third, national regulations on drugs and food products make that there are small establishments of foreign companies in most countries. If national regulations of drugs and food product become more standardized within Europe, probably many national centers will close. The few which remain will expand to large establishments which supply and service a larger area.

Transport costs

The ratio of transport costs and the fixed investment of a new plant has an impact on the international distribution. Governments cannot affect the fixed investments per plant, because these are determined by technical opportunities. However, the European governments have instruments which affect transport costs. Europe can attract investors from America and Asia if it supplies lower transport costs within this continent and higher trans-continental transport cost. How can governments achieve this and what are probable consequences?

If the transport costs within Europe are reduced, economies of scale on European establishments can be better exploited, which favors cheap production. This attracts companies from Asia and America, while big European companies are more eager to invest in Europe and export to other continents instead of investing there. Instruments which stimulate such a development are investments in better networks of physical infra-structure and electronic traffic control systems, and policies which stimulate economic European integration. If a single country, say the Netherlands, invests more

[118] For empirical support, see Grubert and Mutti, (1996), who base their analysis on 500 US companies in 60 countries.

[119] Devereux and Griffith (1996)

[120] As an example, a survey especially mentioned the stable Dutch guilder. If the exchange rates between the EMU and the dollar or yen are getting more volatile, it has an impact on the international distribution of investments. Then multinationals will spread their plants among continents in order to avert risks. This implies that more violent exchange rates of the EMU with the dollar and yen, speeds investments of US' and Japanese companies in Europe. In turn, European companies will shift their investments from Europe to America and Japan. See Goldberg and Kolstad (1995) for the arguments and empirical evidence based on two-way bilateral FDI-flows between US-Canada, US-UK and US-Japan. This reasoning has not taken account of possible disturbances in inter-continental dividend payments.

in traffic systems than other European countries, it creates an advantage within Europe as a location for enterprises to invest.

If European policy makers make a fortress Europe, which is difficult to enter due to high trade barriers, the trans-continental transport costs rise. As a direct effect, American and Asian multinationals are stimulated to invest in Europe. But their governments probably will retaliate. This leads to considerable market distortions. World trade will drop and the big companies will invest in all continents. Then, economies of scale in these plants are not fully exploited and the number of products is reduced. These factors lead to less welfare[121].

[121] Even the threat of a fortress Europe can distort the market mechanism. It stimulates multinationals from other continents to invest in Europe if they anticipate the real erection of the barrier. These companies try to gain from first mover advantages compared with their non-European rivals. However, these companies need not get their reward. This happens if a European target, such as a lower unemployment rate, has been reached by means of the non-European investors, before the barrier is erected. Then, the threat is lifted and the first movers have a loss compared to their rivals, who abstained from investment in Europe and kept exporting to this continent. See for a deteiled analysis Blonigen and Feenstra (1996)

5. Macro-economic impact of new products

Abstract

New products and their substitutability with existing ones contribute to macro-economic growth, in spite of the destruction of existing products by created ones. This section describes the relevant mechanism and offers empirical illustrations. The combination of the rate of product creation and substitutability has consequences to assess the contribution of industries to growth, changing R&D-strategies of corporations and official statistical information. First, on average, new electronics, computers, vehicles and drugs stimulate growth and welfare more than new mechanical machines, desserts, beers, or ice-creams, if these industries have equal growth rates of product differentiation. Second, the present shift in emphasis from Research to Development of many big R&D-intensive corporations may hurt future economic growth. Third, the growth rate of productivity is underrated and inflation exaggerated if statisticians insufficiently take account of changes in product differentiation.

Introduction

This section leaves the board-rooms of the directors. The corporations battle on a bounded playing field. But the impact of their investment behavior extends far beyond this area. The R&D-intensive products are bought by enterprises anywhere in the economy, which use them as inputs in their production processes. These buyers gain from higher productivity. For example, computers developed by electronic companies are bought by bankers; trucks made in the car-industry are used in the transport industry; copiers are used in offices, and drugs in hospitals. Also, the consumer enjoys directly from more choice out of, for example, a wider variety of compact discs or season beers.

This section explores briefly the impact of new products on economic development according to key topics in the view on endogenous growth of Grossman and Helpman (1991). More precisely, this section is concerned with the process of product creation, the impact of the growth rate of the number of products and their mutual substitutability on macro-economic production and welfare, and creative destruction. The arguments are supported with empirical evidence. Also, this section assesses why the shift in emphasis from research to development of many big R&D-intensive companies may hurt future economic growth. Finally it is explained how the rise in national productivity is underrated and inflation exaggerated if statisticians do not take properly account of creation and the substitutability of products.

Creation of products

R&D-corporations invest much in the creation of products to satisfy the need of their clients. Their number is determined by the size of the R&D-budgets and the efficiency in the creative centers of the companies. The efficiency is determined in several ways as section 3 explained in detail. This reasoning can be summarized in formulas[122]:

(1) $\Delta n/n = \gamma H n^{\rho-1}$

where $\Delta n/n$ is the growth rate of the number of products, H the combination of research employment and scientific equipment, γ the efficiency of creation centers, n stock of know-how, which directly corresponds with the stock of products, and $0 < \rho < 1$. Thus, given the R&D-employment, the growth rate of the number of products is accelerated if 1) researchers are more efficient, which makes γ larger and 2) concentration of research, institutional agreements or technological improvements give more access to existing know-how, so that ρ rises.

Table 5.1 New patent applications in Europe (1994)[a]

	absolute number
Information technology	19,734
Electronics, Electrical (30,31)	9,714
Instruments (26,27,28)	10,020
Health, New materials	16,760
Health, Soap (4,5)	5,107
Food, Agriculture (2,1)	1,334
Chemistry, Drugs (12-16)	10,319
New Mechanics	9,096
Aircraft, cars (10)	2,440
Shaping (7,8)	3,158
Machinery (22,23,25)	3,498
Extraction/ Better processes	6,859
Metals (17)	952
Nucleonics (29)	147
Mining (21)	222
Mixing, Internal transport (6,11)	4,307
Light, Heating (24)	1,231
Rest	5,366
Total	57,815

[a] European Patent Office, Annual Review 1994, Statistical Annex, tab. 2.3. Between brackets: the row of table 2.3.

There is plenty of evidence that the number of products which is annually added to the stock of products is enormous. On a general level this can be demonstrated with the

[122] This is the shortened knowledge production function in section 3.3, where $H = L_{RD}^{\lambda} I^{\mu}$, $\delta=0$.

absolute number of patent applications in Europe. Each application is potentially a new product, which is based on research in the exact and natural sciences. It appears that almost 60 thousand new technical ideas are registered with an emphasis on information technology (Table 5.1).

Ad-hoc evidence supports the view that the increase in the number of products is high. The maker of office devices 3M earns 7% of its revenues on products which are less than a year old, and 30% on products less than 4 years old[123]. The copier producer Océ launches a new type each year in the USA, because Americans want a new machine every 3-5 years, although a type technically lives for 10-15 years[124]. On the borderline of banking, marketing, retail trade and telecommunication emerge new products, like chip cards. Moreover, many new compact discs are released each year, which differ from each other. In biotechnology, Unilever e.g. expects rapid growth in the number of products based on bio-technology, with sales boosting from $ 7 billion in 1995 to $ 100 billion in a few years[125]. Each year about 48 'NCEs' (new chemical substances) are introduced by the pharmaceutical industry[126]. More than a third of the sales of Johnson & Johnson, the world's biggest producer of medical devices, comes from products launched in the past five years[127] and 50% of Bayer's revenues originate from products which did not exist 15 years ago[128]. In 1995, 20% of all brands of Unilever's ice creams have been introduced in the recent 2 years[129]. A hundred new perfumes were launched in 1995, while a decade ago it were only 30-50 new ones[130].

There are even indications that the growth rate of the number of products is accelerating. For instance, Siemens launched almost 70% of its products less than 5 years ago, while this share was much lower in 1980 (Table 5.2).

[123] Data 1994, The Economist 18/11/1996

[124] Océ's director Dix in FD 6/10/1995

[125] mr Peelen, member management board Unilever in FD 10/11/1995

[126] Nefarma Annual Review 1994

[127] The Economist, 29/4/1995

[128] Bayer, 1995, Research, Das Bayer-Forschungsmagazin, Ausgabe 7, p.4

[129] NRC 21/7/1995

[130] NRC 20/11/1995

Table 5.2 Siemens' Product innovation[a]

	1980	1994
Introduced	%	
Less than 5 years ago	48	68
Between 5-10 years ago	30	23
Longer than 10 years ago	22	9

[a] Source: Siemens in WirtschaftsWoche, nr 44/26.10.1995.

Impact number of products on macro-economic production and welfare

The stock of products determines macro-economic production and welfare levels. Products are professional goods if they are inputs in production processes. Inputs can be machines or intermediates[131]. The enterprise which buys the devices combines them to an equipment system. Assume, that this system is mixed with jobs in such a way that on a macro-economic level the employees earn 3/4 of the added value according to:

(2) $y = L^{3/4} S^{1/4}$

where y is macro-economic production, L national employment and S national equipment system. The equipment system is built up of different types of machines. Assume that the plants accommodate an equal number of each type. Each type contributes in a specific way to the equipment system. In other words, they can only partly be substituted for each other. Therefore the value of the system exceeds the sum of its components. This can be expressed as follows:

(3) $S = (nx^{\alpha})^{1/\alpha} = (xn)\, n^{(1-\alpha)/\alpha}$

where n is the number of types, x number of machines per type and $0<\alpha<1$. The substitution elasticity between types equals $1/(1-\alpha)$. This elasticity is low if the types are mutually very different. This elasticity increases as the types are becoming more alike. In the extreme case, the types are equal. Then they are homogeneous and the elasticity of substitution is infinite.

Moreover, the total number of machines, irrespective of their type, equals

(4) $C = nx$.

where C is the total number of machines, irrespective of type. Substitution of (3) and (4)

[131] The only difference between them is that machines live longer. This difference does not matter for the reasoning here. Therefore, we use "machines" instead of "machines and intermediates".

in (2) gives:

(5) $y = L^{3/4} * C^{1/4} * n^{(1-\alpha)/(4\alpha)}$

Thus, macro-economic production depends on employment and capital as if it is a homogeneous input in a constant returns to scale relation. On top of that, the stock of types contributes to production with elasticity $(1-\alpha)/(4\alpha) > 0$.

Consumers derive pleasure from consumer products. Their so-called welfare function can be derived from the number of consumer products along the same reasoning as an enterprise which uses machine-types as inputs. Consequently, the same formulas apply for consumer products as for professional ones. Only, the interpretation of the symbols differ: y is welfare, L the amount of homogeneous consumer goods, C the amount of heterogeneous products expressed in kilograms, and n the number of consumer products.

In conclusion, the number of products is a determinant of the levels of production and welfare in theory. There is ample evidence that this number is high in practice, which suggests that the impact on production and welfare levels cannot be neglected. For instance, in information technology, Philips sells 10 different video apparatus and 44 CD-recorders[132]. Philips owns 60,000 patents and 700 trade-marks[133] and this corporation assembles 400 different types of television sets at its Brugge plant[134]. Siemens boasts to sell 65 thousand product types[135]. Sun Microsystems supplies 'more than 9,300 third-party software and hardware products'[136]. Computer Associates International writes: 'Our product family of over 300 leading-edge applications covers virtually every kind of business software there is'[137].

The number of medicines and health products is enormous as well. Merck, Sharpe and Dohme, for instance, distributes 3,300 drugs from its Haarlem-location over Europe[138]. Pfizer sells 166 pharmaceutical and health trademarks[139], Astra 59 trademarks[140] and

[132] Philips Europa Magazine 95/96

[133] Philips (1995), p.55

[134] FD 22/3/1995

[135] Siemens Annual Review 1995

[136] Annual Report 1994

[137] Annual Report 1995

[138] Advertisement in FD-Jaarboek 1994, p.32

[139] Annual Review 1995, p. 63

[140] Annual Review 1995, p. 68

GlaxoWellcome 33 principal trademarks[141]. The 'Food Specialities Division' of the Dutch biochemical specialist Gist-Brocades has a product list of 61 trademarks[142]. Procter & Gamble sells 2,200 products in the USA[143]. The Dutch food-producer Mona sells almost 100 desserts, and introduces each month a new 'dessert of the month'[144].

The basic chemical-industry, often considered to produce commodities, makes in fact many distinct product types. For example, Dow Chemical manufactures 2000 semi-finished varieties in its Dutch locations[145], and Du Pont produces 1200 items of technical plastics at Dordrecht, its Dutch location[146].

Nyloplast, a Dutch maker of plastic connectors, produces 1200 varieties[147]. And Geerts Metaalwaren, a small Dutch manufacturer of metal products, manufactures 3 thousand products[148].

Creative destruction

Creation destructs. The launch of new products leads to a drop in sales of existing products. Assume that the total number of machines or consumption goods expressed in joules, kilograms or liters is given. Then C = nx = a given amount in joules etc, which implies by approximation $\Delta n/n=-\Delta x/x$. Hence, the entry of new product leads to a decline in the sales of existing products.

For consumer products, this effect can easily be demonstrated with beer, where the number of liters per capita even remained constant. Since 1980, a German citizen drinks

[141] Annual Review 1995, p.84

[142] Annual Review 1995, p. 80-81

[143] It is noteworthy that P&G is cutting its product variety. In 1991 this corporation sold 3,400 items. The reason is that the brands are resembling each other too much. This high substitution elasticity combined with low sales per item is not profitable, because the marketing costs are too high. For instance, P&G supplied 31 varieties of Head & Shoulders in the USA. Also, 'in Japan, P&G cut the number of its Max Factor cosmetics items from 1,385 in June, 1995, to 828 nine month later'. The cutting of variety led to a decline in P&G's marketing budget from 25% of sales to 20% today. (Source Business Week, 9/9/1997)

[144] NRC 22/8/1996

[145] Dow, "Dow in Terneuzen", 1995

[146] FD 7/2/1997

[147] FD 19/5/1995

[148] FME/CWM, Metalectro Profiel, february 1997

about 140 liters of beer annually[149]. However, the variety of beers has increased considerably since that year. But commodity-beer is replaced by season-brands, regional champions and low-priced beer, as Table 5.3 illustrates for Germany. In order to distinguish their products from those of their competitors, brewers raise their investments in advertising: 'marketing used to be an unknown word. Now, image is crucial'[150].

Table 5.3 Beer market shares in Germany[a]

	1970	1994	2000
	%		
Specialties	10	36	45
Medium class	88	53	40
Low-price	2	11	15

[a] Source: GfK, Brau und Brunnen quoted in WirtschaftsWoche 29/2/1996.

Ice-cream is another nice illustration. Many years ago, a consumer could choose between an ice-cream for children or adults, which differed in amount only. Today, an ice-lover buys emotions like 'self-pampering' and 'refreshment' and chooses from niche-markets with different mixes of image, shape, taste, amount and color. For example, children can select from dinosaurs- to space-shuttle-ices, and slimming persons can pick out calorie-poor, small-sized creams[151]. Yet, ice-consumption in liters per consumer has not changed much.

Examples of radical innovations are color TV-sets which replaced black/white screens and compact discs which pushed gramophone-records from the market. In both cases the number of sets respectively releases have hardly changed.

Also, in professional goods new varieties have pushed existing ones from the market. For instance, the Dutch instrument maker Nedap supplies no products which are older than 5 years[152]. The product life cycle of a drug has shrunk by about two years during the 1990s[153]. And Siemens mentions implicitly in Table 5.2 that it does not sell devices

[149] Source: Productschap voor gedestilleerde dranken in association with NTC Publications Ltd, 1993, "World drink Trends 1993". For the Netherlands, the same holds. A Dutchman drinks a constant amount of 86 liters of beer per capita annually since 1980, while the number of imported beer brands rose from 2,5 liters in 1980 to 4 liters in 1995. Source: Productschap voor gedestilleerde dranken, bijlage bij het jaarverslag 1995, p.18.

[150] A German brewer in Business Week 21/8/1995

[151] NRC 21/7/1995

[152] Interview J. Hogen Esch in NRC 18/7/1996

[153] Nefarma Annual Review 1994

which were launched longer than fifteen years ago. Also, new software-versions of word-processors push existing aside ones, keeping the total number of programs fixed. Furthermore, the generations of central micro-processors follow each other fast, while each personal computer still contains one such a chip.

The engine of economic growth

The endogenous economic development follows from two arguments. First, the manufacturing of new products needs scarce resources, such as labor and scientific equipment. Moreover, the output of new products ($\Delta n/n$) in equation (1) is an input in the macro-economic production function, which determines economic growth. More precisely, from relation (5) follows the impact of the growth rate of products and the substitution-elasticity between products on long-run macro-economic growth:

(6) $\Delta y/y = (1-\alpha)/(4\alpha)\ \Delta n/n$

Hence, the combination of the substitution elasticity and the growth rate of products is the engine of economic growth. By way of illustration, Table 5.4 lists for some substitution-elasticities the impact on long-run economic growth of 1% more products. It reveals that new products which equal existing ones -substitution elasticity infinite- have no impact on economic growth. In contrast, if the new products are rather radical inventions, they are hardly substitutable for existing products. If all products are based on this type of inventions, say with substitution-elasticity 2, an annual increase of 1 percent in the number of products leads to a long-run economic growth of 1/4 percent each year.

Table 5.4 Relation substitution elasticity on economic growth[a]

Substitution elasticity between products	Economic growth due to 1% growth in number of products
2	1/4%
5	1/16%
infinite	0

[a] The coefficient α ($0<\alpha<1$) determines several other key notions as follows: substitution elasticity $1/(1-\alpha)$, production growth due to 1% growth in number of products and profit margins is: $(1-\alpha)/(4\alpha) > 0$ and profit margin of the supplier of the product $1/\alpha$.

Industries differ as regards the substitution-elasticity between their products. Consequently, their contributions to economic growth differ given an equal growth rate of products. On average, companies who develop electronics, computers and vehicles produce apparatus which are more or less radical innovations. Thus, their substitutability is low and their contribution to economic growth is considerable. Assume that their substitution-elasticity equals 2 and the growth rate in products is 4%[154], than the economy grows 1 percent annually[155]. In contrast, machine makers mainly adapt existing products to the specific needs of their customers by changing them slightly. Then, these types can rather easily replace each other. If, for example, their substitution elasticity equals 5 and the number of types also grows with 4% each year, then macro-economic growth rises annually only with 1/4 percent.

The same kind of reasoning holds for the direct impact of new products on welfare. For example, drugs which fight different diseases, such as high blood pressure or cancer, have a low substitution-elasticity. The contribution of more drugs on welfare growth is therefore higher than an equal growth rate in types of desserts, ice-creams, beers or perfumes.

The danger of a shift from Research to Development

Many corporations have reorganized their creative centers in recent years in shifting the emphasis of the R&D-efforts from Research to Development. Research is experimental or theoretical work undertaken primarily to acquire new knowledge, with or without a practical objective. In contrast, Development draws on existing knowledge and is directed to producing new devices, processes or systems or to substantial improvement of existing products[156]. For example, at present Philips Research 'is for the prototypes, the technical science. Not for the Nobel Prize'[157]. Also Shell is shifting its emphasis from Research to Development and improvement of existing products. Characteristically, 'Technical' is added to the name of Shell's main Dutch laboratory to 'Shell Research & Technology Center Amsterdam'[158].

There is a danger that this strategy-shift by many R&D-intensive corporations in the world will hurt long-run macro-economic growth. Conditional on the assumed formulas above, the reasoning can be illustrated as follows. Suppose that before the reorganizations started, the products had a substitution-elasticity of 2 and that each year the stock of products increased with 4 percent. This led to a long-run production increase of 1 (=4/4) percent per year according to Table 5.4. The shift to development makes that the

[154] For some empirical support for this rate of growth, see de Graaf, Minne, Noordman, 1996, p.17-18.

[155] The most radical inventions, such as the steam engine, the electric dynamo and the computer, also fit into this reasoning. The reason is that these products have not been invented in one time. In fact, each radical invention consists of a large number of incremental improvements on an original basic concept, which has no practical significance. And up till today steam engines and electric dynamos are improved, while nobody knows the present stage of the computer revolution.

[156] OECD (1994) p. 29

[157] R&D-director dr. Schuurmans in NRC 31/8/1996 (translated from Dutch)

[158] NRC 31/8/1996

growth rate of the number of products accelerates, say to 8 percent per year. However, the new products have got a higher substitution-elasticity as well, say 5. Table 5.4 tells that in the economy grows with 1/2 (=8/16) percent each year, which is a decline compared with the original rate.

Of course, it is not certain that economic growth will decelerate. Even within the limits of the assumed relations above, there are combinations between higher growth in products and more mutual substitutability of products, which even lead to accelerating economic growth. This does not refute that the danger exists that the shift in emphasis from Research to Development may hurt future economic growth.

Unreliable information due to neglecting creation and limited substitution

The rise in economic growth is underrated and inflation exaggerated if statisticians do not take properly account of creation and the limited substitutability of products. If statisticians neglect differences between products, then they regard them as perfect substitutes and neither their rising number nor their specific characteristics influence growth. The analogous reasoning holds for consumer welfare. The statistics produce unreliable information if in fact the number of products grows fast or the products have a low substitution elasticity. By way of illustration, the exercise above showed that an underrating of a half to one percent is imaginable, conditional on the assumed relations in this section. Along the same reasoning, it is imaginable that inflation is exaggerated with an equal rate, if the annual quality rise of the consumer basket is neglected. This exaggeration of the inflation rate agrees with careful and broader statistical analyses, which indicate that inflation rates are overrated with 0.5-2 percent per year[159]. However, this agreement is possibly due to chance.

National productivity[160] and inflation are beacons for policy makers. Productivity growth and inflation are used as performance indicators of countries. As long as all countries rely on the same methodology, false information may not damage a just opinion on the nation's performance compared with other countries.

However, productivity growth and inflation are also main arguments in wage negotiations, while inflation also determines social security benefits. Then unreliable information may produce unwanted outcomes.

[159] See Oulton (1995), p. 60. Griliches and Cockburn (1994) examined the impact of a new drug on the price-index. It turns out that there is no robust solution, method determines the outcome.

[160] There is a direct link between economic growth and national productivity growth, because productivity growth equals economic growth minus employment growth. If we assume that in the long run employment stagnates due to a constant labor supply, economic growth coincides with productivity growth.

Welfare gain due to more television channels

Welfare has significantly increased due to more TV-channels, which is hardly measured as a rise in national income. Ten years ago, a Dutch citizen could receive two channels. Today, he can choose out of thirty. By way of illustration, a 15-20% rise in welfare is imaginable due to the larger number of channels. This follows from two assumptions. First, an average citizen watches television 28% of his spare time in 1995 and this share has not changed since 1985[1]. Second, watchers lack strong preference for a specific channel, because they conveniently zap from one channel to another. This implies that the substitution rate between channels is rather high, say an elasticity of 6 respectively 5. According to equation (6), these assumptions correspond with welfare gains of 15 respectively 19%.

However, statisticians hardly register a rise in national income due to more TV-channels. TV-watching is measured with its costs. These have remained almost constant for the watcher, because the contribution to the cable network, and the costs of receivers and energy consumption are independent of the number of channels. The national accounts show a rise in real advertisement on macro-economic level. However, this increase is not spectacular, because more TV-advertising is largely compensated by less advertising in newspapers.

The rise in the number of channels converges welfare between people, because the gain is independent of their income. On top of that, people who have the habit to watch long each day (people with only basic education), have not enjoyed significant more welfare than those who have the custom to watch a short period (people with high education)[1]. More watching-hours gives more welfare from more channels. But people who watch a short time, select their programs more carefully, and hence regard them with a low substitution elasticity, which enhances their welfare.

[1] SCP (1996), p.372.

Furthermore, this way of reasoning may also contribute to the explanation of the so-called productivity paradox. Statisticians provide information of a strong decline in productivity growth since 1973. At the same time, computers have invaded the economy, but they and their economic impact can hardly be found in the official statistics. A contribution to the explanation can be that product differentiation is not properly processed.

There are hardly official data on product differentiation and the size of their mutual substitutability. Therefore, it is highly probable that the measurement of productivity and inflation contains errors of which the sign is rather robust. More attention for these topics is needed in order to avoid unreliable information on the increase in national productivity and inflation.

6. The role of industrial design underrated?[161]

Abstract

Economists and policy makers underrate the role of industrial design for welfare growth compared to their attention for Research & Development. This is explained with ten theses on key issues in the theory of endogenous growth. There appear many correspondences between industrial design and R&D with gradual differences. Labor requirements of designers and researchers are more and more converging. Design has a lower entry barrier than R&D-intensive products. To little is spent on industrial design, because the designer cannot appropriate all social gains. The market failures are due to easy copying, eco-design, quality of life and the pleasure derived from shopping.

Introduction

Of old, economists and policy makers are anxious about Research & Development. R&D 'comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of the stock of knowledge to device new applications'[162]. For the business sector, this broad definition is empirically limited in practice. Official statistics restrict R&D to the fields of exact and natural sciences. This narrow definition is living its own life. For instance, policy makers fear that enterprises carry out too little research in those fields than is socially desirable due to external effects.

Industrial design is statistically not classified as R&D[163]. Possibly, due to this fact, policy makers hardly pay attention to it. They are silently supported by scientific papers. Economic theorists[164] use 'R&D' as the engine of growth, which suggests to practical economists that they exclude design. Still, the same explanation of the role of R&D in endogenous growth can be given for design. This section explores if economists and policy makers underrate the role of design. The answer follows from the correspondences and differences between design and R&D explored in 11 theses on key issues in the theory of endogenous growth.

[161] Some of the statements in this section are based on an enquiry of 53 design departments of US-companies in Business Week, 5/6/1995

[162] OECD (1994) p. 29

[163] OECD (1994) p.44

[164] Examples are Grossman and Helpman (1991) and Jones (1995)

Theses

1. Just as a new product based on R&D, a new design differs from existing ones, which make them imperfect substitutable. Each design seeks a unique balance of, for instance, attractive shape, comfort, light weight, safety and low production costs.

2. Like R&D-based products, there are many designs. A large number is launched annually. By way of illustration, intellectual protection rights have been applied for 2.8 thousand new designs with a coverage in the Benelux in 1994[165].

3. Compared to R&D, the barrier to market entry of a new design is much lower, due to lower development costs. In the Netherlands, for instance, it takes on average NLG 0.5 million to develop a new design, with an average development period of 1.6 years[166]. The corresponding figures for R&D-based products are higher. Moreover, design is less risky than R&D, because it supplies the final customer, whose wishes are relatively easy to grasp. In contrast, R&D is often concerned with intermediates and is more abstract. Thus, market barriers due to fixed costs and risks before a product launch are less important for design than for R&D.

4. Firm size is of less importance for industrial design than for R&D. There are many important independent designers as Tables 6.1 and 6.2 show. These are small and medium sized. The largest in the USA employ two hundred people.

There are several explanations for this scale-difference. The low barrier to enter the market with a design, makes that also small firms can enter. Moreover, industrial design requires less fixed capital compared with R&D. Main research laboratories take tens of millions of guilders to build, while scientific instruments are expensive and depreciate fast. Still, the design-production process is becoming more capital intensive. 'Ten years ago, a pencil and a $ 100 drafting table were all the tools needed for industrial design. Today it's more like $50,000 to $100,000 per person', because computers have replaced the drafting table[167]. Finally, industrial designers can exploit less tacit or secret know-how than researchers. Tacit knowledge is an important determinant of scale, because only the company's employees can exploit it. It is difficult for designers to keep their know-how tacit, because a launched design can easily be disentangled in components and copied.

5. Generally, design contributes less to economic growth than more radical inventions

[165] These designs consist of 2-dimensional drawings and 3-dimensional models. Source: Annual Report Benelux Merkenbureau 1994.

[166] Average of 28 nominated product designs (Roerinkholder, 1995, p.21). Moreover, the development costs of the new banknote of 100 guilders took De Nederlandsche Bank NLG 3 million (NRC 10/1/1996).

[167] Business Week 5/6/1995

from the research laboratories. New designs look like existing ones, which corresponds with their low costs of development and the small firm size. Section 5 explains that if products are highly substitutable, the growth rate of new products, thus including designs, have a small impact on economic growth.

6. Industrial design is often complementary with R&D. Design is important in R&D-intensive industries, in particular in information technology and cars according to the list of prize-winners in the USA list (Table 6.1). Design in information technology (IT) is important in software, like user-interfaces and graphics, and in electronic products. The importance of design in the car-industry is evident: its shape contributes to its status, safety and last but not least energy-consumption. Also, in the Netherlands IT-companies dominate, for the design-departments of Philips and Océ have won most awards[168] (Table 6.2).

Regularly, good industrial design is a even a condition for a successful launch of a research intensive product, because it adds emotion and user-friendliness to the results of R&D. According to Stefano Marzano, director of Philips Corporate Design: 'New technology often becomes available in bare form. Little is done to escape from its technical roots'. ... 'Therefore we must shift the emphasis from the present culture of 'hardware' to a more expressive culture of 'human ware'-from products which radiate the values of the producers to products which reflect the values of the users. These contain the eternal human values of affection, relevance, conservation of nature and pleasure. Therefore we start to give many objects a more reliable and softer shape'[169]. The additional value of design to technical advancement can be summarized as: the value of a product is not so much determined by what the product does, but what the consumer does with the product[170].

7. Industrial design is also important in some R&D-extensive industries, such as (office-) furniture, bicycles, toys and textiles. In these industries, design is a main determinant to make the product attractive. This conclusion follows from the award-winners in Tables 6.1. and 6.2. Hence, inventiveness outside of the area of the exact and natural sciences can also provide a strong competitive advantage.

[168] In design, the patterns of international specialization are discernable too. Compared to Americans, Dutchmen are cyclists and skippers. This is revealed by the high number of awards for design on bicycles and ship necessaries. The cycle-makers Batavus and Gazelle even have own design departments. By contrast, the Dutch car-industry is small, and this is reflected in the low number of awards compared with the USA.

[169] NRC 5/10/1995 (translated from Dutch).

[170] Philips' director Carrubba in De Ingenieur 4/12/1996 (translated from Dutch)

Table 6.1 US' best designers (1980-1994)[a]

			number of awards
	Producers with design department		
1	AT&T (Lucent, NCR)	IT	24
2	General Motors	Cars	21
3	Steelcase	Furniture	18
4	Apple	IT	17
5	IBM	IT	16
6	Herman Miller	Furniture	14
7	Chrysler	Cars	13
8	Black & Decker	Consumer machines	10
9	Digital	IT	9
10	Fisher-Price	Toys	8
11	Knoll Group	Health	8
12	Microsoft	IT	8
13	Texas Instruments	IT	8
14	Thomson Electronics	IT	8
	Independent designers		
1	IDEO		36
2	Ziba Design		27
3	Fitch		22
4	Frogdesign		21
5	Design Continuum		19

[a] Business Week 5/6/1995, p.47

8. The broadening of the scope of industrial designers has led to an increasing overlap with the skills of researchers. In the course of time designers have developed from artists focussed on styling in the 1970s to business workers with a helicopter view on complex processes at present. Designers master the whole assortment of product development, such as user research, mechanical engineering of design, rapid proto-typing, ergonomics, software of interface design, graphics, packaging and compatibility[171]. Industrial research also deals with these areas. Also, designers must be able to develop their products faster, just as researchers[172].

[171] Business Week 5/6/1995

[172] Business Week 5/6/1996

Table 6.2 *Best design in Holland (1995-1996)*[a]

		number awards
Producers with design department		
Philips	Electronics	16
Océ	Copiers	6
de Ploeg/Aronson	Textiles	5
Ucosan	Health: Showers	4
Batavus	Bicycles	3
Car/Hamelink	Furniture	3
Other[b]		7
Total		44
Producers without design department[c]		
Stork	Machines	4
Arco	Furniture	3
Kembo	Furniture	3
Total		17
Independent designers[c]		
ninaber/peters/krouwel		8
Flex Development		5
van Dijk		5
TNO		3
Other		65
(of which furniture		24)
Total		86
Total awards		147

[a] Certificate Stichting Goed Industrieel Ontwerp 1995 and 1996. Source: Technisch Weekblad, April 1996 and 1995 Annexes. Not listed foreign companies, such as Tupperware (Belgium), and the furniture producers Wilkhahn (Germany) and Akaba (Spain).
[b] Firms with less than 3 awards
[c] Producers respectively designers with at least 3 awards.

9. Just as with R&D, designers operate on markets with failures. The designer does not get enough impulses from the market in order to produce as much as is socially desirable. First, intellectual property rights, which protect the designer, are not very effective. Designs can be easily copied. And, designs are less uniform protected by the law than patents. The patent system, which protects new ideas based on R&D, is much more standardized in the world, with the Patent Offices of the USA and Europe (at München and Rijswijk) as main sources of access. Consequently, probably designs are less protected than technical ideas.

Second, the social gain of eco-design is probably not appropriated sufficiently by the designer. Eco-design targets at the use of environmental friendly materials and easy decomposition at the end of life-time. For instance, the use of components which can easily be recycled. Eco-design is favorable for society, but it is far less sure that the consumer will pay for it to the design-enterprise.

Third, quality of life improves after well applied ergonomics in design. To many extents the gains can be appropriated by the designer. For instance, a handsome remote controller will encourage the purchase of a television apparatus. However, probably customers do not pay fully for the gains of chairs designed to avoid future back-injuries, while the social returns of less pain and less absence on work are high.

Fourth, shoppers enjoy welfare if they look around, even if they buy nothing. This pleasure is often provided by design. But the designers do not earn from these shoppers.

10. Compared to R&D, design has a larger impact on welfare than on macro-economic productivity. Generally, design is more important for consumer products than for professional goods, because consumers like comfort and professionals prefer advanced technical merits[173]. Consumer products have a direct impact on welfare and professional goods on productivity.

Role of design

What do these theses mean in order to assess the role of industrial design? There are a large number of correspondences between design and R&D with gradual differences. Annually a large number of different designs is launched, which differ from existing ones (theses 1, 2). Compared with R&D, design is an activity which needs less scale, while a higher substitutability between designs makes that the impact on economic productivity is smaller (theses 3-5).

However, there are arguments which favor design. Often design is complementary or even a condition to make a new R&D-intensive product a success (thesis 6). In these cases, the impact of design on economic growth can be considerable, because design may be the bottleneck-factor. Moreover, design is important in R&D-extensive industries, such as furniture, toys, textiles and clothing (thesis 7). And the needed skills of designers increasingly overlap those of researchers (thesis 8). Finally, the market failures due to external effects make that there is less investment in design than is social desirable (thesis 9). The degree of under-investment in design might be even greater than in research, because design is less protected by intellectual property rights, and the welfare effect of pleasure of shopping does not hold for hardware technology.

In total, design is about as important as R&D. There are two explanations why economists and policy makers are less worried about design. First, R&D catches the eye, because the expenditures on R&D are much higher than on industrial design. However, the amount of expenditure should not be the criterion, but the returns on a marginal change in expenditures. It is not clear that the returns of marginal investment in design are lower than of R&D. Second, R&D is mainly targeted at new professional goods, which lead to more productivity. In contrast, industrial design directly satisfies

[173] The Economist 6/1/1996

consumer-welfare (thesis 10)[174], and welfare is much more difficult to measure. Consequently, the role of industrial design can be underrated.

[174] Grossman and Helpman (1991) prove that in a theoretical model, the contribution of more brands on welfare is equivalent as on productivity.

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Annex Investments by industry neglecting rivals

1. Hypotheses
2. Regression equations
3. Discussion of the results

Tables
A R&D-equations by industry
B Fixed-assets equations by industry

1 Hypotheses

This annex tests if the investments in R&D and fixed assets of a company depend on its own profits and debt/assets ratio, and the interest rate of the OECD given the assumption that all companies which belong to an industry respond equally to a change in a dependent variable.

We start from the assumption that companies have as basic strategy that they spend a constant share of their revenues on investment in R&D- and fixed assets. Below, we test six hypotheses which lead to a change in this basic strategy (the symbols refer the notation in the regression-equations).

Hypothesis 1
A drop in net *profits* leads to a fall in investments later.

Explanation: We expect that higher profits stimulate investments, because the company can save on interest payments by internal financing. Moreover, the managers can better exploit their advantage in information on the prospects of investment projects compared to the capital market. In that case some projects will be carried out when sufficient internal financial resources are available, while external capital suppliers avert risks. This latter reason may be especially important for R&D-projects. Hypothesis: $\alpha_1 > 0$.

Hypothesis 2
Companies save radically on investments when profits are below a *critical value*.

Explanation: The managers of the medium sized enterprises predict they do so in the enquiry carried out by the EIM (Economisch Instituut Midden- en Kleinbedrijf). We test two values of critical profits values: a loss respectively net profits lower than 2% of the sales. The test has been carried out by adding a critical profit dummy for P/S<0, respectively P/S<2%. Hypothesis: $\alpha_2<0$.

Hypothesis 3
A higher *debt/assets ratio* leads to a drop in investments later.

Explanation: A company takes risks sooner if it has more risk-taking capital at its disposal. A low debt/assets ratio reflects this ability to bear risks. Moreover, a higher debt/assets ratio gives a low capacity to lend and coincides with a high interest burden. Therefore, a high debt/assets ratio leads to lower investments. Hypothesis: $\alpha_3 < 0$.

Hypothesis 4
The *strategy shift* in R&D since 1990 has led to a structural decline in R&D.

Explanation: Many companies have changed their R&D-strategies since 1990[175]. The hypothesis is that this has lead to a structural decline in the R&D/sales ratio since that year. It is tested by adding to the R&D-equation a strategy dummy for all years since (and including) 1990 in the specification with the other variables lagged two years. The hypothesis is that this coefficient is negative: $\alpha_4<0$.

Hypothesis 5
A higher *interest rate* leads to a drop in investments later.

Explanation: Higher capital costs discourage investment. Moreover, it has been suggested that the drop in R&D-expenses in many companies since the late 1980s is caused by the high real interest rates about 1985. The OECD-interest rate is taken as the relevant one[176], because the companies in this report can lend on the international capital market. Four alternatives are explored:

- Real interest rate (real=corrected for consumer price index)
- Nominal interest rate. The best real interest rate for a company is the nominal interest rate minus that firm's price increase. For R&D-intensive companies the consumer price index is not representative. For instance: the prices of many electronic products decline in the course of time, while the consumer price index rises. Price data for individual companies are absent. An alternative is to neglect the impact of the consumer price and assume that the yearly price changes of each company is equal, so that they are captured by the constant in the regression. Then, regressions are allowed with the nominal interest rate.
- The interest rates show a trend in the course of time. This trend may wrongly be interpreted as an interest effect. A trend variable has been added to correct for this trend, so that fluctuations in the interest rates dominate as determinant for investments. Hypothesis $\alpha_5<0$, sign α_6 not clear.

Hypothesis 6

[175] Source: Business Week 3/7/1995. These reasons hold for US-companies, but they agree with those mentioned by Dutch multinationals, like Philips, Shell, Akzo Nobel, Unilever and DSM. See also NRC 31/8/1996.

[176] Source nominal interest rate and the consumer price rises: CPB, CEP, bijlagen. Real interest rate = nominal interest rate minus % price increase.

Future profits and interest rates determine investments instead of the realizations of these variables.

Explanation: The former hypotheses assume that managers wait for realized profits and the interest rate and decide on investments next. However, in practice investment decisions depend on expected returns. Then, future profits and interest rates are crucial. We test the profits and interest rate one year after the year of investment as determinant. We assume that the firms can predict these variables perfectly. The hypothesis is that profits (respectively real interest) with a lead of one year stimulate (discourage) present investments. Hypothesis: $\alpha_1>0$, $\alpha_5<0$.

2. Regression equations

The basic assumption is that a company spends a constant share of its sales revenues on investment in R&D- and fixed assets. The hypotheses lead to a change in this basic strategy, which are estimated according to:

$$R\&D/S_i = \alpha_1\ P/S_{i,-j} + \alpha_2\ dt + \alpha_3\ D/TA_{i,-j} + \alpha_4\ ds + \alpha_5\ r_{-j} + \alpha_6\ t + c$$

$$I^{FA}/S_i = \alpha_1\ P/S_{i,-j} + \alpha_2\ dt + \alpha_3\ D/TA_{i,-j} + \alpha_4\ ds + \alpha_5\ r_{-j} + \alpha_6\ t + c$$

where:

$R\&D/S_i$	R&D to sales ratio of company i (%)
I^{FA}/S_i	Fixed investment to sales ratio of company i (%)
P/S_i	Net profits to sales ratio of company i (%) (in tables: profits)
dt	Critical profit dummy for P/S<0 respectively P/S<2%
D/TA_i	Debt/assets ratio of company i (%) (in tables: debt-ratio)
ds	Strategy shift dummy
r	Interest rate (%) real respectively nominal (in tables: interest)
t	Trend
j	Time lag 1,2 years (lead:-1 for P/S and r)
c	Constant

Moreover in both equations, each company (except one) has a specific dummy to correct for structural differences between firms in their investment-ratios[177]. This specification has also the advantage that heteroskadasticity is reduced by dividing the variables with

[177] Causality-question: more investment can also lead to higher profits. Usually, this time lag is high, for it takes many years to bring a new product to the market. Hence, this relation can be neglected. Leeuwen G. v, H. Nieuwenhuijzen (1995), "R&D-uitgaven en bedrijfsprestaties", in *CBS, Speur- en Ontwikkelingswerk in Nederland 1993*, p.51-55 show that permanent R&D-activities are correlated with higher returns. On causality they found for the Netherlands stronger support that more profits give more R&D than the reversed relation. Method: Micro-economic data of 212 enterprises in the Netherlands, which substantially carried out R&D in 1985 as well as 1989.

historical trends by the sales.

The hypotheses are: $\alpha_1>0$, $\alpha_2<0$, $\alpha_3<0$, $\alpha_4<0$, $\alpha_5<0$

Each test has been carried out with one and two years time lag of the explaining variables, except the strategy dummy and the leading variables.

Section 3 discusses the outcomes of the regressions on the basis of the tables at the end.

First the results for the information industries are shown, next the health-industries and finally the chemical industry.

The reading of the tables is helped as follows:
( ) between brackets t-ratios
[R] real OECD-interest rate
[N] nominal OECD-interest rate
[<0%] critical profits: dummy for years with losses
[<2%] critical profits: dummy for years with profit/sales ratio less than 2%.
The constant and the dummies are not shown.

Each table list below:
- the R^2 for regressions with only the company dummies and a constant. the difference between this R^2 and the one in the table gives the contribution in the explanation of the financial variables.
- the number of observations in the regression

3. Discussion of the results

The equations in the main text

The main text lists the best equation per industry. This one is derived as follows. In the first stage the equation is selected which has most variables with an estimated sign which significantly meets the hypotheses. Significant is defined as t-ratio>1,4. In unclear cases the fit is the criterium. Then, it appeared that some variables were not significant or showed the `wrong' sign. In the second stage the selected equation has be re-computed, without the latter variables. This result has been shown in the main text.

Take, for example, R&D-equation of consumer electronics. First stage: only the debt/assets ratio has a significant sign which meets the hypothesis. A time lag of 1 year gives a better the best fit (R^2=60) than with 2 years (R_2=58). Second stage: the equation has been re-run with the debt/assets ratio (lag 1 year) as the only explaining variable. This result is presented in the main text.

General

In general, the companies do not follow the simple strategy that they invest a constant share of their sales in R&D and fixed assets. They take at least one financial variable into account which after one or two years, leads to a deviation from the simple strategy. The makers of electronic components and pharmaceuticals are an exception with research. They have as R&D-strategy a constant share of their sales. Explanation: for these three industries no significant determinants for R&D are found with the expected sign.

A shift in a determinant leads one year later to a change in fixed investments and two years later to a change in R&D. Only producers of consumer electronics may follow another lag pattern. Therefore most R&D-variants (respectively fixed investment variants) are shown with a time lag of 2 years (respectively 1 year).

The R&D/sales ratios are better explained than the fixed investment ones, with the R^2 as measure. It should be noted that most of the variation is explained by the company-dummies. This follows from the comparison of the R^2 with only company-dummies (shown in note [a] below every table) and the R^2 in the last column of the tables). This implies that the companies within an industry have quite different R&D- and fixed investment to sales ratios.

It is not allowed to draw immediate economic conclusions from these differences. The companies are not homogenous within an industry. For example some chemical companies have a large pharmaceutical division which needs much research but in turn is not very fixed capital intensive (e.g. AKZO Nobel), whereas such a division is absent in companies which are specialized in basic chemicals and which demand much fixed capital (e.g. DSM). Moreover, it is probable that the companies use different R&D-definitions.

The conclusions are restricted to the companies in the regressions. Therefore it is possible that these will change considerably if more companies are included. With this reservation in mind, the results are robust, with which we mean that it hardly affects the estimated impact of a variable if other explanatory variables are added to the equation.

Testing the hypotheses

Hypothesis 1
A drop in *net profits*[178] leads in many industries to a fall in investments. The impact on marginal fixed investments is stronger compared with R&D-expenditures. A present 1 dollar drop in profits leads makers of computers, food products and detergents, and chemicals to spend $ 0,11-0,33 less on fixed assets investment next year, and $ 0,05-0,09 less on R&D the year thereafter.

Moreover, the impact of net profits is more pervasive on fixed investments, because this variable has in more industries a significant impact on fixed assets than on R&D. Explanation: there is one more industry (instruments) with a significant impact on R&D, whereas fixed investments are influenced by the profits of two industries (drugs and electronic components). On top of that, fixed investments in professional electronics and instruments depend significantly positive on net profits in the absence of the critical profit variable.

Sharp in contrast to the hypothesis is the significant negative impact of the profits on R&D in consumer- and professional electronics after one year. There is no explanation for this result. However, with a lag of two years, which gives the best fit in the other industries, this significancy disappears.

Hypothesis 2
Most industries do not save radically on their investments when profits are below a *critical value*, but there are important exceptions. At the critical value when profits are below 2%, chemical corporations drop their R&D/sales ratio with 0,57%-points, and the ratio of fixed investments to sales drops in professional electronics (1,5%-points), instruments (5,6%-points) and food/soap (4%-points). However, no significant impact is found at the critical value where companies cross the border of losses. It is not certain if this has really economic significance, because there are few observations with losses[179].

It has been noticed before, that there is a correlation between net profits and the critical

[178] Experiments for the electronic companies showed that their cash flow does not explain investments better than net profits. These results are not shown.

[179] Sometimes there is no observation with P/S < 0, hence this test cannot be carried out in this case (example drugs). Experiments with another threshold value than zero (e.g. P/S<0,01) have not been carried out, because the outcomes with zero as critical value were not promising.

profits. This makes that the addition of the critical variable leads to a drop of the estimated impact of the profits. Take, for example, R&D in the chemical industry with the time lag of 2 years. A drop in profits of one dollar leads to a drop of $ 0,14 if the critical value of 2% is omitted. Inclusive this variable, one dollar less profits discourages R&D with only $ 0,09.

This effect is the cause that the best fixed investment equation of professional electronics implies that net profits have no impact, unless they cross the critical value.

Hypothesis 3
A higher *debt/assets ratio* leads to a drop later in fixed investment and to a less extent in R&D. In all industries, except food/soap, this impact is (almost) significant for fixed investment. And in four industries the debt/assets ratio influences R&D negatively. Of these, R&D of the electronic consumer and producer good industries is noteworthy. For example, a drop of 1%-point of the debt/assets ratio in professional electronics gives a fall of 0,33%-point in the R&D-ratio.

Hypothesis 4
No evidence is found that the *strategy shift* of the companies since 1990 has led to a separate effect on the R&D/sales ratio, excepted software. It strikes that the impact of this strategy shift has been positive on the R&D-intensity in electronic consumer and professional goods, instruments and chemicals according to the regression results. It needs further investigation to find an economic explanation for this outcome.

Hypothesis 5
A significant negative impact of the *interest rate* on investment can hardly be found although four variants have been tried out. Most regression results indicate a positive impact, which is not plausible from an economic point of view.

Hypothesis 6
Future profits and interest rates do not explain present investments better than the lagged realizations of these variables. There is no outcome which meets this hypothesis.

Tables A R&D-equations by industry

Consumer Electronics, R&D/S[a]

Profit	Debt-ratio	Interest	Critical profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
	-0,08 (2,4)					55
-0.18 (2.5)	-0.12 (3.3)					60
-0.13 (2.0)	-0.13 (4.2)	0.21 (4.1) [R]				69
-0.17 (2.3)	-0.13 (3.5)	-0.08 (1.1) [N]				60
explaining variables lagged 2 years[b]						
-0.05 (0.7)	-0.11 (3.0)					58
-0.04 (0.4)	-0.11 (3.0)		0.15 (0.2) [<0%]			59
-0.02 (0.2)	-0.11 (2.9)		0.29 (0.8) [<2%]			59
-0.03 (0.3)	-0.14 (3.3)				0.45 (1.4)	60
-0.00 (0.0)	-0.12 (3.8)	0.20 (3.8) [R]				67
0.05 (0.6)	-0.17 (4.6)	0.11 (1.7) [R]		0.09 (2.4)		70
-0.05 (0.6)	-0.11 (2.9)	-0.00 (0.0) [N]				58
0.03 (0.5)	-0.19 (5.3)	0.12 (1.7) [N]		0.15 (4.6)		70
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
-0.09 (1.7)	-0.11 (3.3)	0.18 (2.7) [R]				64

[a] R²: 52 (N=66) for regression with only a dummy variable for each company
[b] N is 65 with lag 1, 62 with lag 2 and 61 with lead 1.

Professional electronics, R&D/S[a]

Profit	Debt-ratio	Interest	Critical Profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
-0.03 (0.7)	-0.32 (10.9)					85
-0.03 (0.6)	-0.32 (9.2)	0.00 (0.0) [R]				85
-0.01 (0.2)	-0.29 (9.4)	-0.17 (2.7) [N]				86
explaining variables lagged 2 years[b]						
0.03 (0.7)	-0.33 (11.5)					87
-0.02 (0.3)	-0.33 (11.5)		-1.00 (1.1) [<0%]			87
0.01 (0.2)	-0.32 (11.3)		-0.26 (1.0) [<2%]			87
0.02 (0.4)	-0.28 (9.3)				0.72 (3.2)	88
-0.03 (0.7)	-0.32 (9.5)	0.03 (0.5) [R]				87
0.02 (0.6)	-0.26 (7.5)	0.05 (1.0) [R]		0.11 (3.8)		88
0.03 (0.8)	-0.32 (10.9)	-0.08 (1.3) [N]				88
0.03 (0.6)	-0.27 (7.8)	-0.02 (0.3) [N]		0.07 (2.5)		89
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
-0.04 (0.5)	-0.03 (3.3)	0.33 (3.6) [R]				52

[a] R²: 65 (N=131) for regression with only a dummy variable for each company

[b] N is 112 with lag 1, 106 with lag 2 and 105 with lead 1.

Electronic components, R&D/S[a]

Profit	Debt-ratio	Interest	Critical Profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
-0.13 (1.9)	0.01 (0.2)					43
-0.09 (1.5)	0.01 (0.1)	0.63 (3.2) [R]				56
-0.09 (1.3)	0.04 (0.5)	0.60 (2.5) [N]				52
explaining variables lagged 2 years[b]						
0.03 (0.4)	0.04 (0.5)					36
0.03 (0.2)	0.05 (0.5)		-0.09 (0.0) [<0%]			36
0.03 (0.3)	0.04 (0.5)		0.14 (0.1) [<2%]			36
0.06 (0.8)	0.08 (0.9)				-1.35 (1.3)	40
0.06 (0.8)	0.04 (0.5)	0.53 (2.3) [R]				46
0.11 (1.4)	0.10 (1.2)	0.85 (3.2) [R]		-0.24 (2.1)		53
0.05 (0.7)	0.06 (0.9)	0.80 (3.3) [N]				53
0.04 (0.6)	0.04 (0.5)	0.96 (3.5) [N]		0.13 (1.3)		56
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
-0.00 (0.0)	-0.01 (0.1)	0.89 (3.9) [R]				59

[a] R²: 31 (N=42) for regression with only a dummy variable for each company
[b] N is 39 with lag 1, 36 with lag 2 and 36 with lead 1.

Computers, R&D/S[a]

Profit	Debt-ratio	Interest	Critical Profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
0.06 (2.1)	0.02 (0.9)					88
0.08 (2.8)	0.04 (2.2)	-0.33 (1.8) [R]				87
0.06 (2.2)	0.01 (0.6)	-0.10 (1.2) [N]				88
explaining variables lagged 2 years[b]						
0.12 (5.0)	0.05 (2.8)					93
0.12 (3.9)	0.05 (2.7)		0.10 (0.2) [<0%]			93
0.14 (5.6)	0.04 (2.7)		0.65 (2.2) [<2%]			94
0.12 (5.0)	0.05 (2.7)				0.15 (0.8)	93
0.13 (5.3)	0.07 (4.3)	-0.34 (2.4) [R]				93
0.10 (4.4)	0.05 (3.0)	-0.60 (3.1) [R]		-0.11 (2.1)		94
0,06 (3,0)		-0,60 (2,8) [R]		-0,07 (1,3)		92
0.12 (5.0)	0.04 (2.6)	-0.05 (0.7) [N]				93
0.12 (4.7)	0.04 (2.5)	-0.06 (0.7) [N]		-0.01 (0.1)		93
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
-0.02 (1.2)	-0.00 (0.3)	-0.51 (2.4) [R]				90

[a] R²: 86 (N=74) for regression with only a dummy variable for each company
[b] N is 68 with lag 1, 62 with lag 2 and 61 with lead 1.

Software, R&D/S[a]

Profit	Debt-ratio	Interest	Critical Profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
0.07 (1.0)	-0.05 (1.0)					94
0.05 (0.8)	-0.02 (0.4)	1.38 (2.5) [R]				95
0.11 (1.8)	-0.02 (0.7)	0.82 (2.9) [N]				96
explaining variables lagged 2 years[b]						
0.05 (0.7)	-0.02 (0.4)					94
0.14 (0.9)	-0.01 (0.2)		1.59 (0.6) [<0%]			95
0.02 (0.3)	0.00 (0.1)				-2.05 (3.4)	97
0.05 (0.8)	0.02 (0.5)	1.44 (3.0) [R]				97
0.02 (0.5)	0.03 (1.2)	0.48 (1.1) [R]		-0.42 (4.0)		98
0.06 (0.8)	-0.01 (0.3)	0.28 (0.8) [N]				95
0.01 (0.2)	0.03 (0.9)	-0.16 (0.7) [N]		-0.52 (5.4)		98
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
-0.00 (0.0)	-0.06 (1.2)	0.77 (1.0) [R]				95

[a] R^2=93 (N=25) for regression with only a dummy variable for each company
[b] N is 24 with lag 1, 22 with lag 2 and 21 with lead 1.
Results critical profits [<2%] the same as [<0%] because there are no observations in between

Scientific instruments, R&D/S[a]

Profit	Debt-ratio	Interest	Critical Profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
0.07 (1.4)	-0.06 (2.3)					85
0.07 (1.4)	-0.06 (1.7)	-0.01 (0.1) [R]				85
0.07 (1.4)	-0.06 (2.4)	-0.14 (1.5) [N]				86
explaining variables lagged 2 years[b]						
0.10 (1.7)	-0.05 (1.9)					85
0.08 (1.1)	-0.05 (1.9)		-0.45 (0.5) [<0%]			85
0.12 (1.8)	-0.05 (1.9)		0.76 (0.8) [<2%]			85
0.11 (1.9)	-0.04 (1.6)				0.57 (2.0)	86
0.10 (1.7)	-0.06 (1.7)	-0.07 (0.6) [R]				85
0.11 (2.1)	-0.04 (1.2)	-0.12 (1.0) [R]		0.11 (2.7)		88
0.11 (1.9)	-0.04 (1.5)	-0.13 (1.3) [N]				86
0.12 (2.1)	-0.01 (0.4)	0.09 (0.8) [N]		0.13 (2.5)		87
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
-0.01 (0.1)	-0.07 (2.3)	-0.06 (0.4) [R]				86

[a] R^2=82 (N=54) for regression with only a dummy variable for each company
[b] N is 49 with lag 1, 45 with lag 2 and 46 with lead 1.

Drugs, R&D/S[a]

Profit	Debt-ratio	Interest	Critical Profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
-0.02 (0.6)	0.13 (4.0)					91
-0.05 (1.0)	0.13 (4.0)	-0.30 (1.0) [R]				91
-0.06 (1.1)	0.13 (4.0)	-0.16 (1.1) [N]				91
explaining variables lagged 2 years[b]						
-0.09 (1.8)	0.12 (3.3)					91
-0.14 (1.9)	0.12 (3.4)				0.53 (1.0)	91
-0.14 (2.3)	0.12 (3.5)	-0.50 (1.5) [R]				91
-0.20 (1.8)	0.12 (3.4)	-0.36 (0.9) [R]		0.10 (0.6)		91
0.11 (1.8)	0.12 (3.3)	-0.10 (0.6) [N]				91
-0.21 (1.9)	0.12 (3.3)	-0.08 (0.4) [N]		0.18 (1.2)		91
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
-0.07 (1.7)	0.11 (3.8)	-0.72 (2.5) [R]				94

[a] R^2=86 (N=47) for regression with only a dummy variable for each company
[b] N is 44 with lag 1, 40 with lag 2 and 40 with lead 1.
No observations with a loss or P/S<2%

Food / Soap, R&D/S[a]

Profit	Debt-ratio	Interest	Critical Profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
0.02 (1.1)	0.01 (1.8)					93
0.01 (0.3)	0.01 (1.5)	0.09 (4.2) [R]				95
0.00 (0.1)	0.01 (1.1)	-0.11 (4.1) [N]				94
explaining variables lagged 2 years[b]						
0.06 (2.3)	0.01 (1.1)					94
0.06 (2.2)	0.01 (1.0)		0.02 (0.1) [<0%]			94
0.04 (1.4)	0.01 (1.1)		-0.17 (1.2) [<2%]			94
0.04 (1.2)	0.00 (0.6)				0.14 (1.2)	94
0.03 (1.4)	0.00 (0.8)	0.10 (5.3) [R]				96
-0.01 (0.3)	-0.00 (0.1)	0.07 (3.1) [R]		0.03 (2.4)		96
0.03 (1.3)	0.00 (0.5)	-0.06 (1.8) [N]				94
0,05 (1,9)		-0,04 (1,3) [N]				94
-0.03 (1.2)	-0.00 (0.8)	-0.04 (1.3) [N]		0.05 (4.5)		96
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
0.07 (3.5)	0.01 (1.1)	0.03 (1.0) [R]				94

[a] R^2=92 (N=71) for regression with only a dummy variable for each company
[b] N is 63 with lag 1, 57 with lag 2 and 58 with lead 1 (alternative 11).

Chemicals, R&D/S[a]

Profit	Debt-ratio	Interest	Critical Profits	Trend	Strategy shift	R^2
explaining variables lagged 1 year[b]						
0.09 (3.1)	-0.03 (3.2)					74
0.07 (2.7)	-0.03 (3.1)	0.13 (4.1) [R]				76
0.07 (2.8)	-0.04 (3.8)	-0.20 (5.8) [N]				79
explaining variables lagged 2 years[b]						
0.14 (5.2)	-0.03 (2.9)					77
0.17 (5.4)	-0.03 (2.9)		0.75 (1.9) [<0%]			78
0.09 (3.0)	-0.03 (2.4)		-0.57 (2.6) [<2%]			78
0.10 (4.3)	-0.04 (4.9)				1.0 (8.8)	85
0.13 (5.1)	-0.03 (2.9)	0.04 (4.9) [R]				81
0.09 (4.6)	-0.04 (4.9)	-0.02 (0.6) [R]		0.13 (9.5)		89
0.13 (4.8)	-0.03 (3.1)	0.15 (4.0) [N]				80
0.09 (4.6)	-0.04 (4.9)	0.02 (0.5) [N]		0.13 (10.5)		89
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]						
0.06 (1.9)	-0.04 (3.4)	0.09 (2.1) [R]				73

[a] R^2=70 (N=184) for regression with only a dummy variable for each company
[b] N is 169 with lag 1, 160 with lag 2 and 160 with lead 1

Tables B Fixed-assets equations by industry

Consumer Electronics, I^{FA}/S^{a}

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.13 (1.1)	-0.01 (0.3)				41
0.06 (0.5)	-0.01 (0.2)		-0.89 (1.0) [<0%]		42
0.13 (1.0)	-0.01 (0.2)		0.06 (0.1) [<2%]		41
-0,17 (1.5)	-0.03 (0.6)	0.20 (2.2) [R]			46
0.27 (2.6)	-0.16 (2.7)	-0.02 (0.2) [R]		0.21 (3.8)	56
0.14 (1.2)	-0.02 (0.4)	-0.08 (0.6) [N]			42
0.25 (2.4)	-0.17 (2.9)	0.14 (1.3) [N]		0.23 (4.7)	58
explaining variables lagged 2 years[b]					
-0.20 (1.7)	-0.11 (1.9)				44
-0.17 (1.4)	-0.12 (2.1)	0.13 (1.4) [R]			46
-0.17 (1.4)	-0.12 (2.0)	-0.14 (1.1) [N]			45
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
-0.08 (0.9)	-0.07 (1.4)	0.25 (2.3) [R]			47

[a] R^2=41 (N=68) for regression with only a dummy variable for each company
[b] N is 66 with lag 1, 62 with lag 2 and 62 with lead 1.
Companies (regression period) included: Matsushita (78-94), Sony (77-95), Philips (77-95), Sanyo (1985-1995)

Professional electronics, I^{FA}/S^{a}

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.16 (2.2)	-0.12 (2.8)				50
0.14 (1.4)	-0.12 (2.8)		-0.34 (0.2) [<0%]		50
0.03 (0.3)	-0.11 (2.6)		-1.41 (3.7) [<2%]		56
0.18 (2.6)	-0.02 (0.4)	0.33 (4.2) [R]			58
0.18 (2.6)	-0.04 (0.6)	0.35 (4.1) [R]		-0.03 (0.6)	58
0.13 (1.7)	-0.17 (3.6)	0.24 (2.5) [N]			53
0.12 (1.6)	-0.09 (1.7)	0.35 (3.4) [N]		0.11 (2.4)	56
explaining variables lagged 2 years[b]					
0.14 (1.9)	-0.08 (1.9)				52
0.15 (2.1)	-0.01 (0.1)	0.24 (2.9) [R]			56
0.11 (1.5)	-0.12 (2.6)	0.23 (2.3) [N]			55
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
-0.04 (0.6)	-0.16 (6.6)	0.06 (0.8) [R]			78

[a] R^2=41 (N=119) for regression with only a dummy variable for each company
[b] N is 112 with lag 1, 106 with lag 2 and 105 with lead 1
Companies (regression period) included: Hitachi (78-95), Siemens (78-94), Toshiba (78-95), NEC (78-95), Ericsson (78-94), Electrolux (78-94), Honeywell (87-94), Bosch (83-94)

Electronic components, I^{FA}/S^{a}

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.18 (2.5)	-0.16 (2.0)				68
0.22 (2.4)	-0.16 (2.0)		1.62 (0.8) [<0%]		69
0.14 (1.5)	-0.16 (2.0)		-0.93 (0.6) [<2%]		68
0.16 (2.3)	-0.16 (2.0)	-0.32 (1.4) [R]			70
0.12 (1.6)	-0.19 (2.2)	-0.48 (1.7) [R]		0.12 (1.0)	71
0.15 (2.1)	-0.18 (2.2)	-0.30 (1.1) [N]			69
0.16 (2.2)	-0.16 (1.8)	-0.11 (1.3) [N]		-0.09 (0.7)	70
explaining variables lagged 2 years[b]					
0.09 (1.1)	-0.11 (1.2)				60
0.10 (1.1)	-0.11 (1.2)	0.06 (0.2) [R]			60
0.09 (1.0)	-0.11 (1.3)	-0.25 (0.9) [N]			61
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
-0.05 (0.6)	-0.19 (2.2)	-0.38 (1.3) [R]			65

[a] R^2=47 (N=43) for regression with only a dummy variable for each company
[b] N is 40 with lag 1, 37 with lag 2 and 37 with lead 1.
Companies (regression period) included: Motorola (83-94), Intel (78-94), Texas Instruments (78-94)

Computers, I^{FA}/S^{a}

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.15 (2.8)	-0.07 (1.7)				77
0.20 (3.2)	-0.08 (2.0)		1.43 (1.6) [<0%]		78
0.14 (2.5)	-0.06 (1.6)		-0.29 (0.6) [<2%]		77
0.21 (4.7)	0.00 (0.1)	0.27 (1.0) [R]			75
0.15 (2.8)	-0.04 (0.9)	-0.18 (0.7) [R]		-0.12 (1.0)	77
0.15 (2.9)	-0.04 (1.1)	0.27 (1.9) [N]			78
0.15 (2.8)	-0.04 (1.0)	0.27 (1.6) [N]		0.00 (0.0)	78
explaining variables lagged 2 years[b]					
0.09 (1.3)	-0.11 (2.0)				65
0.17 (2.8)	-0.01 (0.2)	0.29 (0.8) [R]			61
0.09 (1.3)	-0.11 (2.0)	-0.01 (0.0) [N]			65
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
0.02 (0.5)	-0.18 (5.3)	-0.18 (0.5) [R]			72

[a] R^2=40 (N=64) for regression with only a dummy variable for each company
[b] N is 59 with lag 1, 54 with lag 2 and 52 with lead 1
Companies (regression period) included: IBM (84-94), Canon (85-94), Digital (86-94), Compaq (86-94), AT&T (86-94), Apple (85-94), Ricoh (88-95)

Software, I^{FA}/S^a

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.02 (0.4)	-0.10 (2.6)				55
-0.07 (0.6)	-0.12 (2.7)		-1.65 (0.9) [<0%]		57
0.02 (0.2)	-0.12 (3.4)	0.89 (2.8) [R]			69
0.02 (0.5)	-0.11 (3.6)	0.30 (0.7) [R]		-0.17 (2.0)	75
0.04 (0.9)	-0.13 (3.4)	0.41 (2.3) [N]			66
0.03 (0.6)	-0.11 (3.2)	-0.00 (0.0) [N]		-0.21 (2.3)	74
explaining variables lagged 2 years[b]					
0.09 (1.5)	-0.01 (0.3)				43
0.09 (1.6)	-0.01 (0.4)	0.77 (2.2) [R]			56
0.09 (1.5)	-0.04 (0.9)	0.31 (1.50 [N]			50
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
-0.04 (0.6)	-0.11 (2.3)	0.10 (0.2) [R]			60

[a] R^2=31 (N=24) for regression with only a dummy variable for each company
[b] N is 23 with lag 1, 21 with lag 2 and 20 with lead 1.
No other observations between 0<P/S<2% → same outcome for [<2%]
Companies (regression period) included: Getronics (84-95), Sun Microsystems (92-95), Unisys (88-94)

Scientific instruments, I^{FA}/S^a

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.21 (1.7)	-0.08 (1.4)				34
0.15 (1.0)	-0.08 (1.4)		-1.44 (0.7) [<0%]		34
0.03 (0.2)	-0.07 (1.2)		-5.37 (2.6) [<2%]		43
0.20 (1.7)	-0.13 (1.6)	-0.25 (0.8) [R]			35
0.20 (1.7)	-0.13 (1.5)	-0.25 (0.8) [R]		-0.00 (0.0)	35
0.21 (1.7)	-0.07 (1.4)	0.18 (0.8) [N]			35
0.21 (1.7)	-0.06 (0.9)	0.29 (1.0) [N]		0.06 (0.6)	35
explaining variables lagged 2 years[b]					
0.24 (1.8)	-0.04 (0.6)				32
0.25 (1.8)	-0.02 (0.2)	0.08 (0.3) [R]			32
0.25 (1.8)	-0.04 (0.6)	0.21 (0.9) [N]			34
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
-0.49 (2.2)	-0.10 (1.5)	0.11 (0.4) [R]			46

[a] R^2=20 (N=50) for regression with only a dummy variable for each company
[b] N is 47 with lag 1, 44 with lag 2 and 44 with lead 1
Companies (regression period) included: Fuji (87-94), Delft Instruments (89-94), Medtronic (84-95), Océ (78-95)

Drugs, I^{FA}/S^{a}

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.77 (4.9)	-0.37 (2.6)				63
0.81 (4.2)	-0.36 (2.4)	0.38 (0.4) [R]			63
0.82 (2.7)	-0.15 (0.9)	-0.32 (0.2) [R]		-0.43 (0.8)	65
0.76 (4.0)	-0.37 (2.4)	0.00 (0.0) [N]			63
0.97 (3.5)	-0.32 (2.0)	-0.30 (0.5) [N]		-0.43 (1.0)	64
explaining variables lagged 2 years[b]					
0.87 (4.4)	-0.36 (2.2)				60
1.01 (4.3)	-0.35 (2.1)	1.32 (1.1) [R]			62
0.86 (3.9)	-0.36 (2.1)	-0.06 (0.1) [N]			60
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
0.28 (3.1)	-0.02 (0.3)	-0.39 (0.6) [R]			62

[a] R^2=32 (N=40) for regression with only a dummy variable for each company
[b] N is 37 with lag 1, 34 with lag 2 and 33 with lead 1
No observations P<S<2%
Companies (regression period) included: Astra (90-94), MSD (84-94), Roche (84-94), Glaxo (78-94), Abbott (78-94)

Food / Soap, I^{FA}/S^{a}

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.30 (2.9)	-0.05 (1.3)				56
0.25 (2.2)	-0.04 (1.1)		-2.09 (1.2) [<0%]		57
0.10 (1.1)	-0.02 (0.7)		-3.93 (5.0) [<2%]		66
0.28 (2.7)	-0.05 (1.3)	0.22 (1.5) [R]			57
0.30 (2.5)	-0.04 (1.2)	0.24 (1.4) [R]		-0.01 (0.2)	58
0.28 (2.5)	-0.05 (1.3)	-0.09 (0.5) [N]			57
0.27 (2.3)	-0.04 (1.3)	-0.07 (0.4) [N]		0.01 (0.2)	57
explaining variables lagged 2 years[b]					
0.20 (1.6)	0.01 (0.3)				56
0.17 (1.4)	0.02 (0.4)	0.30 (1.9) [R]			58
0.24 (1.7)	0.02 (0.4)	0.14 (0.7) [N]			56
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
0.30 (2.5)	-0.08 (2.1)	0.04 (0.2) [R]			58

[a] R^2=48 (N=116) for regression with only a dummy variable for each company
[b] N is 105 with lag 1, 96 with lag 2 and 97 with lead 1
Companies (regression period) included: Nutricia (81-94), Gist (77-94), Unilever (79-94), Sara Lee (85-95), Avebe (86-94), CSM (84-94), Suikerunie (88-94), Procter & Gamble[1] (78-94)

Chemicals, I^{FA}/S^{a}

Profit	Debt-ratio	Interest	Critical Profits	Trend	R^2
explaining variables lagged 1 year[b]					
0.31 (3.3)	-0.07 (1.8)				49
0.38 (3.4)	-0.07 (1.8)		1.50 (1.1) [<0%]		49
0.32 (2.9)	-0.07 (1.8)		0.22 (0.3) [<2%]		49
0.33 (3.6)	-0.07 (1.8)	0.17 (1.4) [R]			51
0.32 (3.5)	-0.07 (1.9)	-0.25 (1.8) [R]		0.07 (1.1)	51
0.30 (3.2)	-0.06 (1.7)	-0.10 (0.7) [N]			49
0.31 (3.3)	-0.06 (1.7)	-0.16 (1.0) [N]		-0.04 (0.7)	49
explaining variables lagged 2 years[b]					
0.38 (3.9)	-0.05 (1.3)				51
0.38 (4.0)	-0.06 (1.5)	0.02 (0.2) [R]			53
0.34 (3.6)	-0.05 (1.4)	-0.31 (2.1) [N]			54
profit and real interest with lead 1 year, debt-ratio with lag 1 year[b]					
-0.10 (0.9)	-0.22 (7.1)	-0.17 (1.1) [R]			45

[a] R^2=42 (N=188) for regression with only a dummy variable for each company
[b] N is 174 with lag 1, 165 with lag 2 and 164 with lead 1
Companies (regression period) included: Hoechst (78-94), BASF (78-94), Bayer (79-94), Dow Chemical (78-94), Akzo Nobel (78-94), Solvay (88-94), Norit (78-94), Avery (88-94), Hercules (83-94), Nalco (78-93), 3M (78-94), DSM (77-95)